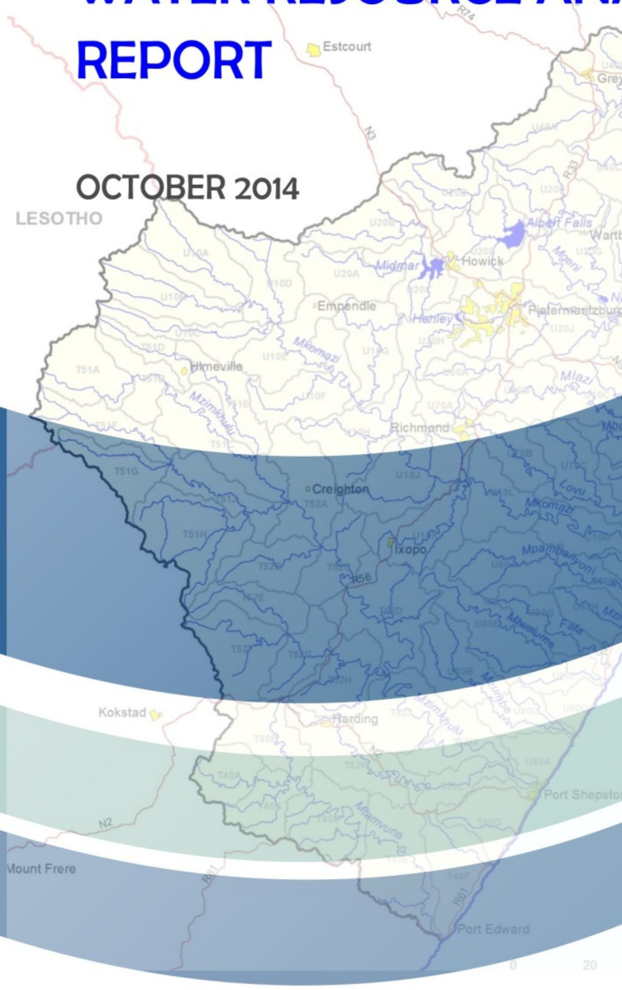
REPORT NO: RDM/WMA11/00/CON/CLA/0514

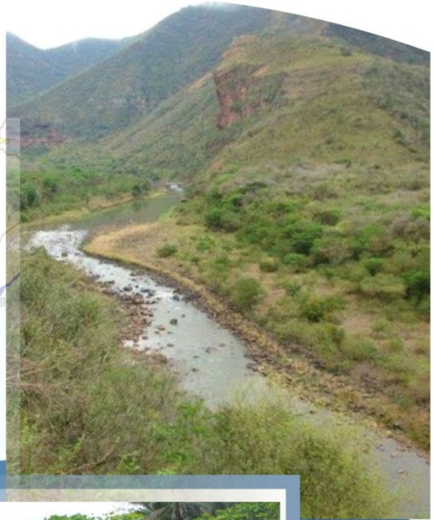
CLASSIFICATION OF WATER RESOURCES AND DETERMINATION OF THE COMPREHENSIVE RESERVE AND RESOURCE QUALITY OBJECTIVES IN THE MVOTI TO UMZIMKULU WATER MANAGEMENT AREA

PROJECT NUMBER: WP 10679

WATER RESOURCE ANALYSIS REPORT

OCTOBER 2014





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Water and Sanitation
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CLASSIFICATION OF WATER RESOURCES AND DETERMINATION OF THE COMPREHENSIVE RESERVE AND RESOURCE QUALITY OBJECTIVES IN THE MVOTI TO UMZIMKULU WATER MANAGEMENT AREA

WATER RESOURCE ANALYSIS REPORT

Report Number: RDM/WMA11/00/CON/CLA/0514

OCTOBER 2014

REFERENCE

This report is to be referred to in bibliographies as:

Department of Water and Sanitation, South Africa, October 2014. Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area: Water Resource Analysis Report. Prepared by: Rivers for Africa eFlows Consulting (Pty) Ltd. Authored by WRP Consulting Engineers.

DOCUMENT INDEX

Index Number	DWA Report Number	Report Title
1	*Report Number: RDM/WMA11/00/CON/CLA/0112*	*Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area:* **Inception report**
2	*Report Number: RDM/WMA11/00/CON/CLA/0113*	*Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area:* **Status quo assessment, IUA and biophysical node delineation and identification.**
3	*Report Number: RDM/WMA11/00/CON/CLA/0213*	*Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area:* **River Resource Units and EWR sites**
4	*Report Number: RDM/WMA11/00/CON/CLA/0313*	*Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area:* **Desktop Estuary EcoClassification and EWR**
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5.1	*Report Number: RDM/WMA11/00/CON/CLA/0114*	*Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area:* **Volume 1: EWR estimates of the River Desktop Biophysical Nodes**
5.2	*Report Number: RDM/WMA11/00/CON/CLA/0214*	*Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area:* **Volume 2: EcoClassification and EWR assessment on the Mtamvuna, Lovu, uMngeni, Karkloof and uMnsunduze Rivers**
5.3	*Report Number: RDM/WMA11/00/CON/CLA/0314*	*Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area:* **Volume 3: EcoClassification and EWR assessment on the Mkomazi, uMngeni and Mvoti Rivers**
6	*Report Number: RDM/WMA11/00/CON/CLA/0212*	*Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area:* **BHNR**
7	**Report Number: RDM/WMA11/00/CON/CLA/0514**	**Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area: Water Resource Analysis Report**
8	**Operational Scenario and Management Class report volumes**	
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8.2	*Report Number: RDM/WMA11/00/CON/CLA/0714*	*Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area:* **Volume 2: Estuary Ecological Consequences**
8.3	*Report Number: RDM/WMA11/00/CON/CLA/0814*	*Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area:* **Volume 3: Estuary ecological consequences - specialist appendices (available electronically only)**
8.4	*Report Number: RDM/WMA11/00/CON/CLA/0914*	*Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area:* **Volume 4: Economic consequences**
8.5	*Report Number: RDM/WMA11/00/CON/CLA/1014*	*Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area:* **Volume 5: EGSA consequences**
8.6	*Report Number: RDM/WMA11/00/CON/CLA/1214*	*Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area:* **Volume 6: Water quality consequences**
8.7	*Report Number: RDM/WMA11/00/CON/CLA/1314*	*Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area:* **Volume 7: Recommended Management Classes.**
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11	*Report Number: RDM/WMA11/00/CON/CLA/0415*	*Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area:* **Main report**

DEPARTMENT OF WATER AND SANITATION

CHIEF DIRECTORATE: RESOURCE DIRECTED MEASURES

CLASSIFICATION OF WATER RESOURCES AND DETERMINATION OF THE COMPREHENSIVE RESERVE AND RESOURCE QUALITY OBJECTIVES IN THE MVOTI TO UMZIMKULU WATER MANAGEMENT AREA

WATER RESOURCE ANALYSIS REPORT

Approved for RFA by:

…………………………………	…………………………………
Delana Louw	*Date*
Project Manager	

DEPARTMENT OF WATER AND SANITATION (DWS)
Approved for DWS by:

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	Date
Chief Director: Water Ecosystems	

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Report Editor: Shael Koekemoer

REPORT SCHEDULE

Version	Date
First draft	*October 2014*

EXECUTIVE SUMMARY

BACKGROUND

The Mvoti to Umzimkulu Water Management Area (WMA) encompasses a total catchment area of approximately 27,000 km^2 and occurs largely within Kwazulu-Natal. A small portion of the Mtamvuna River and the upper and lower segments of the Umzimkulu River straddle the Eastern Cape, close to the Mzimvubu and Keiskamma WMA in the south (DWA, 2011). The Chief Directorate: Resource Directed Measures of the Department of Water and Sanitation initiated a study during 2012 for the provision of professional services to undertake the Comprehensive Reserve, classify all significant water resources and determine the Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area. The integrated steps for the study are provided below.

Step	Description
1	*Delineate the units of analysis and Resource Units, and describe the status quo of the water resource(s) (completed).*
2	*Initiation of stakeholder process and catchment visioning (on-going).*
3	**Quantify the Ecological Water Requirements and changes in non-water quality ecosystem goods, services and attributes**
4	**Identification and evaluate scenarios within the integrated water resource management process.**
5	*Evaluate the scenarios with stakeholders.*
6	*Develop draft RQOs and numerical limits.*
7	*Gazette and implement the class configuration and RQOs.*

*This report forms part of **Steps 3** and **4** described in the table above.*

STUDY AREA

The WMA extends from the town of Zinkwazi, in the north to Port Edward and on the south along the KwaZulu-Natal coastline and envelopes the inland towns of Underberg and Greytown up until the Drakensberg escarpment. The WMA spans across the primary catchment "U" and incorporates the secondary drainage areas of T40 (Mtamvuna River in Port Shepstone) and T52 (Umzimkulu River).

AVAILABLE INFORMATION

The approach adopted for the water resource assessment task of this study was to obtain and use information available from previous studies. A review of the various past and current studies in the study area was conducted as part of the Status Quo assessment (DWA, 2013a) in order to confirm the availability and status of both the hydrology and water resource models available.

IUAS AND DESKTOP BIOPHYSICAL NODES (DBNS)

The delineation of the Integrated Units of Analysis (IUAs) and the identification of biophysical nodes in the Mvoti WMA were done as part of the Status Quo assessment. Details of the IUAs and desktop biophysical nodes (DBNs) are described in the Status Quo report (DWA, 2013a) and were used as units of reference for the Water Resource Analyses.

WATER RESOURCE ANALYSIS

The main purpose of the Water Resource Analysis task is to asses the water resource availability of the various water supply systems within the context of alternative development conditions. Natural and Present Day flow time series data were derived for all the desktop biophysical nodes as well as for the estuaries. System configurations of available Decision Support Systems (DSSs) were obtained and refined to enable modelling of Present Day (PD) flow at the DBNs. Operational scenarios were subsequently formulated and analysed for four selected catchments, namely the Lovu, Mvoti, Mkomazi and the uMngeni.

This report provides information on the hydrological database and Decision Support Systems (Section 2) and basic assumptions (Section 4) used for the Water Resource Analyses undertaken as part of this study.

SUMMARISED RESULTS

With reference to the natural and PD assessments described in Section 5 the following should be noted:

- *Data sets of natural time series of flows were generated for 244 DBNs.*
- *Low confidence PD time series of flows were simulated for 219 DBNs.*
- *The above-mentioned time series of flows were provided to the Ecological team for further assessment and for use in the quantification of the EWR.*

The results of the operational scenario analyses documented in Section 8 of this report informed the integrated water resource management processes. Four main systems were evaluated (Mvoti, Lovu, uMngeni and Mkomazi) and the result are summarised below.

Mvoti River System

The Mvoti River system's operational scenarios included the modelling of the proposed Isithundu Dam as well as the new Imvutshane Dam (situated on a tributary of the Hlimbtiwa River) which is currently in construction. Analyses were undertaken with the Water Resource Yield Model (WRYM). The impact of implementing the EWR at Mv_I_EWR2 was assessed within context of the available system yield. The operational scenarios are described in the Table 1, the yield results are presented in Table 2 and the average annual flows simulated at the EWR sites are summarised in Table 3.

Table 1 Mvoti: Summarised description of Scenarios

Scenario	Scenario Variables				
	Update water demands	Ultimate development demands and return flows (2040)	EWR	MRDP[1]	Imvutshane Dam
MV1	*Yes*	*No*	*No*	*No*	*No*
MV21	*Yes*	*No*	*REC tot[2]*	*No*	*No*
MV22	*Yes*	*No*	*REC low[3]*	*No*	*No*
MV3	*Yes*	*Yes*	*No*	*Yes*	*Yes*
MV41	*Yes*	*Yes*	*REC tot[2]*	*Yes*	*Yes*
MV42	*Yes*	*Yes*	*REC low[3]*	*Yes*	*Yes*
MV43	*Yes*	*Yes*	*REC low+[4]*	*Yes*	*Yes*

1 Mvoti River Development Project (Isithundu Dam). 2 Recommended Ecological Category (Total Flows)
3 Recommended Ecological Category (Low Flows).
4 Recommended Ecological Category (Total Flows for January, February, March and Low Flows for remaining months).

Table 2 Mvoti: Summary of yield results

Scenario	EWR[1]	Isithundu EFY (million m^3/a)	Reduction in yield due to EWR (million m^3/a)
MV3	*No*	*34.88*	*-*
MV41	*REC tot*	*8.02*	*26.86*
MV42	*REC low*	*15.22*	*19.66*
MV43	*REC low+*	*13.77*	*21.11*

Mv_I_EWR2

Table 3 Mvoti: Simulated results for operational scenarios

EWR site name	SQ reach	Total Flow: 1921 - 1994 (million m^3/a)			
		MV3	MV41	MV42	MV43
Mv_I_EWR1	*U40B-03770*	*6.93*	*6.93*	*6.93*	*6.93*
Mv_I_EWR2	*U40H-04064*	*128.88*	*156.12*	*148.86*	*150.40*
Estuary	*-*	*187.78*	*217.02*	*209.13*	*211.12*

Lovu River System

The Lovu River catchment was analysed using the WRSM2000. The operational scenarios are described in Table 4 and the average annual flows simulated at the EWR sites are summarised in Table 5.

Table 4 Lovu: Summary of operational scenarios

Scenario	Scenario variables			
	Update water demands	Ultimate development demands and return flows (2040)	EWR	Reduced abstraction and afforested areas
LO1	*Yes*	*No*	*No*	*No*
LO2	*Yes*	*Yes*	*No*	*No*
LO3	*Yes*	*Yes*	*No*	*Yes (25% reduction)*
LO4	*Yes*	*Yes*	*No*	*Yes (50% reduction)*

Table 5 Lovu: Summary of simulated results for operational scenarios

EWR site name	Average Annual Flow for indicated operational Scenarios: 1921 - 1994 (million m^3/a)				WRSM2000 route number
	LO1	LO2	LO3	LO4	
Lo_R_EWR1	*73.42*	*70.84*	*77.40*	*84.03*	*18*
Estuary	*82.77*	*80.19*	*89.18*	*98.02*	*25*

uMngeni River System

The uMngeni River system was analysed using the WRPM which was updated to include modelling of the 2022 urban and industrial water requirements. The operational scenarios are described in Table 6.

Table 6 uMngeni: Summary of operational scenarios

Scenario	Scenario Variables							
	Update water demands	Update demands and return flows (2022)	Ultimate development demands and return flows (2040)	EWR	MMTS2	uMWP-1	Darvill re-use	eThekwini re-use
UM1	Yes	No	No	No	No	No	No	No
UM2	No	Yes	No	No	Yes	No	No	No
UM41	Yes	No	Yes[3]	No	Yes	No	No	No
UM42	Yes	No	Yes[4]	No	Yes	No	No	No
UM51	Yes	No	Yes[3]	No	Yes	No	Yes	Yes
UM52	Yes	No	Yes[4]	No	Yes	No	Yes	Yes

1 Mooi-Mgeni Transfer Scheme Phase 2
2 uMkhomazi Water Project Phase 1
3 All future return flows from Phoenix and Mhlanga WWTW to the uMngeni System: Total return flows of 282 Ml/d.
4 All future return flows from Phoenix, Umhlanga and Tongati WWTW to the uMngeni System: Total return flows of 408 Ml/d.

Scenario **UM2** *included a maximum load shift volume from the Upper to the Lower uMngeni River System via the Western Aqueduct (direct support from Midmar Dam to the eThekwini Durban Heights WTW) while maintaining a 3 months available storage in Midmar Dam as a buffer storage for supplying the Upper uMngeni Demand Centres. The uMngeni system was operated at full utilization of its water resources for the remaining scenarios. The average annual flows simulated at the relevant EWR sites are summarised in Table 7.*

Table 7 uMngeni: Summary of simulated results for operational scenarios

EWR site name	SQ reach	Average Annual flow for indicated operational scenarios: 1921 - 1994 (million m^3/a)						WRPM Channel No.
		UM1	UM2	UM41	UM42	UM51	UM52	
Mg_I_EWR2	U20E-04243	105.40	96.82	131.62	131.62	131.55	131.55	572
Mg_I_EWR5	U20L-04435	245.25	273.78	261.00	261.00	240.12	240.12	649
Estuary	-	199.13	259.50	340.00	386.01	299.92	345.93	841 & 825

Mkomazi River System

The existing Mkomazi catchment is relatively undeveloped. Three future development options, the MWP (proposed Smithfield Dam and its associated conveyance infrastructure), the Bulwer Water Supply Scheme and the Ngwadini Off-channel Dam (OCD), were included in the water resource analyses that were carried out with the WRYM. The recently completed Mkomazi Study (DWA, 2014c) was the major source of information for this catchment. There is only one industrial water user, SAPPI-SAICCOR, with an abstraction of 53 million m^3/s. The abstraction is from the Lower Mkomazi at the inlet to the estuary. The Mkomazi River is SAPPI-SAICCOR's only resource and for the purposes of the operational scenarios it was assumed that SAPPI-SAICCOR is supported from the proposed Smithfield Dam by means of river releases. A loss of 10% was associated with these releases. An estuary flow requirement of 1 m^3/s was also included in all the operation scenarios which are listed in Table 8.

Table 8 Mkomazi: Summary of operational scenarios

Mkomazi: Summary of operational scenarios

Scenario	Scenario Variables				
	Update water demands	**Ultimate development demands and return flows (2040)**	**EWR**	**uMWP-1**	**Ngwadini OCD**
MK1	*Yes*	*No*	*No*	*No*	*No*
MK2	*Yes*	*Yes*	*No*	*Yes*	*Yes (no support)*
MK21	*Yes*	*Yes*	*REC tot[1] (EWR 2)*	*Yes*	*Yes (no support)*
MK22	*Yes*	*Yes*	*REC low[2] (EWR 2)*	*Yes*	*Yes (no support)*
MK23	*Yes*	*Yes*	*REC low+[3] (EWR 2)*	*Yes*	*Yes (no support)*
MK31	*Yes*	*Yes*	*REC tot[1] (EWR 3)*	*Yes*	*Yes (no support)*
MK32	*Yes*	*Yes*	*REC low[2] (EWR 3)*	*Yes*	*Yes (no support)*
MK33	*Yes*	*Yes*	*REC low+[3] (EWR 3)*	*Yes*	*Yes (no support)*
MK4	*Yes*	*Yes*	*No*	*Yes*	*Yes (with support)*
MK41	*Yes*	*Yes*	*REC tot[1] (EWR 2)*	*Yes*	*Yes (with support)*
MK42	*Yes*	*Yes*	*REC low[2] (EWR 2)*	*Yes*	*Yes (no support)*

1 Recommended Ecological Category (Total Flows).
2 Recommended Ecological Category (Low Flows).
3 Recommended Ecological Category (Total Flows for January, February, March and Low Flows remaining months).

The yield results are presented in Table 9 and the average annual flows simulated at the EWR sites are summarised in Table 10. The yield results are important from a water resources point of view as it provides an indication of how the water supply capability of the system is affected by the implementation of additional system components (such as the EWR) or by changing an operating rule (e.g. support to Ngwadini). The yield results can also be applied to assess the socio-economic implications of releasing water to meet the EWR.

Table 9 Mkomazi: Summary of yield results

Scenario	Description	Smithfield HFY[1] (million m^3/a)	Ngwadini HFY (million m^3/a)	Total HFY (million m^3/a)	Difference in total HFY due to EWR (million m^3/a)
MK2	*No EWR; No support to Ngwadini*	*196.0*	*11.99*	*207.99*	*-*
MK21	*Total Flow EWR (EWR2); No support to Ngwadini*	*142.2*	*8.03*	*150.23*	*57.76*
MK22	*Low Flow EWR (EWR2); No support to Ngwadini*	*150.6*	*8.03*	*158.63*	*49.36*
MK23	*Low Flow+ EWR (EWR2); No support to Ngwadini*	*150.6*	*8.03*	*158.63*	*49.36*
MK31	*Total Flow EWR (EWR3); No support to Ngwadini*	*150.1*	*5.98*	*156.08*	*51.91*
MK32	*Low Flow EWR (EWR3); No support to Ngwadini*	*161.0*	*6.63*	*167.63*	*40.36*
MK33	*Low Flow+ EWR (EWR3); No support to Ngwadini*	*161.0*	*6.63*	*167.63*	*40.36*

Scenario	Description	Smithfield HFY[1] (million m³/a)	Ngwadini HFY (million m³/a)	Total HFY (million m³/a)	Difference in total HFY due to EWR (million m³/a)
MK4	No EWR; Support to Ngwadini	142.5	54.8	197.3	-
MK41	Total Flow EWR (EWR2) ; Support to Ngwadini	84.1	54.8	138.9	58.40
MK42	Low Flow EWR (EWR2); Support to Ngwadini	92.5	54.8	147.3	50.00

1 Historic Firm Yield

Table 10 Mkomazi: Summary of simulated results for operational scenarios

EWR site name	SQ reach	Average annual flow for indicated operational scenarios: 1920 - 2008 (million m³/a)										WRYM Channel No.
		MK2	MK21	MK22	MK23	MK31	MK32	MK33	MK4	MK41	MK42	
EWR_Site_1b	-	486.4	540.4	532.1	532.6	532.5	521.7	521.7	539.8	598.5	590.1	278
Mk_I_EWR2	U10J-04679	621.0	677.0	668.7	669.2	669.0	658.2	658.2	672.8	732.6	724.3	205
Mk_I_EWR3	U10M-04746	755.5	813.5	805.1	805.6	807.5	796.0	796.0	764.7	822.6	814.3	120
Estuary	-	719.1	779.1	770.8	771.2	773.1	761.6	761.6	728.2	788.1	779.8	118

The yield results are important from a water resources point of view as it provides an indication of how the water supply capability of the system is affected by the implementation of additional system components (such as the EWR) or by changing an operating rule (e.g. support to Ngwadini). The yield results can also be applied to assess the socio-economic implications of releasing water to meet the EWR.

CONCLUSIONS AND RECOMMENDATIONS

In summary, the following should be noted in terms of the hydrological data and models applied in the water resource assessments of this study:

- *High resolution and high confidence models were available for only two catchments (Mkomazi and Umzimkulu).*
- *There are four catchments (uMngeni, Mvoti, Mdloti and Tongati) with relatively old high confidence hydrology and high resolution high confidence models.*
- *The remaining twelve catchments have low confidence hydrology (WR2005 Study information) and no water resource assessment models configured. The WRSM2000 was applied for these catchments.*
- *The hydrological time periods differ for the catchments.*
- *Groundwater surface water interaction was not accounted for in the assessment of the catchments.*
- *Various assumptions were made in terms of the disaggregation of hydrological and catchment development information to enable modelling of DBNs impacting on the confidence associated with DBN results.*

The following conclusions are made based on the results of the operational scenarios presented above and discussed in more detail in Section 8:

- *Implementation of the EWR in the Mvoti River catchment will have a significant impact on the yield available from the proposed Isithundu Dam. The reduction in excess yield varies from 77% for the total flow EWR to 56% for the low flow EWR.*
- *Conclusions in terms of operational scenario results for the Lovu catchment can only be made by evaluation of simulated flows at the EWR site and the estuary. It was noted that*

a 25% reduction in abstractions (Scenario **LO3***) has caused a 9% increase in average annual flow at Lo_R_EWR1. A more significant impact should, however, be observed in the base flows.*

- *Operational scenario results for the uMngeni River system should be evaluated in terms of the flows simulated at the selected EWR sites. The re-use from Darvill WWTW has no impact on the supply from the system, but influences the flows at the downstream EWR sites (Mg_R_EWR4 and Mg_I_EWR5).*
- *As expected, the implementation of the EWR in the Mkomazi catchment has a significant impact on the firm yield of the system. For scenarios excluding support to Ngwadini OCD the reduction in firm yield varies from 29.7% for Scenario* **MK21** *to 19.4% for Scenario MK33.*
- *The firm yield of the Mkomazi system is reduced by 5% when support to Ngwadini OCD is allowed from Smithfield Dam (comparison of scenarios* **MK2** *and* **MK4***). The increase in yield at Ngwadini due to support from Smithfield Dam (***MK4***) should thus be evaluated within the context of the total firm yield of the system.*
- *Evaluation of the Scenario* **MK21** *and* **MK31** *yield results show that the implementation of the total EWR at Mk_I_EWR2 is causing the total HFY of the Mkomazi system to be about 5.85 million m^3/a less compared to the when the total EWR at Mk_I_EWR3 is implemented.*
- *In general, the inclusion of the EWR at Mk_I_EWR2 has a higher impact on the total firm yield of the Mkomazi system compared to the implementation of the EWR at Mk_I_EWR3.*

It is recommended that:

- *The information provided in this report is used for further assessment and decision making but that due cognisance be taken of the confidence associated with the results.*
- *The firm yield results provided for the Mvoti and Mkomazi catchments are used to determine the impact of implementation of the EWR on the current socio-economics.*

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TERMINOLOGY AND ACRONYMS

BAS	*Best Attainable State*
CD: RDM	*Chief Directorate: Resource Directed Measures*
DBN	*Desktop Biophysical Node*
DSS	*Decision Support System*
DWA	*Department Water Affairs (Name change from DWAF applicable after April 2009)*
DWAF	*Department Water Affairs and Forestry*
DWS	*Department Water and Sanitation (Name change from DWA applicable after May 2014)*
EC	*Ecological Category*
EFY	*Excess Firm Yield*
EWR	*Ecological Water Requirements*
FSA	*Full Supply Area*
FSC	*Full Supply Capacity*
FSV	*Full Supply Volume*
HFY	*Historic Firm Yield*
IAP	*Invasive Alien Plant*
IUA	*Integrated Unit of Analysis*
MMTS	*Mooi-Mgeni Transfer Scheme*
MMTS2	*Mooi-Mgeni Transfer Scheme Phase 2*
MRDP	*Mvoti River Development Project*
MRU	*Management Resource Unit*
nMAR	*Natural Mean Annual Runoff*
OCD	*Off-channel Dam*
PD	*Present Day*
PES	*Present Ecological State*
pMAR	*Present Day Mean Annual Runoff*
RDRM	*Revised Desktop Reserve Model*
REC	*Recommended Ecological Category*
RQO	*Resource Quality Objective*
RU	*Resource Unit*
SFRA	*Streamflow Reduction Activities*
SQ	*Sub Quaternary*
TS	*Time Series*
uMWP-1	*uMkhomazi Water Project Phase 1*
UWS	*Ultimate Waste Water Scenario*
WMA	*Water Management Area*
WRCS	*Water Resources Classification System*
WRPM	*Water Resource Planning Model*
WRSM2000	*Water Resource Simulation Model 2000*
WRYM	*Water Resource Yield Model*
WSS	*Water Supply Scheme*
WWTW	*Waste Water Treatment Works*

1 INTRODUCTION

1.1 BACKGROUND

There is an urgency to ensure that water resources in the Mvoti to Umzimkulu Water Management Area (WMA) are able to sustain their level of uses and be maintained at their desired states. The determination of the Water Resource Classes of the significant water resources in Mvoti to Umzimkulu WMA will ensure that the desired condition of the water resources, and conversely, the degree to which they can be utilised is maintained and adequately managed within the economic, social and ecological goals of the water users (DWA, 2011). The Chief Directorate: Resource Directed Measures (CD: RDM) of the Department of Water and Sanitation (DWS) initiated a study during 2012 for the provision of professional services to undertake the Comprehensive Reserve, classify all significant water resources and determine the Resource Quality Objectives (RQOs) in the Mvoti to Umzimkulu WMA.

1.2 STUDY AREA

The Mvoti to Umzimkulu WMA encompasses a total catchment area of approximately 27,000 km^2 and occurs largely within Kwazulu-Natal. A small portion of the Mtamvuna River and the upper and lower segments of the Umzimkulu River straddle the Eastern Cape, close to the Mzimvubu and Keiskamma WMA in the south (DWA, 2011).

The WMA extends from the town of Zinkwazi, in the north to Port Edward and on the south along the KwaZulu-Natal coastline and envelopes the inland towns of Underberg and Greytown up until the Drakensberg escarpment. The WMA spans across the primary catchment "U" and incorporates the secondary drainage areas of T40 (Mtamvuna River in Port Shepstone) and T52 (Umzimkulu River). Ninety quaternary catchments constitute the water management area and the major rivers draining this WMA include the Mvoti, uMngeni, Mkomazi, Umzimkulu and Mtamvuna (DWA, 2011).

Two large river systems, the Umzimkulu and Mkomazi rise in the Drakensberg. Two medium-sized river systems the uMngeni and Mvoti rise in the Natal Midlands and have been largely modified by human activities, mainly intensive agriculture, forestry and urban settlements. Several smaller river systems (e.g. Mzumbe, Mdloti, Tongaat, Fafa, and Lovu Rivers) also exist within the WMA (DWAF, 2004). Several parallel rivers arise in the escarpment and discharges into the Indian Ocean and the water courses in the study area display a prominent southeasterly flow direction (DWA, 2011).

The WMA is very rugged and very steep slopes characterise the river valleys in the inland areas for all rivers. Moderate slopes are found but comprise only 3% of the area of the WMA (DWAF, 2004). These flatter areas are mainly subject to intensive agricultural activities (DWAF, 2004).

According to DWAF (2004) the following eight key areas exist within WMA 11:

- *Mvoti (Tertiary catchment U40);*
- *Mdloti (Tertiary catchment U30);*
- *uMngeni (Tertiary catchment U20);*
- *Mlazi and Lovu (Tertiary catchments U60 and U70);*
- *Mkomazi (Tertiary catchment U30);*
- *Mpambanyoni to Mzumbe or South Coast (Tertiary catchment U80);*
- *Umzimkulu (Tertiary catchments T51 and T52); and*

- *Mtamvuna (Tertiary catchment T40).*

The study area is shown in Figure 1.1.

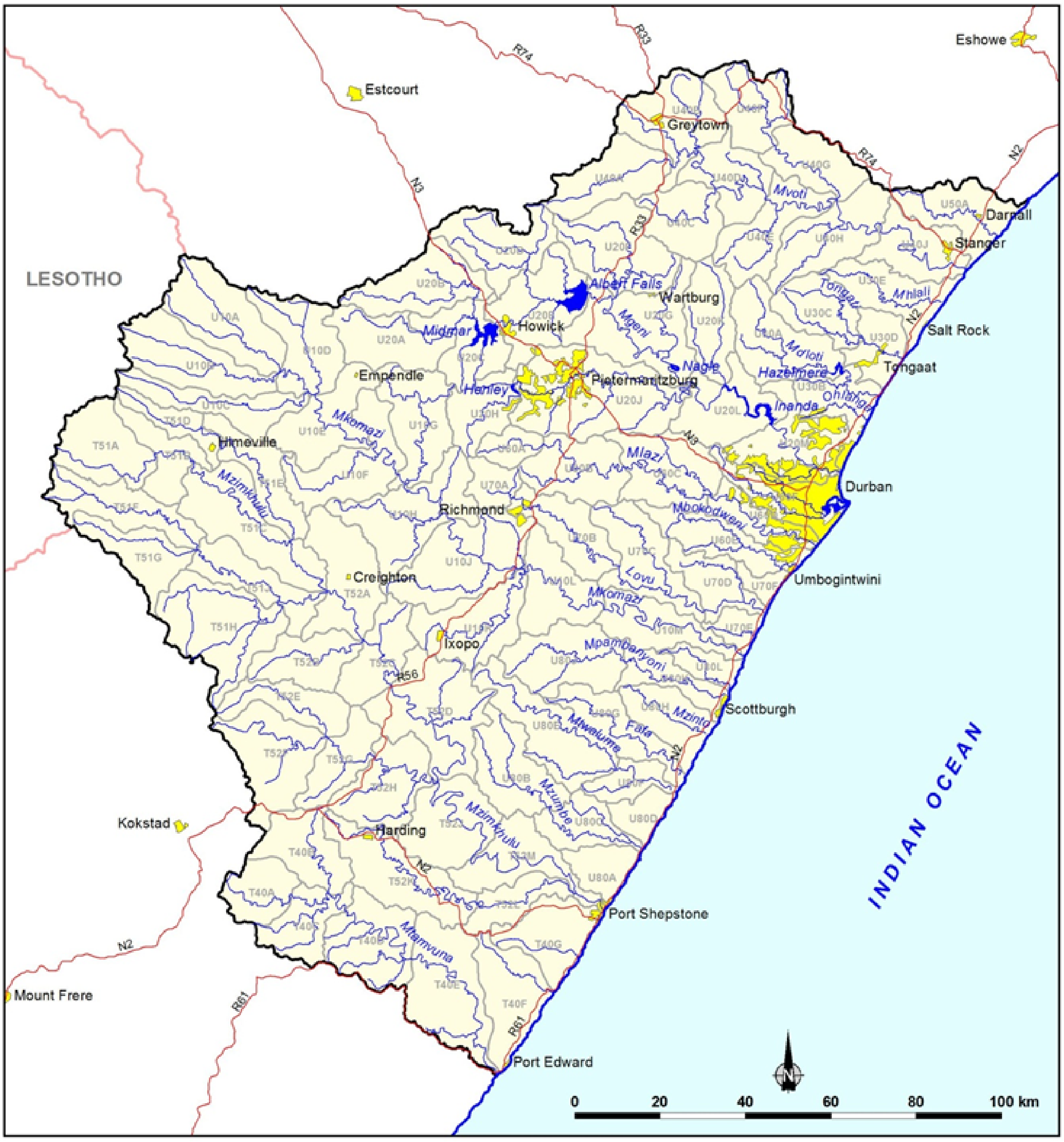

Figure 1.1 The Mvoti to Umzimkulu Water Management Area – WMA 11

1.3 INTEGRATED STEPS APPLIED IN THIS STUDY

The integrated steps for the National Water Classification System, the Reserve and RQOs are summarised in Table 1.1. The Water Resource Analysis task, which is the subject of this report, forms part of ***Steps 3*** *and* ***4*** *as described in the table below.*

Table 1.1 Integrated study steps

Step	Description
1	*Delineate the units of analysis and Resource Units, and describe the status quo of the water resource(s) (completed).*
2	*Initiation of stakeholder process and catchment visioning (on-going).*
3	**Quantify the Ecological Water Requirements and changes in non-water quality ecosystem goods, services and attributes**
4	**Identify and evaluate scenarios within the integrated water resource management process.**
5	*Evaluate the scenarios with stakeholders.*
6	*Develop draft RQOs and numerical limits.*
7	*Gazette and implement the class configuration and RQOs.*

1.4 WATER RESOURCE ANALYSIS TASK

The main purpose of the Water Resource Analysis task is to assess the water resource availability of the various water supply systems within the context of alternative development conditions. The delineation of the Integrated Units of Analysis (IUAs) and the identification of biophysical nodes in the Mvoti WMA were done as part of the Status Quo assessment. Details of the IUAs and desktop biophysical nodes (DBNs) are described in the Status Quo report (DWA, 2013a) and were used as units of reference for the Water Resource Analyses. Natural and Present Day flow time series data were derived for all the desktop biophysical nodes as well as for the estuaries. System configurations of available Decision Support Systems (DSSs) were obtained and refined to enable modelling of Present Day (PD) flow at the DBNs. Operational scenarios were subsequently formulated and analysed for four selected catchments, namely the Lovu, Mvoti, Mkomazi and the uMngeni.

This report, therefore, provides information on the hydrological database, DSSs and basic assumptions used for the Water Resource Analyses undertaken as part of this study. The results of the Water Resource Analyses documented in this report informed the Ecological Water Requirements (EWR) quantification and integrated water resource management processes.

1.5 OUTLINE OF REPORT

The report structure is outlined below.

Chapter 1: Introduction
This chapter provides an overview of the study area, objectives of the study and the Water Resource Analysis task as well as the outline of the report.

Chapter 2: Data and Information Availability
The data and information available for the assessment of the different water resource systems are summarised in this chapter.

Chapter 3: Integrated Units of Analysis and desktop biophysical nodes
The delineation of IUA and selection of DBNs are briefly described and summarised in this chapter.

Chapter 4: Approach
This chapter outlines the various methodologies adopted during the Water Resource Analysis task.

Chapter 5: Natural and Present Day Flows

A brief description of each water resource catchment as well as the base data used for the assessment of Natural and Present Day flow results are provided in this chapter.

Chapter 6: EWR Requirements

This chapter summarises the ecological quantification results for the respective EWR sites and provides background to the determination of EWR structures included in the Water Resource Yield Model (WRYM) and the Water Resource Planning Model (WRPM).

Chapter 7: Operational Scenarios

Background to the identification of operational scenarios is given in this chapter.

Chapter 8: Main River Systems Influenced by Operational Activities

Operational scenarios, as defined for four of the main river systems, are described in this chapter. The scenario results are also summarised and discussed.

Chapter 9: Conclusions and Recommendations

Background to the identification of operational scenarios is given in this chapter.

Chapter 10: Data Repository

The structure adopted for the provision of electronic data resulting from this study is outlined in this chapter.

Chapter 11: References

Report references are listed.

Chapter 12: Appendix A: Maps

Relevant maps are included in this appendix.

Chapter 13: Appendix B: EWR Structures

EWR structures are provided for relevant EWR sites.

Chapter 14: Appendix C: Report Comments

2 DATA AND INFORMATION AVAILABILITY

2.1 INTRODUCTION

The approach adopted for the water resource assessment task of this study was to obtain and use information available from previous studies. A review of the various past and current studies in the study area was conducted as part of the Status Quo assessment (DWA, 2013a) in order to confirm the availability and status of both the hydrology and water resource models available. This section summarises the resulting information.

2.2 HYDROLOGY

The Mvoti to the Umzimkulu WMA was divided into water resource zones based on similar water resource operation, location of significant water resource infrastructure (including proposed infrastructure) and distinctive functions of the catchments in context of the larger system. Information is subsequently presented in terms of these water resource zones/key areas.

It is important to note that detailed hydrological assessments were only undertaken for the larger river systems (e.g. Mvoti, Mdloti, Tongati, uMngeni, Mkomazi and Umzimkulu). In the cases where there are gaps the results from the Water Resources of South Africa 2005 study (WRC, 2005) were considered as sources of information. There are, however, several known problems with the WR2005 study data sets for this WMA, such as that no farm dams were taken into account during the Water Resources Simulation Model 2000 (WRSM2000) calibration process. The WR2012 study, which is an update of the WR2005 study, was tasked to address the farm dam issues, but does not allow for the general updating of demands due to budget constraints. Although the WR2012 study has not yet been completed and no official results have been released, information was obtained for the Lovu and Mtamvuna catchments and used for the purposes of this study.

The source of the hydrological information, the record period (in terms of hydrological years) and the number of years covered by the available hydrology are summarised in Table 2.1. With the exception of the Lovu and Mtamvuna catchments, the last year of the record period is also indicative of the relevant catchment development level considered for the PD analysis of the individual catchments. The PD analyses for the Lovu and Mtamvuna were based on the 2004 development conditions applicable to all catchments where the WR2005 results were used.

Table 2.1 Hydrological information

Key Area	Rivers	Quaternaries	Source of information	Record Period	Number of Years
Mvoti	*Nonoti and Zinkwazi*	*U50A*	*WR2005 Study (WR2005, 2011)*	*1920 - 2004*	*85*
	Mvoti	*U40A to U40J,*	*Mvoti River Dam Feasibility Study Extension (DWA, 2000)*	*1921 - 1994*	*74*
Mdloti	*Mhlali*	*U30E*	*WR2005 Study (WR2005,2011)*	*1920 - 2004*	*85*
	Tongati	*U30C and U30D*	*Inflows to Tongati Estuary - Knight Piesold Study (DWA, 2006)*	*1920 - 2003*	*84*
	Mdloti	*U30A and U30B*	*Raising of Hazelmere Dam - Feasibility Study (DWA, 2003)*	*1925 - 1995*	*71*
uMngeni	*uMngeni*	*U20A to U20M*	*uMngeni Hydrology Update (DWA, 1999)*	*1925 - 1995*	*71*

Key Area	Rivers	Quaternaries	Source of information	Record Period	Number of Years
Mlazi and Lovu	*Umbilo and Mhlathuzana*	*U60F*	*WR2005 Study (WR2005,2011)*	*1920 - 2004*	*85*
	Mlazi	*U60A to U60D*	*uMWP Phase1 Study (uMWP-1) (DWA, 2014) and WR2005 Study (WRC, 2005)*	*1925 - 2004*	*80*
	Mbokodweni	*U60E*	*WR2005 Study (WRC, 2005)*	*1920 - 2004*	*85*
	Manzimtoti and Little Manzimtoti	*U70F*	*WR2005 Study (WRC, 2005)*	*1920 - 2004*	*85*
	Lovu	*U70A to U70D*	*WR2012 Study*	*1920 - 2009*	*90*
	Msimbazi, Mgababa and Ngane	*U70E*	*WR2005 Study (WRC, 2005)*	*1920 - 2004*	*85*
Mkomazi	*Mkomazi*	*U10A to U10M*	*uMWP-1 Study (DWA, 2014)*	*1925 - 2008*	*84*
South Coast	*Mahlongwana and Mahlongwa*	*U80L*	*WR2005 Study (WRC, 2005)*	*1920 - 2004*	*85*
	Mpambanyoni	*U80J and U80K*	*WR2005 Study (WRC, 2005)*	*1920 - 2004*	*85*
	Mzinto, Mkhumbane, Sezela and Mdesingane	*U80H*	*WR2005 Study (WRC, 2005)*	*1920 - 2004*	*85*
	Fafa	*U80G*	*WR2005 Study (WRC, 2005)*	*1920 - 2004*	*85*
	Mtwalume	*U80E and U80F*	*WR2005 Study (WRC, 2005)*	*1920 - 2004*	*85*
	Mnamfu, KwaMakosi, Mfazazana, Mhlungwa and Mzimayi	*U80D*	*WR2005 Study (WRC, 2005)*	*1920 - 2004*	*85*
	Mzumbe	*U80B and U80C*	*WR2005 Study (WRC, 2005)*	*1920 - 2004*	*85*
	Ntshambili, Koshwana, Domba, Mhlangamkulu and Mtentweni	*U80A*	*WR2005 Study (WRC, 2005)*	*1920 - 2004*	*85*
Umzimkulu	*Umzimkulu*	*T51A to T51J T52A to T52M*	*Umzimkulu River Catchment Water Resources Study (DWA, 2011)*	*1920 - 2007*	*88*
Mtamvuna	*Mbango, Boboyi, Zotsha, uMhlanga, Vungu, Bilanhlolo and Mvutshini*	*T40G*	*WR2005 Study (WRC, 2005)*	*1920 - 2004*	*85*
	Mbizana, Kaba, Little Mpenjati, Kandandlovu, Tongazi, Kuboboyi, Sandlundlu, Zolwane	*T40F*	*WR2005 Study (WRC, 2005)*	*1920 - 2004*	*85*
	Mtamvuna	*T40A to T40E*	*WR2012 Study*	*1920 - 2009*	*90*

2.3 DECISION SUPPORT SYSTEM

The models available for the different catchments in the WMA as well as the confidence of the models are presented in Table 2.2. *The higher confidence models were done recently and with recent land use data, while the medium confidence models were based on older analyses and land* *use data. It is, however, important to note that the resolution of the higher confidence models is also relatively high implying that some confidence will be lost when refining the resolution to enable simulation of the biophysical nodes (see Section 2.3).*

Table 2.2 Models available

Key Area	Rivers	Quaternaries	Best available models	Confidence of models
Mvoti	*Nonoti and Zinkwazi*	*U50A*	*WRSM2000*	*Low*
	Mvoti	*U40A to U40J,*	*WRYM*	*Medium*
Mdloti	*Mhlali*	*U30E*	*WRSM2000*	*Low*
	Tongati	*U30C and U30D*	*WRYM*	*Low*
	Mdloti	*U30A and U30B*	*WRYM*	*Low*
uMngeni	*uMngeni*	*U20A to U20M,*	*WRYM and WRPM*	*High*
Mlazi and Lovu	*Umbilo and Mhlathuzana*	*U60F*	*WRSM2000*	*Low*
	Mlazi	*U60A to U60D*	*WRSM2000*	*Low*
	Mbokodweni	*U60E*	*WRSM2000*	*Low*
	Manzimtoti and Little Manzimtoti	*U70F*	*WRSM2000*	*Low*
	Lovu	*U70A to U70D*	*WRSM2000*	*Low*
	Msimbazi, Mgababa and Ngane	*U70E*	*WRSM2000*	*Low*
Mkomazi	*Mkomazi*	*U10A to U10M*	*WRYM and WRPM*	*High*
South Coast	*Mahlongwana and Mahlongwa*	*U80L*	*WRSM2000*	*Low*
	Mpambanyoni	*U80J and U80K*	*WRSM2000*	*Low*
	Mzinto, Mkhumbane, Sezela and Mdesingane	*U80H*	*WRSM2000*	*Low*
	Fafa	*U80G*	*WRSM2000*	*Low*
	Mtwalume	*U80E and U80F*	*WRSM2000*	*Low*
	Mnamfu, KwaMakosi, Mfazazana, Mhlungwa and Mzimayi	*U80D*	*WRSM2000*	*Low*
	Mzumbe	*U80B and U80C*	*WRSM2000*	*Low*
	Ntshambili, Koshwana, Domba, Mhlangamkulu and Mtentweni	*U80A*	*WRSM2000*	*Low*
Umzimkulu	*Umzimkulu*	*T51A to T51J* *T52A to T52M*	*WRYM*	*High*
Mtamvuna	*Mbango, Boboyi, Zotsha, uMhlanga, Vungu, Bilanhlolo and Mvutshini*	*T40G*	*WRSM2000*	*Low*
	Mbizana, Kaba, Little Mpenjati, Kandandlovu, Tongazi, Kuboboyi, Sandlundlu, Zolwane	*T40F*	*WRSM2000*	*Low*
	Mtamvuna	*T40A to T40E*	*WRSM2000*	*Low*

As indicated in Table 2.2 the following three models, each with their own specific capabilities and applications, were used for the Water Resource Analyses undertaken for this study:

- **Water Resource Simulation Model 2000 (WRSM2000):** *This is a mathematical model to simulate movement of water through an interlinked system of catchments, river reaches, reservoirs and irrigation areas. WRSM2000 is a monthly model mostly used for hydrological analyses to calibrate streamflow records taking land-use changes over time into account by comparing the observed flows against those simulated by the model. Although it is used for broad regional assessment of water resources the model is not* *appropriate for determining yields of dams in a complex system of competing water users. One of its main purposes is to produce naturalised flow records (i.e. take out man-made land-use effects). The latter is used as input to more complex water resource system models such as the WRYM and WRPM described below.*

- **Water Resource Yield Model (WRYM):** *The WRYM is a monthly time step model which uses a sophisticated network solver in order to analyse complex water resource systems under various operating scenarios. The WRYM was designed to assess the yield capabilities of a system for a given operating policy and development condition. It is used to analyse systems at constant development levels i.e. the system and the system demands remain constant throughout the full simulation period.*
- **Water Resource Planning Model (WRPM):** *The WRPM is considerably more complex than the WRYM and was designed to carry out detailed operating analyses. The model is capable of modelling demands which increase with time as well as changing system configuration. It can be used both as a planning tool to assess the likely implementation dates of new schemes or resources and also as an operational tool for the month to month operation of the system. The WRPM contains a specific feature, the water resource allocation algorithm, which allows for the implementation of restrictions during periods of drought. For the purposes of this study the WRPM was used to simulate fixed system configurations for specified constant development conditions.*

3 IUAS AND DESKTOP BIOPHYSICAL NODES

3.1 INTRODUCTION

An IUA is a broad scale unit representing a catchment or a linear stretch of river. Nested in an IUA are Resource Units (RUs). RUs are lengths of river referred to in this study as sub-quaternary (SQ) reaches. Each RU is represented by a biophysical node (also referred to as a desktop biophysical node). Biophysical nodes are therefore nested within the IUAs (DWAF, 2007b) and represent flow requirements and ecological state relevant for the RU (SQ). An IUA therefore contains several biophysical nodes and these nodes define at a detail scale specific attributes which together describe the catchment configuration of the IUA.

Scenarios are assessed within the IUA and relevant implications in terms of the Water Resource Classes are provided for each IUA. The objective of defining IUAs is therefore to establish broader-scale units for assessing the socio-economic implications of different catchment configuration scenarios and to report on ecological conditions at a SQ scale.

The identification of IUAs and biophysical nodes within WMA11 was done as part of the Status Quo assessment of this study and detailed descriptions can be found in the relevant report (DWA, 2013a).

3.2 DESKTOP BIOPHYSICAL NODES

A RU or SQ reach is identified by a code, e.g. U20F-04011. As mentioned in Section 3.1, each SQ reach is represented by a biophysical node. The DBN has been set at the end of each SQ and upstream of the estuary (where relevant). In some cases the node has been placed upstream of dams where the dams inundate the downstream section of the SQ. The SQ code (as mentioned above) was subsequently chosen as the name for the relevant desktop biophysical node.

The calculation of DBNs per secondary drainage region is illustrated in Table 3.1.

Table 3.1 Desktop and key biophysical nodes

Secondary drainage region	No of nodes (SQ reaches)	No of river nodes	No of Desktop nodes (RDRM)[1]	New EWR sites	Existing EWR sites	Extrapolated from EWR sites	No of nodes excluded
T4	37	20	14	1	0	5	17
T5	55	54	24	0	14	11	6
U8	33	14	14	0	0	0	19
U1	39	39	21	3	0	10	5
U7	16	14	10	1	0	3	2
U6	14	11	10	0	0	0	4
U2	53	48	33	4	0	5	11
U3	11	7	7	0	0	0	4
U4	27	27	22	2	0	3	0
U5	3	3	3				
TOTAL	**288**	**237**	**158**	**11**	**14**	**37**	**68**

1 Revised Desktop Reserve Model (Hughes et al., 2011).

As shown in Table 3.1, a total of 237 river biophysical nodes were identified from the initial 288 SQ reaches found within WMA11. The methodology and reasoning behind the final selection of the *desktop biophysical nodes are described in the Status Quo report (DWA, 2013a). A total of 158 river desktop biophysical nodes were finally selected for RDRM assessment. Twelve EWR sites (key biophysical nodes) were selected for EWR determination of which seven of these sites were assessed using a revised and extended Intermediate Ecological Reserve Methodology.*

With the exception of the operational scenario analyses discussed in Section 88, the Water Resource Analyses described in Section 5 focussed on providing results for each of the desktop biophysical nodes. To this end, natural flow time series (TS) files were determined for a total of 244 nodes which included some of the estuaries. PD flows were simulated for 219 of these nodes.

4 APPROACH

4.1 BACKGROUND

Information obtained from the WR2005 study (WRC, 2005) is available at quaternary catchment level. The information from the detailed studies is, however, not necessarily available at quaternary catchment level as the focus of these studies are often on simulation catchments relating to specific catchment features such as existing or proposed development options or infrastructure. It is, therefore, necessary to change the resolution of the available hydrological information and DSS configurations to allow for the assessment of flows at the biophysical nodes. The biophysical nodes and the general approaches adopted for the biophysical node flow assessments are described below.

4.2 NATURAL FLOW ASSESSMENT

It was necessary to derive natural runoff time series data for each biophysical node defined in the Status Quo report (DWA, 2013a). It is important to note that the natural runoff time series data were calculated and not simulated.

The following approach was adopted for the calculation of natural runoff time series data for each biophysical node:

- *Use the available database as source of information at quaternary catchment level.*
- *Delineate and determine the catchment area of the biophysical node.*
- *Identify all quaternary catchments contributing to natural flow at the node.*
- *Calculate the portions of the relevant quaternary catchment areas that contribute to runoff at the node.*
- *Apply the above-mentioned quaternary catchment area ratios to the corresponding natural runoff time series data and add the resulting time series data to obtain the total natural runoff at the node.*
- *Provide the time series of historical natural flows to the EWR team for further use.*

4.3 PRESENT DAY FLOW ASSESSMENT

Although general reference is made to PD development conditions throughout the report, it is important to note that the PD development levels applicable to the individual catchments are not the same (refer to Section 2.2 and Table 2.1).

As mentioned in Section 3.1 the hydrological analyses of the various catchments in the study area were not necessarily undertaken at quaternary catchment level as the focus often was on the most representative modelling of specific sub-catchments of interest. Various catchment development components (e.g. small dams, diffuse and controlled water use) as well as natural features such as wetlands located within these larger sub-catchments were also grouped together to represent these simulation catchments. Irrespective of whether information pertained to quaternary catchments or simulation catchments the aim was to determine the most realistic method for splitting the information relative to each biophysical node.

Although the methodology used for each catchment was dictated by the detail of information available, the following general approach was adopted for the simulation of PD time series data at the biophysical nodes:

- *Evaluate the system configuration of the applicable DSS to determine the relevant locations of the biophysical nodes.*
- *Identify all catchment development and water use within each quaternary catchment.*
- *Determine the portion of the catchment development and water use impacting on the flow at each biophysical node by applying the relevant quaternary catchment area ratios calculated as part of the natural flow assessment.*
- *Where necessary, make use of Google Earth images or available land use maps to identify the locations of small dams, wetlands, sugar cane areas and forestry areas to assist with the splitting of this information as described in the previous bullet.*
- *Update the system configuration to include all required biophysical nodes (each node is configured as a specific channel which represents the simulated flow past that point under various conditions).*
- *Undertake a simulation with the updated DSS and store the time series of flows at each of the biophysical nodes.*
- *Provide the simulated PD time series to the EWR team for further use.*

A slightly different approach was followed for biophysical nodes that were defined in catchments where the WR2005 hydrology and WRSM2000 were used. The assessment of PD flows for estuaries was done as part of the Estuary Health Assessment task of this study (DWA, 2013d). For catchments where existing model setups were not available, the estuary assessments relied on the results from a Water Research Commission project (WRC K5/2187) entitled "The vulnerability of South Africa's estuaries to future water resource development based on their resilience". A different DSS, namely the Water Resources Modelling Platform (WReMP), was used for the purposes of the Water Research Commission project. The WReMP, developed largely by IWR Water Resources with input from the Institute of Water Research and the University of Pretoria, is similar to the WRYM in that it is a monthly time series simulation model. Although the WReMP setups included the WR2005 hydrology as basis for the estuary assessments, where possible, information on catchment development and water use was updated with more recent data obtained from various other sources. To ensure consistency with the estuary results it was, therefore, necessary to obtain and apply the same catchment development and water use information as was used in the WReMP. Information on streamflow reduction activities (commercial forestry) and water use by Invasive Alien Plants (IAPs) was also sourced from the WReMP.

The following general approach was adopted for the simulation of PD time series data at biophysical nodes situated in catchments where the WRSM2000 was used as DSS:

- *Adjust the WRSM2000 configuration to enable modelling of Present Day development conditions.*
- *Evaluate information on catchment development and water use sourced from the WReMP and incorporate the data in the WRSM2000 setup.*
- *Evaluate the system configuration to determine the relevant locations of the biophysical nodes.*
- *Determine the portion of the catchment development and water use impacting on the flow at each biophysical node by applying the relevant quaternary catchment area ratios calculated as part of the natural flow assessment.*
- *Where necessary, make use of Google Earth images to assist with the positioning and splitting of small dams and forestry areas.*

- *Update the system configuration to include all required biophysical nodes (each node is configured as a specific channel which represents the simulated flow past that point under various conditions).*
- *Undertake a simulation with the updated WRSM2000 and store the time series of flows at each of the biophysical nodes.*
- *Provide the simulated PD time series to the EWR team for further use.*

5 NATURAL AND PRESENT DAY FLOW ASSESSMENT

5.1 NONOTI, ZINKWAZI AND MDLOTANE (U50A)

The Nonoti, Zinkwazi and Mdlotane rivers fall within quaternary catchment U50A (as shown in Figure 5.1 below) and a desktop biophysical node was identified for each of these rivers.

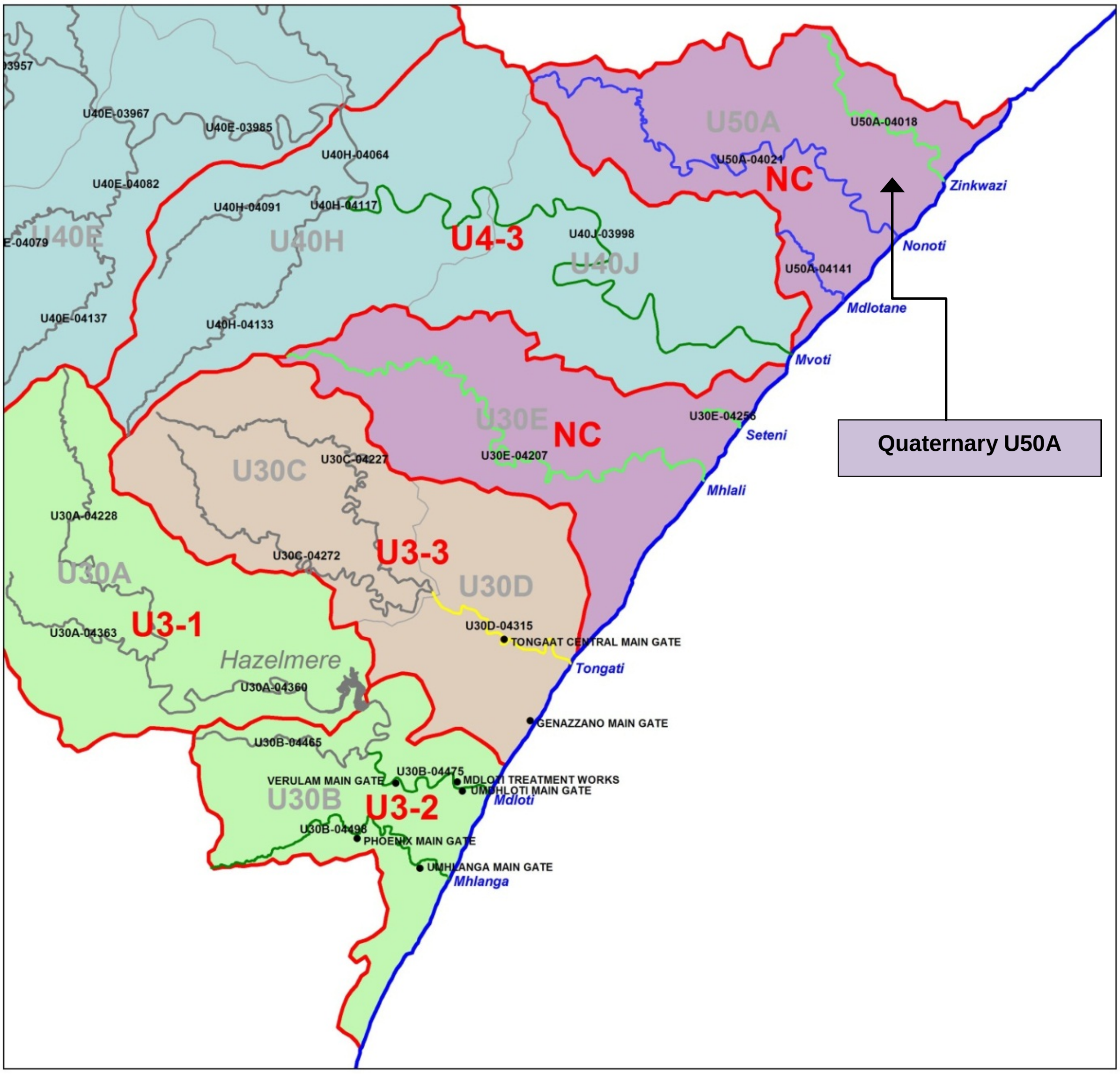

Figure 5.1 Quaternary catchment U50A

The WR2005 hydrology as derived for quaternary catchment U50A was used as basis for the calculation of natural flow at the three DBNs. The information available for quaternary catchment U50A is summarised in Table 5.1.

Table 5.1 U50A: WR2005 Information (1920 - 2004)

Quaternary catchment	Total catchment area (km^2)	Forestry area (km^2)	Alien vegetation area (km^2)	Irrigation area (km^2)	Farm Dams		NMAR[1] (million m^3/a)
					Area (km^2)	Volume (million m^3)	
U50A	*298*	*3.50*	*3.10*	*0.00*	*0.14*	*0.60*	*59.73*

1 Natural Mean Annual Runoff

Table 5.2 presents a breakdown of the portion of natural hydrology included at each DBN, as well as a summary of the average natural flow per node.

Table 5.2 U50A: Details of Natural Flow development at DBNs

Node Name	Rivers	Hydrology reference and factor contributing to natural flow at node	Total catchment area (km^2)	NMAR (million m^3/a)
U50A-04018	Zinkwazi	U50A:0.182	54.22	10.99
U50A-04021	Nonoti	U50A:0.505	150.61	30.19
U50A-04141	Mdlotane	U50A:0.003	0.87	0.18

The WReMP (see Section 4.3) was used for the PD assessments of the three estuaries and the corresponding WReMP catchment development information was used in the assessment of PD flows at the DBNs. The catchment development information relating to the three estuaries are summarised in Table 5.3. The factor contributing to natural runoff at the DBN (as shown in Table 5.2) was applied to the time series files of the various catchment development components to obtain land use information relating to each DBN.

Table 5.3 U50A: PD catchment development

Estuary	Catchment area (km^2)	Water use (million m^3/a)				SFRA[1] (million m^3/a)		Return flows (million m^3/a)	Urban runoff[2] (million m^3/a)
		Rural	Urban	Industrial	Irrigation	Forestry	IAP		
Zinkwazi	71.4	0.000	0.000	0.000	0.000	0.108	0.264	0.000	0.000
Nonoti	177.0	0.500	1.000	2.156	0.000	0.266	0.661	0.400	0.270
Mdlotane	29.8	0.000	0.000	0.000	0.000	0.045	0.110	0.000	0.000
Total	**278.2**	**0.500**	**1.000**	**2.156**	**0.000**	**0.419**	**1.035**	**0.400**	**0.270**

1 Streamflow Reduction Activities (SFRA).
2 Increased runoff from impervious (paved) urban areas.

As shown in Table 5.3 the Nonoti catchment is the largest and most complex of the three river systems. The catchment upstream of the Nonoti DBN includes small dams as well as rural, industrial and urban (Darnal) water use. The flow at the Nonoti DBN is also influenced by urban return flows from Darnal and runoff from paved urban areas. The WRSM2000 model was configured to simulate present day flows at the DBN situated on the Nonoti. Since the remaining two catchments did not include any farm dams and runoff was only affected by forestry and invasive alien plants, the PD flows for the corresponding two DBNs were determined by means of water balance calculations.

The PD results for the three DBNs are presented in Table 5.4.

Table 5.4 U50A: Summary of Natural and PD Flow assessment at DBNs

Node Name	Rivers	REC	Total catchment area (km^2)	NMAR (million m^3/a)	PD MAR (million m^3/a)	Difference between NMAR and PD MAR	
						(million m^3/a)	(%)
U50A-04018	Zinkwazi	B/C	54.22	10.99	10.74	0.25	2.3
U50A-04021	Nonoti	B/C	150.61	30.19	25.95	4.24	14.0
U50A-04141	Mdlotane	B/C	0.87	0.18	0.17	0.01	5.6

It is evident from the results shown in the table above that there is not a significant difference between the NMAR and PD MAR at the Zinkwazi and Mdlotane DBNs. There is, however, a 14% difference in flow at the Nonoti DBN.

5.2 MVOTI (U40)

The Mvoti River catchment is illustrated in Figure 5.2. The major tributaries of the Mvoti River are the Heinespruit, Mvozana, Ikhamanzi, Sikoto, Hlimbitwa, Nsuze and Mushane Rivers.

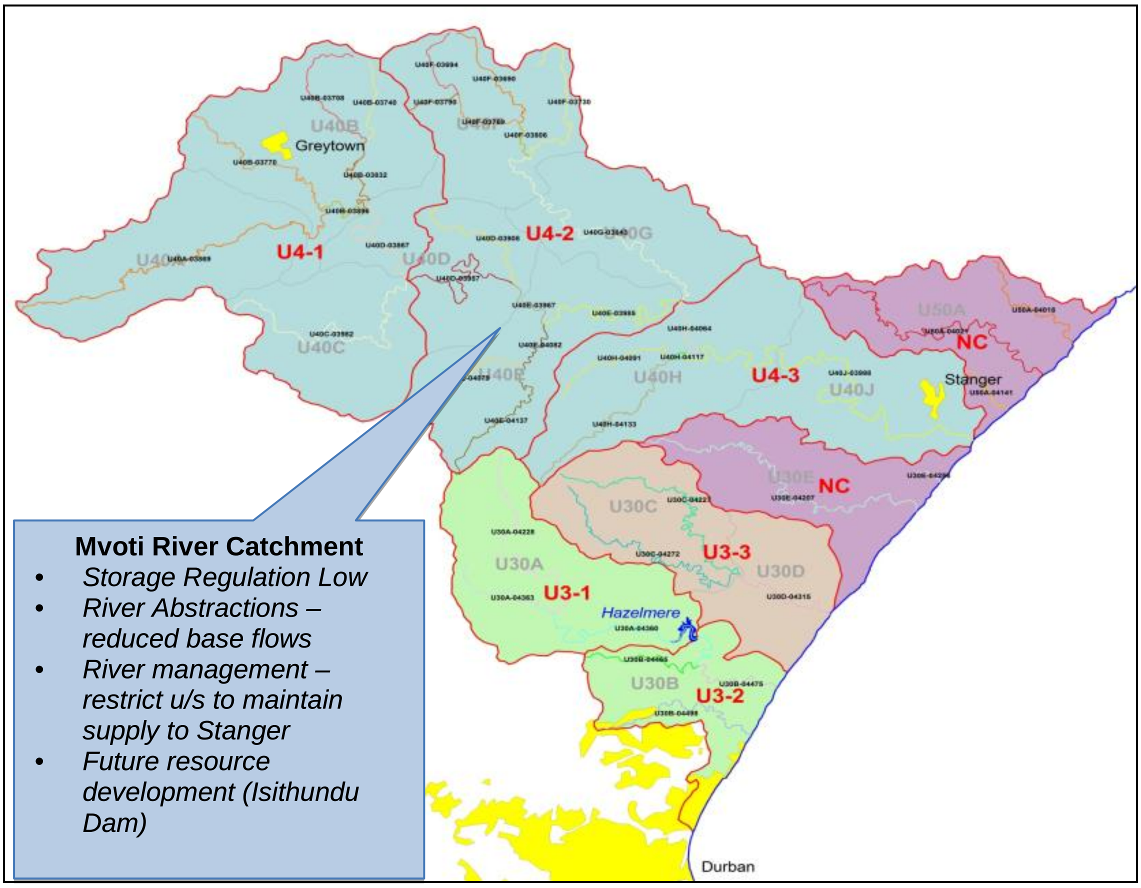

Figure 5.2 Mvoti River Catchment

The hydrology obtained from the Mvoti River Dam Feasibility Study Extension (DWA, 2000), covering a period of 74 years from 1921 to 1994 (hydrological years), was used for the water resource assessments of this study. The hydrology and water use were derived for 13 simulation catchments some of which were subdivided to accommodate existing and proposed future catchment developments. The information for the resulting 20 sub-catchments is summarised in Table 5.5.

Table 5.5 U40: Hydrological Information (1921 - 1994)

Simulation catchment	Quaternary catchments	Total catchment area (km^2)	SFRA[1] (million m^3/a)	NMAR (million m^3/a)
MC1	*Part of U40A*	*164*	*12.23*	*30.5*
MC2	*Part of U40A*	*152*	*6.41*	*18.6*
MC3	*Part of U40B*	*117*	*4.79*	*14.1*
MC4	*Part of U40B*	*136*	*4.67*	*12.9*
MC5	*Part of U40B and part of U40D*	*161*	*5.96*	*20.3*
MC5b	*Part of U40B and part of U40D*	*44*	*1.64*	*5.6*

Simulation catchment	Quaternary catchments	Total catchment area (km^2)	SFRA[1] (million m^3/a)	NMAR (million m^3/a)
MC6	*U40C*	*259*	*11.26*	*32.0*
MC7	*Part of U40E*	*196*	*6.31*	*32.2*
MC81	*Part of U40D and part of U40E*	*187*	*0.88*	*22.7*
MC82	*Part of U40D and part of U40E*	*125*	*0.58*	*15.1*
MC9	*Part of U40F*	*228*	*11.02*	*23.3*
MC10	*Part of U40F and part of U40G*	*315*	*2.53*	*45.4*
MC11	*Part of U40H*	*175*	*0.00*	*29.8*
MC12-1	*Part of U40H*	*23*	*0.41*	*2.9*
MC12-2	*Part of U40H*	*129*	*2.33*	*16.7*
MC13a	*Part of U40H and part of U40J*	*47*	*1.41*	*8.0*
MC13b	*Part of U40J*	*75*	*3.22*	*12.0*
MC13c-1	*Part of U40J*	*50*	*1.52*	*8.0*
MC13c-2	*Part of U40J*	*95*	*2.82*	*16.0*
MC13rem	*Part of U40J*	*50*	*1.50*	*8.0*
Total		**2728**	**81.49**	**374.1**

1 SFRA include impact of forestry and dry-land sugarcane.

Three IUAs were defined for the Mvoti River catchment: U4-1, U4-2 and U4-3 for the Upper, Middle and Lower Mvoti reaches respectively. Two of the 27 DBNs defined within the catchment were selected as key biophysical nodes (Mv_I_EWR1 and Mv_I_EWR2) and Intermediate EWR assessments were carried out for these two sites. Table 5.6 presents a breakdown of the portion of natural hydrology included at each DBN, as well as a summary of the average natural flow per node.

Table 5.6 U40: Details of Natural Flow development at DBNs

Node name	Rivers	Hydrology reference and factor contributing to natural flow at node	Total catchment area (km^2)	NMAR (million m^3/a)
U40A-03869	*Mvoti*	*MC1:1.0; MC2:1.0; MC5:0.1451*	*340.36*	*52.13*
U40B-03708	*Intinda*	*MC4:0.636*	*89.13*	*8.18*
U40B-03740	*Mvozana*	*MC4:0.364*	*50.92*	*4.67*
Mv_I_EWR1 (U40B-03770)	*Heinespruit*	*MC3:1.0; MC5:0.1531*	*141.64*	*17.36*
U40B-03832	*Mvozana*	*MC4:1.0; MC5:0.4681*	*211.37*	*22.36*
U40B-03896	*Mvoti*	*MC1:1.0; MC2:1.0; MC3:1.0; MC5:0.3693*	*493.46*	*70.94*
U40C-03982	*Khamanzi*	*MC6:1.00*	*261.83*	*31.97*
U40D-03867 (Old IFR1)	*Mvoti*	*MC1:1.0; MC2:1.0; MC3:1.0; MC4:1.0; MC5:1.0*	*736.47*	*96.60*
U40D-03908	*Mtize*	*MC81:0.337*	*63.08*	*7.64*
U40D-03957	*Mvoti*	*MC1:1.0; MC2:1.0; MC3:1.0; MC4:1.0; MC5:1.0; MC5b:1.0; MC6:1.0; MC81:0.5254*	*1131.36*	*146.04*
U40E-03967	*Mvoti*	*MC1:1.0; MC2:1.0; MC3:1.0; MC4:1.0; MC5:1.0; MC5b:1.0; MC6:1.0; MC81:1.0; MC82:0.3188*	*1259.98*	*161.62*
U40E-03985 (Old IFR2)	*Mvoti*	*MC1:1.0; MC2:1.0; MC3:1.0; MC4:1.0; MC5:1.0; MC5b:1.0; MC6:1.0; MC7:1.0; MC81:1.0; MC82:0.7224*	*1506.36*	*199.90*
U40E-04079	*Faye*	*MC7:0.415*	*81.33*	*13.35*
U40E-04082	*Sikoto*	*MC7:0.4781*	*194.02*	*32.17*
U40E-04137	*Sikoto*	*MC7:0.9899*	*93.70*	*15.38*

Node name	Rivers	Hydrology reference and factor contributing to natural flow at node	Total catchment area (km^2)	NMAR (million m^3/a)
U40F-03690	*Potspruit*	*MC9:0.1992*	*45.42*	*4.65*
U40F-03694	*Hlimbitwa*	*MC9:0.2198*	*50.12*	*5.14*
U40F-03730	*Cubhu*	*MC9:0.2088*	*47.60*	*4.88*
U40F-03769	*Hlimbitwa*	*MC9:0.4708*	*107.35*	*11.00*
U40F-03790	*Nseleni*	*MC9:0.0543*	*12.37*	*1.27*
U40F-03806	*Hlimbitwa*	*MC9:0.7655*	*174.54*	*17.89*
U40G-03843	*Hlimbitwa*	*MC9:1.0; MC10:0.9086*	*513.80*	*64.60*
Mv_I_EWR2 (U40H-04064)	*Mvoti*	*MC1:1.0; MC2:1.0; MC3:1.0; MC4:1.0; MC5:1.0; MC5b:1.0; MC6:1.0; MC7:1.0; MC81:1.0; MC82:1.0; MC9:1.0; MC10:1.0; MC12-1:0.3775*	*2105.60*	*273.95*
U40H-04091	*Pambela*	*MC11:0.4427*	*77.46*	*13.18*
U40H-04117	*Nsuze*	*MC11:0.9925*	*173.69*	*29.78*
U40H-04133	*Nsuze*	*MC11:0.5273*	*92.27*	*15.70*
U40J-03998 (Old IFR4)	*Mvoti*	*MC1:1.0; MC2:1.0; MC3:1.0; MC4:1.0; MC5:1.0; MC5b:1.0; MC6:1.0; MC7:1.0; MC81:1.0; MC82:1.0; MC9:1.0; MC10:1.0; MC11:1.0; MC12-1:1.0; MC12-2:1.0; MC13a:1.0; MC13b:1.0; MC13C-1:1.0; MC13C-2:0.2054*	*2602.51*	*354.00*

The storage regulation in the Mvoti catchment is low and there are only a number of small farm dams in tributaries and a few instream dams. The dams are of such a nature that no releases are made for downstream users. Greytown is located in the upper reaches of the Upper Mvoti (U4-1) and the discharges from the town's waste water treatment works (WWTW) enter the river system, affecting both the flow and water quality of the river system. The main land use activities in the catchment include extensive forestry and a significant amount of sugarcane plantations. Irrigation (sugarcane, maize etc.) also occurs. There are a few low density settlements and rural settlements located in the catchment. Some groundwater is utilised by the rural villages in the Middle and Lower Mvoti (U4-2 and U4-3 respectively). Industrial water use within U4-3 comprises of the water requirements of the Gledhow Sugar Mill and a paper factory (Sappi Fine Paper). The town Kwadukuza (Stanger) is located in the lower end of U4-3 and water is abstracted directly from the Mvoti River (run of river abstraction) for supplying the town. Discharges from the town's WWTW enter the river system upstream of the estuary impacting on the water quality of the river system.

Three possible dam sites were identified and investigated as part of the original Mvoti River Dam Feasibility Study, namely the Mvoti-Poort, Isithundu and Welverdient dam sites. The proposed Mvoti-Poort and Isithundu Dam sites are located at the lower end of U4-1 and U4-2 respectively. The Welverdient Dam site is located lower down in U4-3. The Isithundu Dam site was, however, found to be the more favourable dam site for development in the Mvoti River catchment and is likely to be developed first.

The WRYM configuration resulting from the Mvoti River Dam Feasibility Study Extension (DWA, 2000) was used for the purposes of this study. The demands were previously updated to be representative of the 2006 development level. All future development options were excluded from the WRYM configuration to reflect PD (2006) conditions. The discharges from the Greytown and Kwadukuza WWTWs, amounting to 0.96 and 4.44 million m^3/a respectively, were included in the system setup. The WRYM configuration was refined to facilitate modelling of representative flows *at all the required biophysical nodes and EWR sites (DBNs). Each site and node is configured as a specific channel which represents the simulated flow past that point. The methodology described in Section 4.3 was applied for the adjustment of catchment development information. The node calculations were done within an Excel spreadsheet which is provided electronically together with the WRYM configuration as part of the information repository (see Section 9).*

The PD (2006) water use within the Mvoti catchment are summarised in Table 5.7.

Table 5.7 U40: Summary of PD (2006) water use

Description	Water Use (million m^3/a)
Total reduction in runoff due to afforestation and dry-land sugarcane	*81.49*
Total Irrigation, Urban, Rural and Industrial water use (excluding losses)	*62.37*
Water use from Mvoti Vlei :	*2.15*
Total water use for Mvoti catchment (excluding losses)	**146.01**

A simulation was carried out, and the time series of flows at each of the biophysical nodes and EWR sites was stored. Again, these time series were handed over to the EWR team for further use.

The PD results for the DBNs, as well as the Mvoti estuary (Mvoti-Mouth), are presented in Table 5.8. The impact of catchment development is evident from these results as the PD flows are significantly less than the natural flow at the majority of the DBNs.

Table 5.8 U40: Summary of Natural and PD Flow assessment at DBNs

Node Name	Rivers	REC	Total catchment area (km^2)	NMAR (million m^3/a)	PD MAR (million m^3/a)	Difference between NMAR and PD MAR (million m^3/a)	(%)	WRYM Channel No.
U40A-03869	*Mvoti*	*B*	*340.36*	*52.13*	*26.65*	*25.48*	*48.9*	*101*
U40B-03708	*Intinda*	*C*	*89.13*	*8.18*	*2.34*	*5.84*	*71.4*	*113*
U40B-03740	*Mvozana*	*C*	*50.92*	*4.67*	*1.24*	*3.43*	*73.5*	*112*
Mv_I_EWR1 (U40B-03770)	*Heinespruit*	*C*	*141.64*	*17.36*	*7.08*	*10.28*	*59.2*	*103*
U40B-03832	*Mvozana*	*C/D*	*211.37*	*22.36*	*6.12*	*16.24*	*72.6*	*104*
U40B-03896	*Mvoti*	*C*	*493.46*	*70.94*	*34.75*	*36.19*	*51.0*	*18*
U40C-03982	*Khamanzi*	*B*	*261.83*	*31.97*	*15.52*	*16.45*	*51.5*	*27*
U40D-03867 (Old IFR1)	*Mvoti*	*B*	*736.47*	*96.60*	*41.79*	*54.81*	*56.7*	*22*
U40D-03908	*Mtize*	*B*	*63.08*	*7.64*	*7.34*	*0.30*	*3.9*	*118*
U40D-03957	*Mvoti*	*B*	*1131.36*	*146.04*	*72.67*	*73.37*	*50.2*	*30*
U40E-03967	*Mvoti*	*B/C*	*1259.98*	*161.62*	*87.66*	*73.96*	*45.8*	*31*
U40E-03985 (Old IFR2)	*Mvoti*	*B*	*1506.36*	*199.90*	*119.39*	*80.51*	*40.3*	*38*
U40E-04079	*Faye*	*B*	*81.33*	*13.35*	*10.73*	*2.62*	*19.6*	*120*
U40E-04082	*Sikoto*	*B*	*194.02*	*32.17*	*25.86*	*6.31*	*19.6*	*29*
U40E-04137	*Sikoto*	*B*	*93.70*	*15.38*	*12.36*	*3.02*	*19.6*	*121*
U40F-03690	*Potspruit*	*C*	*45.42*	*4.65*	*1.52*	*3.13*	*67.3*	*132*
U40F-03694	*Hlimbitwa*	*C*	*50.12*	*5.14*	*1.72*	*3.42*	*66.5*	*122*
U40F-03730	*Cubhu*	*C*	*47.60*	*4.88*	*1.60*	*3.28*	*67.2*	*140*
U40F-03769	*Hlimbitwa*	*C*	*107.35*	*11.00*	*3.88*	*7.12*	*64.7*	*129*

Node Name	Rivers	REC	Total catchment area (km²)	NMAR (million m³/a)	PD MAR (million m³/a)	Difference between NMAR and PD MAR		WRYM Channel No.
						(million m³/a)	(%)	
U40F-03790	*Nseleni*	*B/C*	*12.37*	*1.27*	*0.67*	*0.60*	*47.1*	*125*
U40F-03806	*Hlimbitwa*	*B*	*174.54*	*17.89*	*6.55*	*11.34*	*63.4*	*137*
U40G-03843	*Hlimbitwa*	*B*	*513.80*	*64.60*	*51.33*	*13.27*	*20.5*	*37*
Mv_I_EWR2 (U40H-04064)	*Mvoti*	*B*	*2105.60*	*273.95*	*168.84*	*105.11*	*38.4*	*141*
U40H-04091	*Pambela*	*B*	*77.46*	*13.18*	*13.19*	*-0.01*	*-0.1*	*142*
U40H-04117	*Nsuze*	*B*	*173.69*	*29.78*	*29.78*	*0.00*	*0.0*	*144*
U40H-04133	*Nsuze*	*B*	*92.27*	*15.70*	*15.69*	*0.01*	*0.1*	*143*
U40J-03998 (Old IFR4)	*Mvoti*	*B*	*2602.51*	*354.00*	*214.52*	*139.48*	*39.4*	*150*
Mvoti-Mouth	*Mvoti*	*-*	*2728*	*374.1*	*225.49*	*148.61*	*39.7*	*58*

5.3 MHLALI (U30E)

The Mhlali River catchment falls within quaternary catchment U30E and is shown in Figure 5.3.

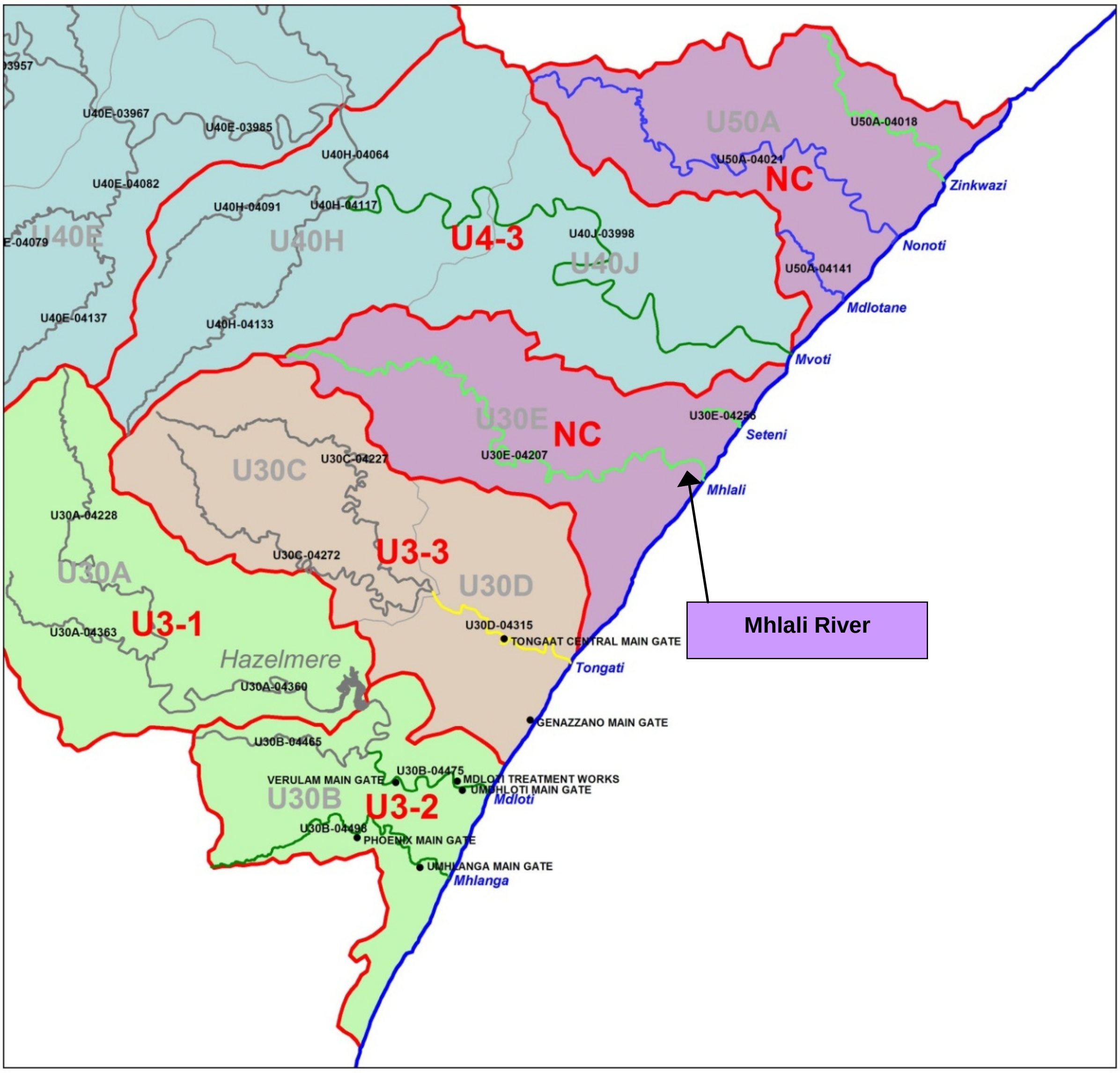

Figure 5.3 Mhlali River Catchment

The WR2005 hydrology as derived for quaternary catchment U30E was used as basis for the calculation of natural flow at the selected DBN. The WR2005 information available for quaternary catchment U30E is summarised in Table 5.9.

Table 5.9 Mhlali (U30E): WR2005 information (1920 - 2004)

Quaternary catchment	Total catchment area (km^2)	Forestry area (km^2)	Alien vegetation area (km^2)	Irrigation area (km^2)	Farm Dams		NMAR (million m^3/a)
					Area (km^2)	Volume (million m^3)	
U30E	290	0.00	6.60	8.30	0.06	0.30	66.19

Table 5.10 presents a breakdown of the portion of natural hydrology included at the DBN and estuary, as well as the average natural flow at the node and estuary.

Table 5.10 Mhlali (U30E): Details of Natural Flow development at DBN

Node Name	Rivers	Hydrology reference and factor contributing to natural flow at node	Total catchment area (km^2)	NMAR (million m^3/a)
U30E-04207	Mhlali	U30E:0.502	145.58	33.23
Estuary	Mhlali	U30E:0.8507	246.70	56.31

The storage regulation in the Mhlali catchment is low. As shown in Table 5.9 the total capacity of farm dams in U30E amount to only 0.29 million m^3 with IAPs covering an area of 6.6 km^2. The U30E catchment is predominantly a sugarcane farming area with most of the area covered with dry-land sugarcane plantations. There are a few small coastal towns, some slightly inland and a few rural villages. There are also return flows from WWTW entering the river systems.

The WReMP (see Section 4.3) was used for the PD assessments of the Mhlali estuary and the corresponding WReMP catchment development information was used in the assessment of PD flows at the DBN. The catchment development information relating to the WReMP setup that was used for the assessment of the estuary is summarised in Table 5.11. It should be noted that farm dams located within a specific catchment are normally grouped together and modelled as a single storage dam. A dam representing a group of small dams is referred to as a dummy dam. A dummy dam with a Full Supply Volume (FSV) of 0.29 million m^3 was modelled in the Mhlali catchment as shown in Table 5.11.

Table 5.11 Mhlali (U30E): PD catchment development information

Node	Catchment area (km^2)	Water use (million m^3/a)				SFRA (million m^3/a)		Return flows (million m^3/a)	Dummy Dam	
		Rural	Urban	Industrial	Irrigation	Forestry	IAP		FSA[1] (km^2)	FSV (million m^3)
Dummy Dam	29.02	0.000	0.000	0.000	2.297	0.000	0.015	0.000	0.060	0.290
Node 2	188.65	0.000	1.500	0.000	4.210	0.000	0.109	0.132	0.000	0.000
Node 3	29.02	0.000	0.000	0.000	0.000	0.000	0.015	1.110	0.000	0.000
Total	**246.69**	**0.000**	**1.500**	**0.000**	**6.507**	**0.000**	**0.139**	**1.242**	**0.060**	**0.290**

1 Full Supply Area.

The WRSM2000 was configured to include modelling of the DBN. The factor contributing to natural runoff at the DBN (as shown in Table 5.10) was applied to the time series files of the various catchment development components to obtain land use information relating to the DBN. The simulated results showed a deficit in the irrigation water supply as the total irrigation water supply was only 4.94 million m^3/a as opposed to the requirement of 6.507 million m^3/a. The dummy dam, as well as a portion of the irrigation water use and SFRA due to IAPs were simulated upstream of the DBN. The urban water use and return flows impact on the river downstream of the DBN and affect the inflow to the estuary. The PD results for the DBN and the Mhlali estuary are summarised in Table 5.12.

Table 5.12 Mhlali (U30E): Summary of Natural and PD flow assessment

Node Name	Rivers	REC	Total catchment area (km^2)	NMAR (million m^3/a)	PD MAR (million m^3/a)	Difference between NMAR and PD MAR	
						(million m^3/a)	(%)
U30E-04207	*Mhlali*	*C*	*145.58*	*33.23*	*31.95*	*1.28*	*3.85*
Estuary	*Mhlali*	*-*	*246.70*	*56.31*	*51.26*	*5.05*	*8.97*

5.4 TONGATI (U30C AND U30D)

The Tongati River catchment, as shown in Figure 5.4, comprises of quaternary catchments U30C and U30D.

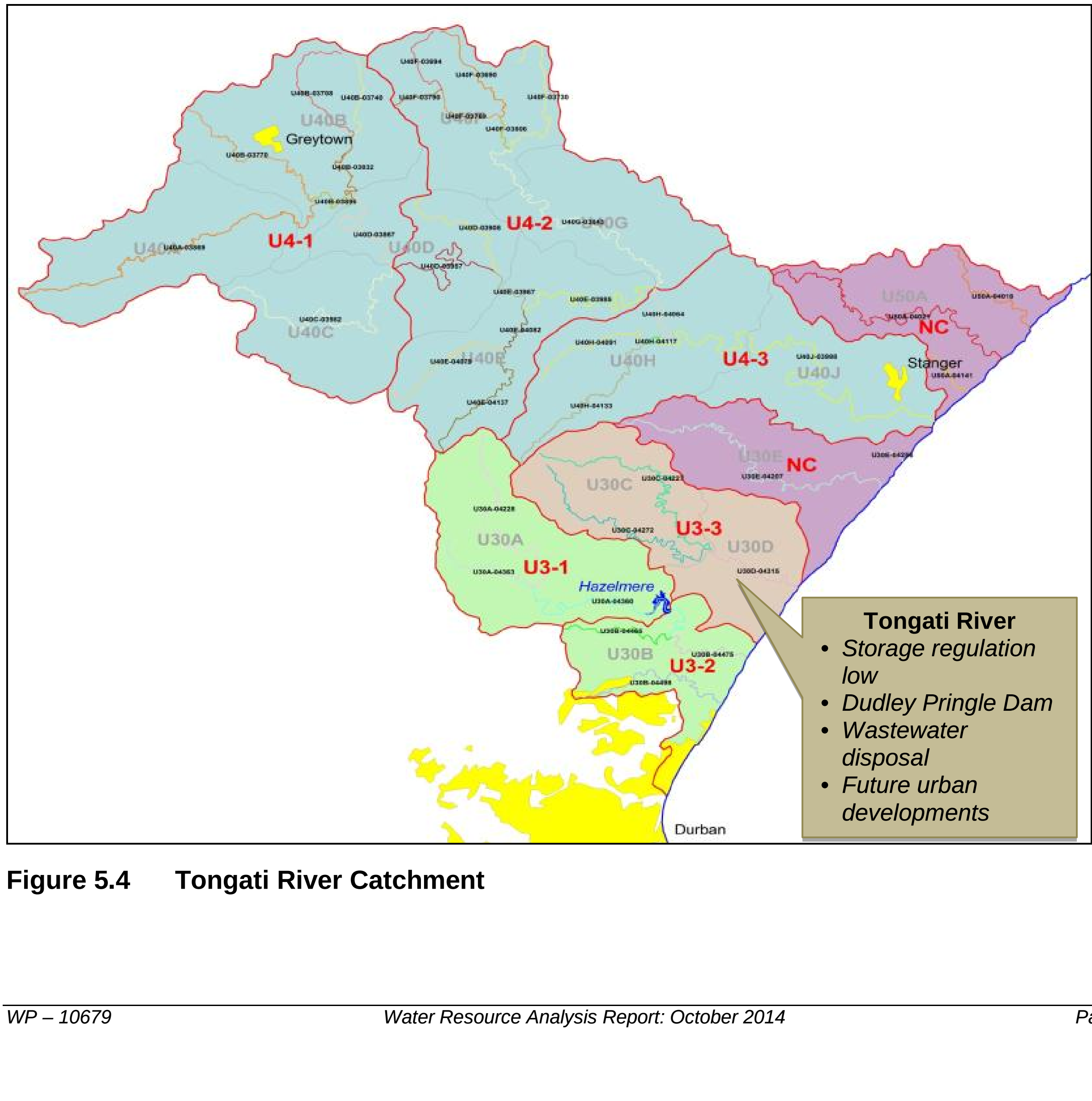

Figure 5.4 Tongati River Catchment

To be consistent with the Estuary Reserve Determination undertaken in 2007, the hydrology resulting from the Knight Piesold Study (DWA, 2006) was used for water resources assessment. The Knight Piesold information is summarised in Table 5.13. There is no forestry or diffuse irrigation water use in the catchment.

Table 5.13 Tongati (U30C and U30D): Hydrological information (1920 - 2003)

Quaternary catchment	Total Catchment Area (km^2)	NMAR (million m^3/a)
U30C	*242*	*41.17*
U30D	*181*	*29.62*
Total	**423**	**70.79**

Two IUAs were defined for the Tongati River catchment: U3-3 and U3-4 for the Upper and Lower Tongati River reaches respectively. Two DBNs were defined within the Upper Tongati. Table 5.14 presents a breakdown of the portion of natural hydrology included at each DBN, as well as a summary of the average natural flow per node.

Table 5.14 Tongati (U30C and U30D): Details of Natural Flow Development at DBNs

Node Name	Rivers	Hydrology reference and factor contributing to natural flow at node	Total catchment area (km^2)	NMAR (million m^3/a)
U30C-04227	*Tongati*	*U30C:0.577*	*139.71*	*23.77*
U30C-04272	*Mona*	*U30C:0.416*	*100.73*	*17.14*
Estuary (U30D-04315)	*Tongati*	*U30C:1.0; U30D:1.0*	*423.00*	*70.79*

The storage regulation in the Upper Tongati (U3-3) is low with no significant dams present. The water resource zone U3-4 is regulated by the Dudley Pringle and Syphon dams situated in a tributary of the Tongati. The dams were built by Tongaat Hullets and since they are not used for irrigation purposes they are normally full and were therefore not included in the WRYM configuration. Tongaat town and industries are located in the Lower Tongati. Discharges from the Tongaat Central, Tongaat South and Frasers WWTWs, as well as the return flows from Tongaat Hullets, enter the Tongati River affecting both the flow and water quality of the river.

The WRYM configuration obtained from the Knight Piesold Study (DWA, 2006) was refined to include the modelling of the two DBNs. There are only two water abstractions from the Tongati River in U3-3: an irrigation water use of 0.283 million m^3/a and other water use amounting to 0.44 million m^3/a. The factors contributing to natural runoff at the DBNs (as shown in Table 5.14) *was applied to the two water use components to obtain land use information relating to each DBN. The simulated PD results are presented in Table 5.15.*

Table 5.15 Tongati (U30C and U30D): Summary of Natural and PD flows at DBNs

Node Name	Rivers	REC	Total catchment area (km^2)	NMAR (million m^3/a)	PD MAR (million m^3/a)	Difference between NMAR and PD MAR		WRYM Channel No.
						(million m^3/a)	(%)	
U30C-04227	*Tongati*	*B/C*	*139.71*	*23.77*	*23.34*	*0.43*	*1.80*	*32*
U30C-04272	*Mona*	*B*	*100.73*	*17.14*	*16.82*	*0.32*	*1.85*	*12*

5.5 MDLOTI (U30A AND U30B)

The Mdloti River catchment is shown in Figure 5.5. The catchment comprises of quaternary catchments U30A and U30B and these two quaternary catchments have each been identified as an IUA (U3-1 and U3-2 respectively). The flow in the catchment is regulated by Hazelmere Dam which is situated at the outlet of U30A. Hazelmere is affected by siltation and a study was conducted to evaluate the feasibility of raising the dam wall. The hydrology and landuse information resulting from the Raising of Hazelmere Dam - Feasibility Study (DWA, 2003) were used for the natural and PD flow assessment at the four DBNs selected within the catchment.

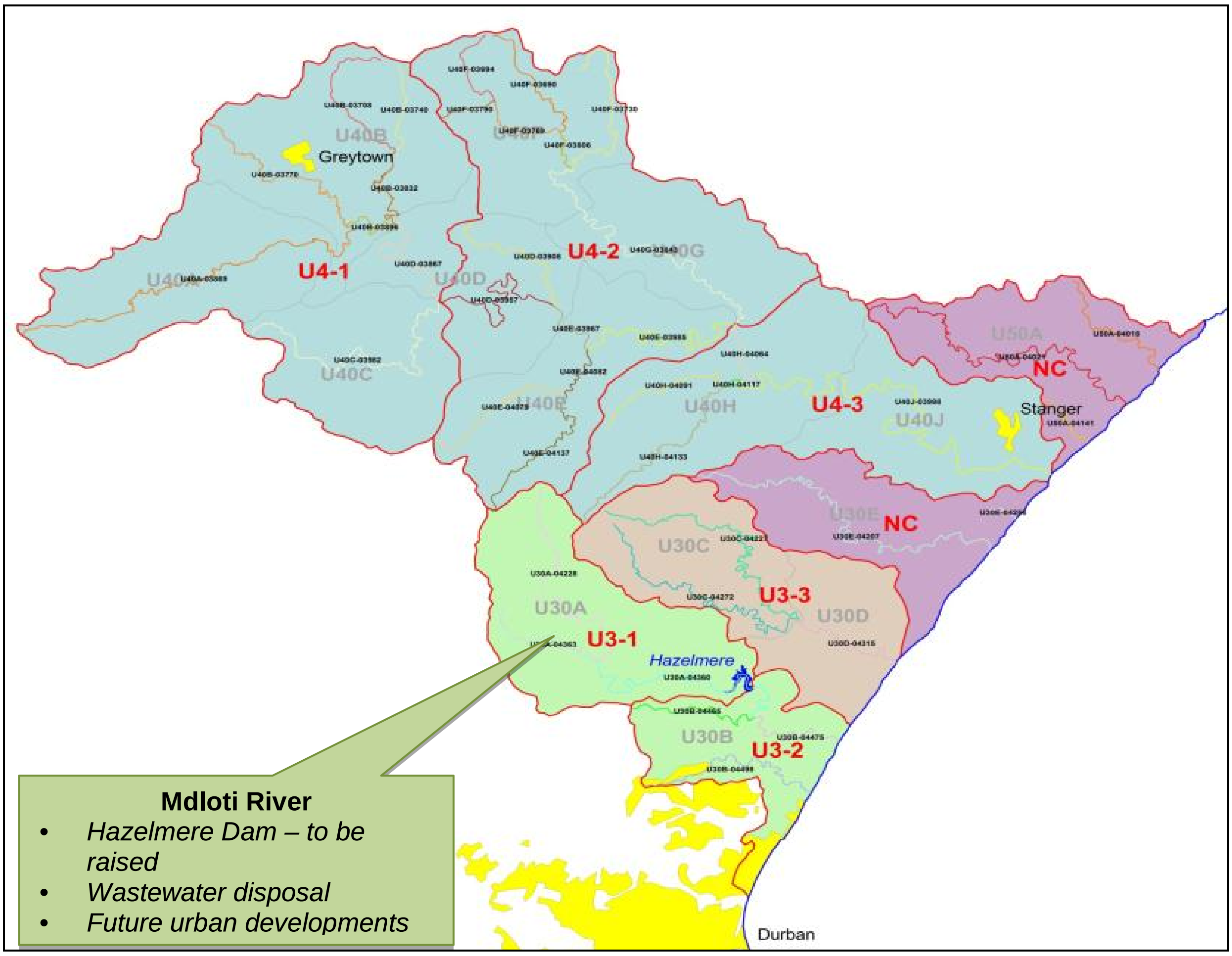

Figure 5.5 Mdloti River Catchment

The hydrological information is summarised in Table 5.16.

Table 5.16 Mdloti (U30A and U30B): Hydrological information (1925 - 1995)

Quaternary catchment	Hydrology reference	Total catchment area (km^2)	Afforestation (million m^3/a)	NMAR (million m^3/a)
U30A	*HAZUP*	*376*	*1.29*	*71.18*
U30B	*HAZLOW*	*116*	*0.00*	*28.98*
Total	**-**	**492**	**1.29**	**100.16**

Table 5.17 presents a breakdown of the portion of natural hydrology included at each DBN, as well as a summary of the average natural flow per node.

Table 5.17 Mdloti (U30A and U30B): Details of Natural Flow Development at DBNs

Node Name	Rivers	Hydrology reference and factor contributing to natural flow at node	Total catchment area (km²)	NMAR (million m³/a)
U30A-04228	*Mdloti*	*HAZUP:0.418*	*157.30*	*29.78*
U30A-04360	*Mdloti*	*HAZUP:1.0; HAZLOW:0.093*	*396.61*	*73.88*
U30A-04363	*Mwangala*	*HAZUP:0.149*	*56.06*	*10.61*
U30B-04465	*Black Mhlashini*	*HAZLOW:0.189*	*41.82*	*5.48*

The Upper Mdloti water resource zone (U3-1) is regulated by the Hazelmere Dam located at the lower end of the zone. The raising of Hazelmere Dam has been approved, which will take place in the near future. There is some dry-land sugarcane located in the upper reaches of the zone and there is a large amount of low density settlements and rural settlements spread throughout the zone.

The flow in the Lower Mdloti (U3-2) is regulated by the upstream Hazelmere Dam and the raising of the dam will have a further impact on river flows in the zone. A large portion of the Lower Mdloti (U3-2) zone is occupied by urban areas (Verulum) and discharges enter the Mdloti River from various WWTWs (Verulam and Mdloti) affecting both the flow and water quality of the river. A significant portion of the zone is also covered by sugarcane (dryland and irrigated). There is a large amount of low density settlements and rural settlements spread throughout the zone.

The storage characteristics of the existing Hazelmere Dam are shown in Table 5.18. Information on water use and discharges, as obtained from the Raising of Hazelmere Dam - Feasibility Study (DWA, 2003), is summarised in Table 5.19.

Table 5.18 Hazelmere Dam: Storage characteristics

Dam name	Bottom level (m)	Dead storage level (m)	Full supply conditions		
			Level (m)	Storage (million m³)	Surface area (km²)
Hazelmere	*71.0*	*72.0*	*85.98*	*10.471*	*1.269*

Table 5.19 Mdloti (U30A and U30B): Summary of PD catchment development information

Catchment	Description	Water use/return flow (million m³/a)
Water use within Mdloti River system		
HAZUP (U30A)	*Umgeni Water Abstraction from Hazelmere Dam*	*10.60*
	Other water use	*0.54*
	Afforestation	*1.29*
HAZLOW (U30B)	*Irrigation water use (Tongaat Hullets and others)*	*5.43*
	Total water use	**17.86**
Return flows within Mdloti River system		
HAZLOW (U30B)	*Discharges from Verulam WWTW*	*2.34*
	Discharges from Mdloti WWTW	*0.38*
	Sanachem return flows	*0.03*
	Total return flows	**2.75**

The WRYM configuration obtained from the Raising of Hazelmere Dam - Feasibility Study (DWA, 2003) was refined to include the modelling of the four DBNs. The factors contributing to natural runoff at the DBNs (as shown in Table 5.17) was applied to the water use components to obtain land use information relating to each DBN. The simulated PD results are presented in Table 5.20. The impact of Hazelmere Dam and its abstraction is reflected in the significant difference of 16.9% between natural and PD conditions observed at node U30A-04360.

Table 5.20 Mdloti (U30A and U30B): Summary of Natural and PD flow at DBNs

Node Name	Rivers	REC	Total catchment area (km^2)	NMAR (million m^3/a)	PD MAR (million m^3/a)	Difference between NMAR and PD MAR		WRYM Channel No.
						(million m^3/a)	(%)	
U30A-04228	*Mdloti*	*B*	*157.30*	*29.78*	*29.00*	*0.78*	*2.61*	*32*
U30A-04360	*Mdloti*	*D*	*396.61*	*73.88*	*61.40*	*12.48*	*16.89*	*17*
U30A-04363	*Mwangala*	*B*	*56.06*	*10.61*	*10.32*	*0.29*	*2.75*	*34*
U30B-04465	*Black Mhlashini*	*B/C*	*41.82*	*5.48*	*5.39*	*0.09*	*1.72*	*36*

5.6 uMNGENI (U20A - U20M)

The uMngeni catchment comprises of 12 quaternary catchments and is shown in Figure 5.6.

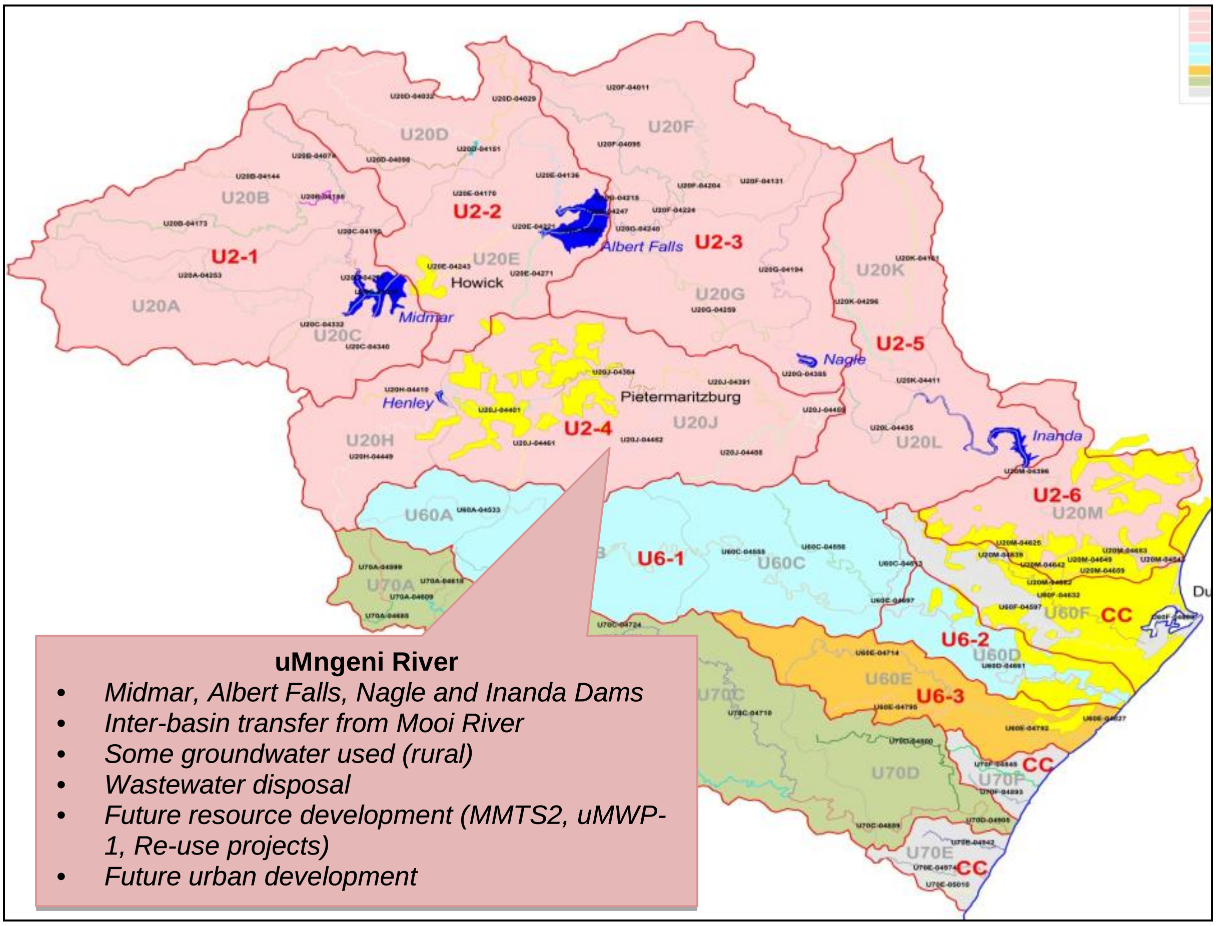

Figure 5.6 uMngeni River Catchment

The hydrology used for the water resources assessment of this study was obtained from the uMngeni Hydrology Update Study (DWA, 1999). The Hydrology Update Study covered the period 1925 to 1995 (hydrological years) and the hydrology was derived for relevant simulation catchments. The hydrology information is summarised in Table 5.21.

Table 5.21 uMngeni (U20A - U20M): Hydrological information (1925 - 1995)

Hydrology reference	Incremental sub-catchment name	Total catchment area (km^2)	Irrigation (million m^3/a)	Afforestation and sugar cane (million m^3/a)	NMAR (million m^3/a)
MID	*Midmar Dam*	*926*	*26.90*	*7.79*	*201.71*
ALB	*Albert Falls Dam*	*728*	*10.48*	*19.05*	*131.33*
NAG	*Nagle Dam*	*885*	*14.46*	*36.85*	*139.73*
HEN	*Henly Dam*	*220*	*0.00*	*0.00*	*40.01*
DUZ	*Msunduze River*	*704*	*6.01*	*1.85*	*56.86*
INA	*Inanda Dam*	*618*	*0.00*	*2.50*	*60.09*
MGEM	*uMngeni River Mouth*	*360*	*0.00*	*0.00*	*41.57*
Total		**4441**	**57.85**	**68.04**	**671.30**

Natural flow time series files were determined for 48 of the 53 DBNs defined within the uMngeni catchment. The DBNs include 3 rapid and two intermediate EWR sites. Table 5.17 presents a breakdown of the portion of natural hydrology included at each DBN, as well as a summary of the average natural flow per node.

Table 5.22 uMngeni (U20A - U20M): Details of Natural Flow Development at DBNs

Node Name	River	Hydrology reference and factor contributing to natural flow at node	Total catchment area (km^2)	NMAR (million m^3/a)
Mg_R_EWR1 (U20A-04253)	*uMngeni*	*MID:0.3905*	*361.58*	*78.76*
U20B-04074	*Ndiza*	*MID:0.0608*	*56.32*	*12.27*
U20B-04144	*Mpofana*	*MID:0.0650*	*60.20*	*13.11*
U20B-04173	*Lions*	*MID:0.1976*	*182.95*	*39.85*
U20B-04185	*Lions*	*MID:0.2879*	*266.61*	*58.07*
U20C-04190	*Lions*	*MID:0.4108*	*380.42*	*82.87*
U20C-04332	*Gqishi*	*MID:0.0788*	*72.98*	*15.90*
U20C-04340	*Nguklu*	*MID:0.0348*	*32.22*	*7.02*
U20D-04029	*Yarrow*	*ALB:0.0880*	*64.06*	*11.56*
U20D-04032	*Karkloof*	*ALB:0.2263*	*164.74*	*29.72*
U20D-04098	*Kusane*	*ALB:0.1283*	*93.43*	*16.85*
U20D-04151	*Karkloof*	*ALB:0.3215*	*234.02*	*42.22*
U20E-04136	*Nculwane*	*ALB:0.1080*	*78.66*	*14.19*
Mg_R_EWR3 (U20E-04170)	*Karkloof*	*ALB:0.5338*	*388.62*	*70.11*
U20E-04221	*uMngeni*	*MID:1.0; ALB:0.7539*	*1474.81*	*300.71*
Mg_I_EWR2 (U20E-04243)	*uMngeni*	*MID:1.0; ALB:0.2016*	*1072.74*	*228.18*
U20E-04271	*Doring Spruit*	*ALB:0.0619*	*45.04*	*8.12*
U20F-04011	*Sterkspruit*	*NAG:0.2171*	*192.14*	*30.34*
U20F-04095	*Mpolweni*	*NAG:0.1259*	*111.39*	*17.59*
U20F-04131	*Mhlalane*	*NAG:0.1036*	*91.70*	*14.48*
U20F-04204	*Sterkspruit*	*NAG:0.3492*	*309.02*	*48.79*
U20F-04224	*Mpolweni*	*NAG:0.5063*	*448.04*	*70.74*
U20G-04194	*Mkabela*	*NAG:0.1425*	*126.10*	*19.91*
U20G-04215	*Cramond Stream*	*NAG:0.0059*	*5.19*	*0.82*

Node Name	River	Hydrology reference and factor contributing to natural flow at node	Total catchment area (km^2)	NMAR (million m^3/a)
U20G-04240	uMngeni	MID:1.0; ALB:1.0; NAG:0.0985	1741.19	346.81
U20G-04259	uMngeni	MID:1.0; ALB:1.0; NAG:0.8197	2379.47	447.58
U20G-04385	uMngeni	MID:1.0; ALB:1.0; NAG:0.9699	2512.36	468.56
U20H-04410	Nqabeni	HEN:0.1385	30.47	5.54
U20H-04449	uMnsunduze	HEN:0..8052	177.15	32.22
Mg_R_EWR4 (U20J-04364)	uMnsunduze	HEN:1.0; DUZ:0.5093	578.58	68.97
U20J-04391	uMnsunduze	HEN:1.0; DUZ:0.7967	780.88	85.31
U20J-04401	uMnsunduze	HEN:1.0; DUZ:0.1528	327.57	48.70
U20J-04452	Mpushini	DUZ:0.1188	83.65	6.76
U20J-04459	uMnsunduze	HEN:1.0; DUZ:0.9622	897.37	94.72
U20J-04461	Slang Spruit	DUZ:0.0701	49.32	3.98
U20J-04488	Mshwati	DUZ:0.1275	89.74	7.25
U20K-04181	Mqeku	INA:0.3248	200.72	19.52
U20K-04296	Tholeni	INA:0.0689	42.61	4.14
U20K-04411	Mqeku	INA:0.4366	269.83	26.24
Mg_I_EWR5 (U20L-04435)	uMngeni	MID:1.0; ALB:1.0; NAG:1.0; HEN:1.0; DUZ:1.0; INA:0.2332	3625.11	583.65
U20M-04396	uMngeni (upstream of Inanda)	MID:1.0; ALB:1.0; NAG:1.0; HEN:1.0; DUZ:1.0; INA:0.7211	3925.65	612.97
U20M-04625		MGEM:0.0076	2.73	0.32
U20M-04639	Palmiet	MGEM:0.0029	1.05	0.12
U20M-04642	Palmiet	MGEM:0.0385	13.87	1.60
U20M-04649	Mbongokazi	MGEM:0.0187	6.75	0.78
U20M-04653	Palmiet	MGEM:0.0931	33.52	3.87
U20M-04659	Palmiet	MGEM:0.0702	25.27	2.92
U20M-04682		MGEM:0.0027	0.98	0.11

Flow in the uMngeni River is regulated by four major dams (Midmar, Albert Falls, Nagle and Inanda) situated on the main stem of the river. There is an inter-basin transfer that transfers water from the Mooi River System (Mearns Weir) to the Midmar Dam catchment (Mpofana River, a tributary of the Lions River that flows into Midmar Dam) and is referred to as the Mooi-uMngeni Transfer Scheme (MMTS). This has resulted in increased flows in the affected rivers. Water has been transferred from the Mearns diversion weir in the Mooi River since January 1983. As part of the first phase of the MMTS additional storage was created at Mearns with the construction of the Mearns Dam which has a Full Supply Storage of 4.91 million m^3. The existing MMTS can transfer a maximum of 3.2 m^3/s (about 101 million m^3/a) to the uMngeni catchment. The second phase of the MMTS (MMTS2) is in the process of being constructed, i.e. Spring Grove Dam in the Mooi River catchment, which will transfer additional volumes of water into the Midmar Dam catchment. Water is abstracted from Midmar Dam to supply uMnsunduze (Pietermaritzburg) and surrounding areas. Water for the eThekwini supply area is abstracted from Nagle Dam which is supported from the upstream Albert Falls Dam. Abstractions are made from Inanda Dam for supplying water to the eThekwini area and the dam is also supported by the upstream dams. Compensation releases are also made from Inanda Dam for environmental purposes. The main land use activities in the catchment include extensive forestry, cultivation (sugarcane and other cash crops) and irrigation. There are also a large number of small farm and instream dams in the catchment. A large portion *of the catchment in the lower reaches of the uMngeni River is semi urban and urban area (eThekwini municipal area). Discharges from the Howick WWTW enter the uMngeni River between Midmar and Albert Falls dams. Discharges from the Darvill WWTW (Pietermaritzburg area) enter the uMsunduze River and affect the flow and especially the water quality of the river. There is a number of discharges from WWTWs within the eThekwini municipal areas that enter the uMngeni River in the lower reaches. These discharges affect both the flow and the water quality of the river and estuary.*

The WRPM was used as DSS to simulate PD flows for the uMngeni River system. The WRPM configuration was updated to include projected urban and industrial water demands that are representative of the 2012 development level. The MMTS2 (Spring Grove Dam and its associated water conveyance infrastructure) was not included in the PD analysis. The remaining catchment development information was sourced from the uMngeni Hydrology Update Study (DWA, 1999).

General information on major dams as well as the dummy dams included in the simulation catchments is presented in Table 5.23.

Table 5.23 uMngeni (U20A – U20M): General information on major and minor dams

Hydrology reference	Major dam or catchment name	Major dam: Full supply conditions			Minor dams: Full supply conditions		
		Level (m)	Storage (million m^3)	Surface area (km^2)	Level (m)	Storage (million m^3)	Surface area (km^2)
I-14	*Midmar*	*1047.50*	*235.41*	*17.93*	*115.0*	*19.60*	*8.67*
I-01	*Albert Falls*	*655.90*	*289.17*	*23.52*	*116.0*	*7.43*	*3.70*
I-18	*Nagle*	*403.81*	*24.61*	*1.56*	*119.8*	*5.95*	*2.96*
I-04	*Henley[1]*	*923.32*	*1.52*	*0.32*	*-*	*-*	*-*
I-02	*uMnsunduze River*	*-*	*-*	*-*	*110.0*	*1.13*	*0.83*
I-07	*Inanda*	*147.00*	*251.64*	*14.63*	*-*	*-*	*-*
Total	-	-	**802.35**	**57.96**	**-**	**34.11**	**16.16**

1 Henley Dam was decommissioned.

The WRPM configuration, as used for the annual operating analysis of the uMngeni River system, was refined to include the modelling of selected DBNs. All landuse and catchment development components had to be adjusted relative to the locations of these DBNs. The strategy followed for the adjustment was firstly to convert simulation catchment data to quaternary catchment level using the WR2005 information as basis. The methodology described in Section 4.3 was then applied to determine landuse and catchment development information relative to each of the DBNs. It is important to note that although natural hydrology was determined for 48 DBNs, PD flows were not required for all the nodes. The simulated PD results are presented in Table 5.24.

Table 5.24 uMngeni (U20A – U20M): Summary of Natural and PD (2012) flow at DBNs

Node name	Rivers	REC	Total catchment area (km^2)	NMAR (million m^3/a)	PD MAR (million m^3/a)	Difference between NMAR and PD MAR		WRYM Channel No.
						(million m^3/a)	(%)	
Mg_R_EWR1	*uMngeni*	*B/C*	*361.58*	*78.76*	*60.46*	*18.30*	*23.24*	*512*
U20B-04074	*Ndiza*	*B*	*56.32*	*12.27*	*10.86*	*1.41*	*11.51*	*542*
U20B-04173	*Lions*	*B*	*182.95*	*39.85*	*34.29*	*5.56*	*13.96*	*548*
U20C-04332	*Gqishi*	*B*	*72.98*	*15.90*	*12.94*	*2.96*	*18.62*	*554*
U20C-04340	*Nguklu*	*C*	*32.22*	*7.02*	*5.88*	*1.14*	*16.21*	*560*

Node name	Rivers	REC	Total catchment area (km^2)	NMAR (million m^3/a)	PD MAR (million m^3/a)	Difference between NMAR and PD MAR		WRYM Channel No.
						(million m^3/a)	(%)	
U20D-04029	Yarrow	B	64.06	11.56	7.81	3.75	32.42	567
U20D-04032	Karkloof	C	164.74	29.72	26.54	3.18	10.70	565
U20D-04098	Kusane	D	93.43	16.85	12.50	4.36	25.85	526
U20D-04151	Karkloof	B	234.02	42.22	35.19	7.03	16.65	569
U20E-04136	Nculwane	C	78.66	14.19	10.73	3.46	24.38	618
Mg_R_EWR3	Karkloof	B	388.62	70.11	56.50	13.61	19.41	532
Mg_I_EWR2	uMngeni	C	1072.74	228.18	105.40	122.78	53.81	572
U20E-04271	Doring Spruit	B/C	45.04	8.12	6.53	1.59	19.60	577
U20F-04011	Sterkspruit	C/D	192.14	30.34	13.44	16.89	55.69	595
U20F-04095	Mpolweni	C/D	111.39	17.59	7.76	9.82	55.86	607
U20F-04131	Mhlalane	C/D	91.70	14.48	6.31	8.17	56.41	600
U20F-04204	Sterkspruit	B/C	309.02	48.79	22.41	26.38	54.08	602
U20F-04224	Mpolweni	B/C	448.04	70.74	33.64	37.10	52.44	611
U20G-04194	Mkabela	C/D	126.10	19.91	16.79	3.12	15.67	617
U20G-04215	Cramond Stream	B/C	5.19	0.82	0.69	0.13	15.29	590
U20G-04259	uMngeni	B	2379.47	447.58	243.44	204.14	45.61	612
U20G-04385	uMngeni	B/C	2512.36	468.56	261.28	207.28	44.24	647
U20H-04410	Nqabeni	C	30.47	5.54	5.54	-	-	626
U20H-04449	uMnsunduze	C	177.15	32.22	32.22	-	-	637
Mg_R_EWR4	uMnsunduze	D	578.58	68.97	88.04	-19.07	-27.65	622
U20J-04391	uMnsunduze	C	780.88	85.31	101.52	-16.21	-19.00	631
U20J-04401	uMnsunduze	D	327.57	48.70	48.41	0.29	0.59	645
U20J-04452	Mpushini	B	83.65	6.76	5.40	1.36	20.12	625
U20J-04459	uMnsunduze	C	897.37	94.72	109.39	-14.67	-15.49	642
U20J-04461	Slang Spruit	C/D	49.32	3.98	3.85	0.13	3.36	653
U20J-04488	Mshwati	B	89.74	7.25	5.90	1.35	18.59	651
U20K-04181	Mqeku	C	200.72	19.52	17.67	1.84	9.45	655
U20K-04296	Tholeni	B/C	42.61	4.14	3.76	0.39	9.36	649
U20K-04411	Mqeku	B	269.83	26.24	23.76	2.47	9.43	657
Mg_I_EWR5	uMngeni	B	3625.11	583.65	245.25	338.40	57.98	618
U20M-04396	uMngeni (upstream of Inanda)	C	3925.65	612.97	271.96	341.01	55.63	532

5.7 U60E AND U60F: UMBILO, MHLATUZANA AND MBOKODWENI

The Mbokodweni River catchment is included in quaternary catchment U60E. Three DBNs were identified in the Mbokodweni catchment. The Umbilo and Mhlatuzana river catchments (also referred to as the Durban Bay catchment) fall within quaternary catchment U60F. Only one DBN was defined for each of these river reaches and these nodes are located just upstream of Durban Bay. These catchments are shown in Figure 5.7.

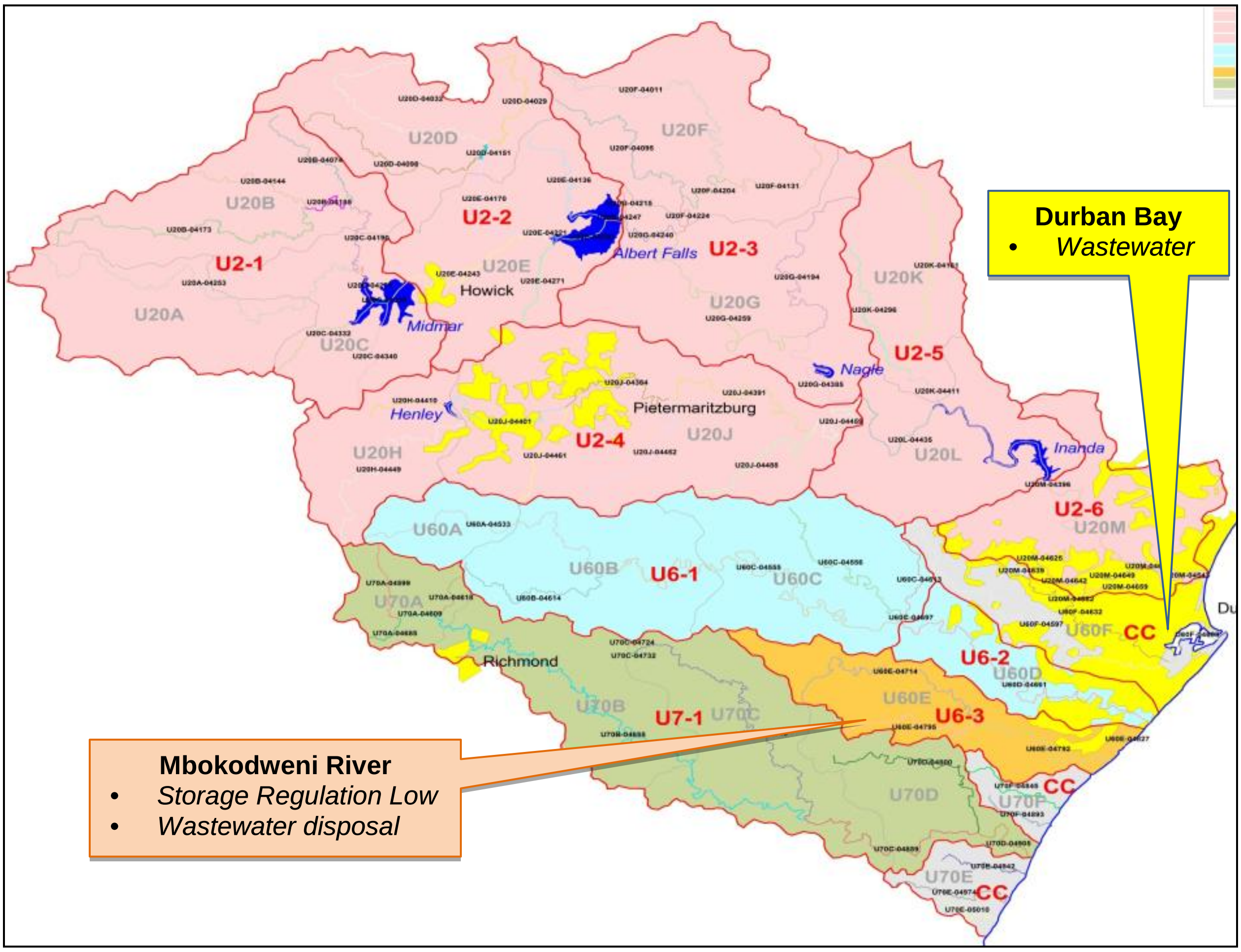

Figure 5.7 Mbokodweni and Durban Bay (Umbilo and Mhlatuzana) catchments

The WR2005 hydrology was used for the assessment of the Umbilo, Mhlatuzana and Mbokodweni catchments. The WR2005 information for the relevant quaternary catchments is summarised in Table 5.25.

Table 5.25: U60E and U60F: WR2005 Information (1920 - 2004)

Quaternary catchment	Total catchment area (km^2)	Forestry area (km^2)	Alien vegetation area (km^2)	Irrigation area (km^2)	Farm Dams		NMAR (million m^3/a)
					Area (km^2)	Volume (million m^3)	
U60E	280	4.50	3.20	0.00	0.44	1.92	36.23
U60F	272	0.60	18.50	0.00	0.20	0.70	43.25

Table 5.26 presents a breakdown of the portion of natural hydrology included at each DBN, as well as a summary of the average natural flow per node.

Table 5.26 U60E and U60F: Details of natural flow development at DBNs

Node Name	Rivers	Hydrology reference and factor contributing to natural flow at node	Total catchment area (km^2)	NMAR (million m^3/a)
U60E-04714	Mbokodweni	U60E:0.465	130.10	16.83
U60E-04792	Mbokodweni	U60E:0.722	202.13	26.15
U60E-04795	Bivane	U60E:0.181	50.73	6.56
U60F-04597	Mhlatuzana	U60F:0.462	125.56	19.96
U60F-04632	Umbilo	U60F:0.293	79.76	12.68

The WReMP (see Section 4.3) was used for the PD assessments of the three estuaries. Due to the location of the Umbilo DBN, the PD flow simulated for the Umbilo River as part of the estuary assessment was also considered as being representative of the flow at the DBN. The Umbilo catchment includes large urbanized areas and the river system is significantly impacted by increased runoff from paved (impervious) areas. Increased urban runoff at PD development levels was assumed to be in the order of 7.8 million m^3/a. The Mhlatuzana node was excluded from further analysis as environmental issues are not flow related. PD flow assessment was, therefore, only carried out for the Mbokodweni catchment. The catchment development information relating to the WReMP setup that was used for the assessment of the Mbokodweni estuary is summarised in Table 5.27.

Table 5.27 U60F: PD catchment development information

Node	Catchment area (km^2)	Water use (million m^3/a)				SFRA (million m^3/a)		Return flows (million m^3/a)	Dummy Dam	
		Rural	Urban	Industrial	Irrigation	Forestry	IAP		FSA (km^2)	FSV (million m^3)
Dummy Dam	*11.20*	*0.000*	*0.000*	*0.038*	*0.000*	*0.000*	*0.153*	*0.000*	*0.440*	*1.920*
Isipingo Node	*11.20*	*0.000*	*0.000*	*0.000*	*10.594*[1]	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*
Estuary Node	*232.31*	*0.000*	*2.230*	*0.440*	*0.000*	*0.450*	*0.562*	*8.500*[2]	*0.000*	*0.000*
Total	**254.71**	**0.000**	**2.230**	**0.478**	**10.594**	**0.450**	**0.715**	**8.500**	**0.440**	**1.920**

1 Flow diverted from Isipingo River (includes urban runoff from paved areas).
2 Discharges from the Amanzimtoti WWTW.

It is important to note that water from the adjacent Isipingo River is diverted to the lower reaches of the Mbokodweni. As indicated in Table 5.27 the Isipingo transfer is considered as an import to the Mbokodweni River system with the transferred flow entering at the Mbokodweni node labelled "Isipingo".

The WRSM2000 was configured for the Mbokodweni catchment to simulate the PD flows at the three DBNs and the WReMP catchment development information presented in Table 5.27 was used in the assessment. The methodology described in Section 4.3 was applied to determine landuse and catchment development information relative to each of the DBNs. The simulated PD results are presented in Table 5.28. As mentioned above and shown in the table below, the Umbilo catchment is highly impacted by urbanization resulting in significantly higher PD flows.

Table 5.28 U60E and U60F: Summary of Natural and PD flow at DBNs

Node name	Rivers	REC	Total catchment area (km^2)	NMAR (million m^3/a)	PD MAR (million m^3/a)	Difference between NMAR and PD MAR		WRYM Channel No.
						(million m^3/a)	(%)	
U60E-04714	*Mbokodweni*	*B*	*130.099*	*16.83*	*15.67*	*1.16*	*6.91*	*U60E-04714*
U60E-04792	*Mbokodweni*	*C*	*202.133*	*26.15*	*24.32*	*1.83*	*7.01*	*U60E-04792*
U60E-04795	*Bivane*	*B*	*50.732*	*6.56*	*6.08*	*0.48*	*7.38*	*U60E-04795*
U60F-04632	*Umbilo*	*D*	*79.759*	*12.68*	*19.43*	*-6.75*	*-53.21*	*U60F-04632*

5.8 MLAZI (U60A - U60D)

The Mlazi River catchment is shown in Figure 5.8.

Figure 5.8 Mlazi River Catchment

The Upper Mlazi catchment comprising of quaternary catchments U60A and U60B was included in the Mkomazi Study (DWA, 2014) and was, therefore, analysed at a high level of detail. The hydrology resulting from the Mkomazi Study covered the period 1925 to 2008 (84 years) and accounted for the impact of wetlands and farm dams. The WR2005 hydrology, covering the period 1920 to 2004, was the most recent hydrology available for the Lower Mlazi (quaternary catchments U60C and U60D). The hydrology from the two sources was used in combination to enable simulation of PD flows for the Mlazi catchment over the common period from 1925 to 2004 (80 years). The hydrological information is summarised in Table 5.29.

Table 5.29 Mlazi (U60A – U60D): Summary of hydrological information (1925 - 2004)

Quaternary catchment	Total catchment area (km^2)	Forestry area (km^2)	Alien vegetation area (km^2)	Irrigation area (km^2)	Farm Dams		NMAR (million m^3/a)
					Area (km^2)	Volume (million m^3)	
U60A	105		0.56		0.55	2.02	22.65
U60B	316				2.26	8.15	36.75
U60C	365	0.50	10.70	19.20	0.58	2.96	28.44
U60D	185	0.00	4.50	0.00			22.32
Total	**971**						**110.16**

Table 5.30 presents a breakdown of the portion of natural hydrology included at each DBN, as well as a summary of the average natural flow per node.

Table 5.30 Mlazi (U60A – U60D): Details of natural flow development at DBNs

Node Name	Rivers	Hydrology reference and factor contributing to natural flow at node	Total catchment area (km^2)	NMAR (million m^3/a)
U60A-04533	Mlazi	U60A:1.0; U60B:0.285	195.16	33.14
U60B-04614	Mkuzane	U60B:0.229	72.31	8.41
U60C-04555	Mlazi	U60A:1.0; U60B:1.00; U60C:0.588	635.68	76.13
U60C-04556	Sterkspruit	U60C:0.335	122.38	9.54
U60C-04613	Wekeweke	U60C:0.064	23.46	1.83
U60D-04661	Mlazi	U60A:1.0; U60B:1.0; U60C:1.0; U60D:0.644	905.11	102.21

The WRSM2000 configuration for quaternary catchment U60A and U60B was obtained from the Mkomazi Study (DWA, 2014) and was adjusted to include modelling of the DBNs. The WRSM2000 configuration resulting from the WR2012 Study (which has not yet been completed), was used for the modelling of U60C and U60D. The benefit from using the WR2012 setup is that it includes the modelling of small dams. Shongweni Dam, one of the major dams with a FSC of 4.5 million m^3 is located at the outlet of U60C and is the most downstream dam within the Mlazi catchment. The Mlazi WWTW discharges into the Sterkspruit a tributary of the Mlazi upstream of Shongweni Dam. It was confirmed that Umgeni Water no longer abstracts water from the Mlazi. There are several WWTWs (Kwandengezi, Pinetown and Dassenhoek) with discharges to the river in U60D.

The WRSM2000 setup for U60C and U60D was adjusted to include the DBNs. The methodology described in Section 4.3 was applied to determine landuse and catchment development information relative to each of the DBNs. The simulated PD results for the common period 1925 to 2004 are presented in Table 5.31.

Table 5.31 Mlazi (U60A – U60D): Summary of Natural and PD flow at DBNs

Node name	Rivers	REC	Total catchment area (km^2)	NMAR (million m^3/a)	PD MAR (million m^3/a)	Difference between NMAR and PD MAR		WRYM Channel No.
						(million m^3/a)	(%)	
U60A-04533	Mlazi	C	195.16	33.14	19.16	13.98	42.18	U60A-04533
U60B-04614	Mkuzane	C/D	72.31	8.41	3.05	5.36	63.73	U60B-04614
U60C-04555	Mlazi	C/D	635.68	76.13	38.76	37.37	49.09	U60C-04555
U60C-04556	Sterkspruit	D	122.38	9.54	8.72	0.82	8.55	U60C-04556
U60C-04613	Wekeweke	C	23.46	1.83	1.05	0.78	42.56	U60C-04613
U60D-04661	Mlazi	C/D	905.11	102.21	65.23	36.98	36.18	U60D-04661
Estuary	Mlazi	-	971.00	110.16	74.1	36.06	32.73	Estuary

5.9 CENTRAL COAST RIVERS (U70E AND U70F)

DBNs were identified within four of the Central Coast river systems: Little Manzimtoti, Manzimtoti, Umgababa and Msimbazi. The Umgababa and Msimbazi rivers are located within quaternary catchment U70E, whilst the Little Manzimtoti and Manzimtoti are situated in U70F. The Central Coast river catchments are shown in Figure 5.9.

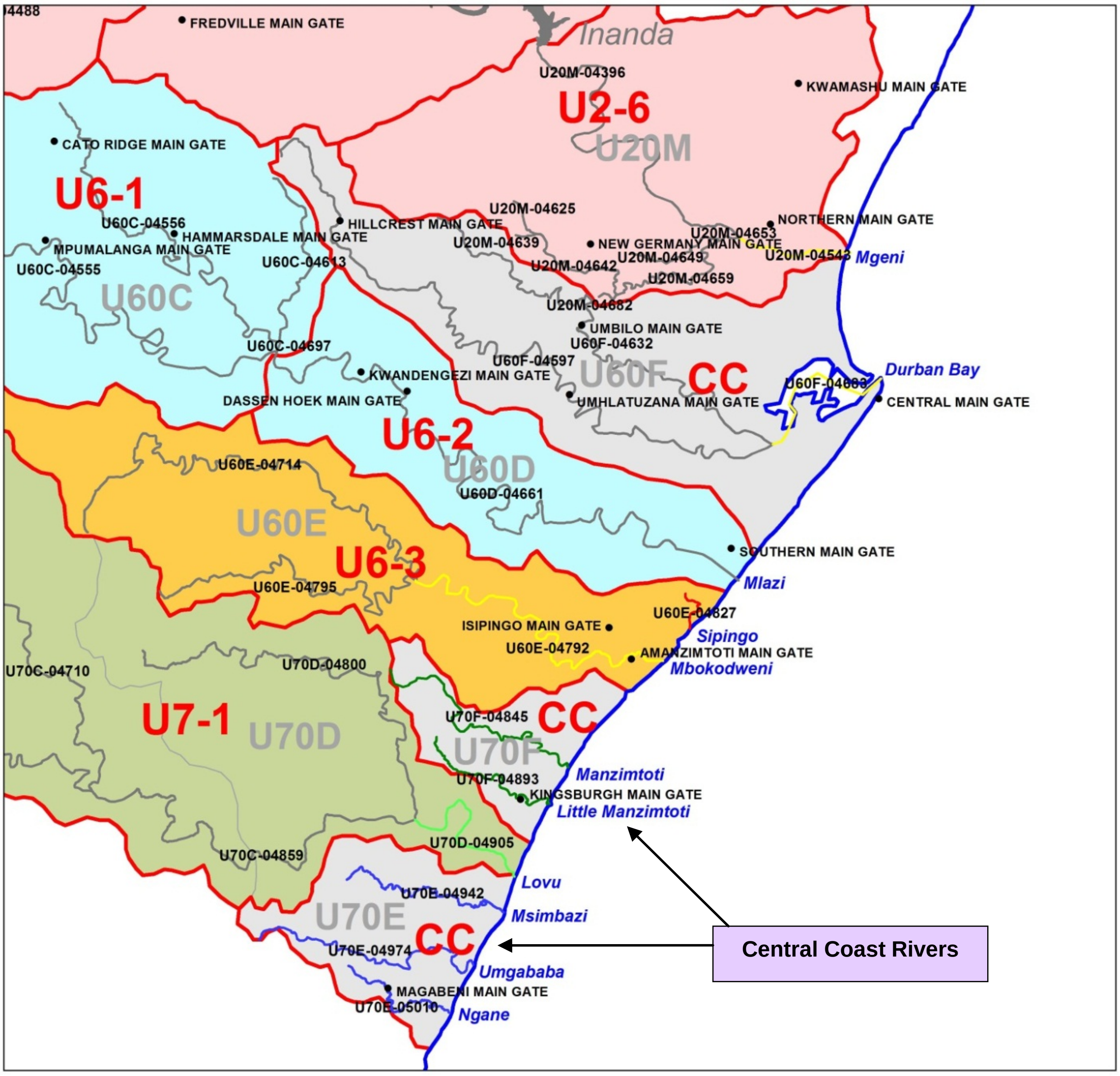

Figure 5.9 Central Coast River Catchments

The WR2005 hydrology, covering the period 1920 to 2004, was used for these catchments. The hydrological information is summarised in Table 5.32.

Table 5.32 Central Coast Rivers (U70E and U70F): Summary of hydrological information (1920 - 2004)

Quaternary catchment	Total catchment area (km^2)	Forestry area (km^2)	Alien vegetation area (km^2)	Irrigation area (km^2)	Farm Dams		NMAR (million m^3/a)
					Area (km^2)	Volume (million m^3)	
U70E	*87*	*0.00*	*1.20*	*0.85*	*-*	*-*	*26.41*
U70F	*59*	*0.00*	*0.00*	*0.00*	*-*	*-*	*9.81*

Table 5.33 presents a breakdown of the portion of natural hydrology included at each DBN, as well as a summary of the average natural flow per node.

Table 5.33 Central Coast Rivers (U70E and U70F): Details of natural flow development at DBNs

Node Name	Rivers	Hydrology reference and factor contributing to natural flow at node	Total catchment area (km^2)	NMAR (million m^3/a)
U70E-04942	*Umsimbazi*	*U70E:0.2983*	*25.95*	*7.88*
U70E-04974	*uMgababa*	*U70E:0.1887*	*16.42*	*4.98*
U70F-04845	*Manzimtoti*	*U70F:0.4831*	*28.50*	*4.74*
U70F-04893	*Little Manzimtoti*	*U70F:0.1470*	*8.67*	*1.44*

The WReMP (see Section 4.3) was used for the PD assessments of these estuaries. The catchment development information relating to the WReMP setups was subsequently obtained and used for the PD assessments of the DBNs.

The WReMP catchment development information for the Umgababa catchment is summarised in Table 5.34. The DBN is situated upstream of the Umgababa Dam and the PD flow at the node was determined by means of a water balance calculation.

Table 5.34 Umgababa (U70E): PD catchment development information

Node	Catchment area (km^2)	Water use (million m^3/a)				SFRA (million m^3/a)		Return flows (million m^3/a)	Dummy Dam	
		Rural	Urban	Industrial	Irrigation	Forestry	IAP		FSA (km^2)	FSV (million m^3)
Umgababa Dam	*3.03*	*0.00*	*1.00*	*0.00*	*0.00*	*0.00*	*0.005*	*0.00*	*0.31*	*1.28*
Node2	*25.96*	*0.15*	*0.00*	*0.00*	*0.00*	*0.00*	*0.001*	*0.00*	*-*	*-*
Node3	*5.62*	*0.05*	*0.00*	*0.00*	*0.00*	*0.00*	*0.005*	*0.00*	*-*	*-*
Total	**34.61**	**0.20**	**1.00**	**0.00**	**0.00**	**0.00**	**0.011**	**0.00**	**0.31**	**1.28**

The WReMP catchment development information for the Msimbazi catchment only indicated a rural demand of 0.2 million m^3/a. The WRSM2000 was adjusted to include modelling of the DBN and the PD flow was simulated at the node.

The WReMP catchment development information for the Manzimtoti River system indicated a rural demand of 0.1 million m^3/a and a reduction in runoff due to IAPs in the order of 0.003 m^3/a. The PD flow at the node was determined by means of a water balance calculation.

The WReMP catchment development information for the Little Manzimtoti River system indicated a WWTW discharge of 1.73 million m^3/a, increased urban runoff amounting to 2.35 million m^3/a and a reduction in runoff due to IAPs in the order of 0.314 m^3/a. The PD flow at the node was determined by means of a water balance calculation.

The PD results for the DBNs of the four river systems are presented in Table 5.35.

Table 5.35 CC Rivers (U70E and U70F): Summary of Natural and PD flow at DBNs

Node Name	Rivers	REC	Total catchment area (km^2)	NMAR (million m^3/a)	PD MAR (million m^3/a)	Difference between NMAR and PD MAR		WRYM Channel No.
						(million m^3/a)	(%)	

Node Name	Rivers	REC	Total catchment area (km^2)	NMAR (million m^3/a)	PD MAR (million m^3/a)	Difference between NMAR and PD MAR		WRYM Channel No.
						(million m^3/a)	(%)	
U70E-04942	*Umsimbazi*	*C*	*25.95*	*7.88*	*7.73*	*0.15*	*1.89*	*U70E-04942*
U70E-04974	*uMgababa*	*C*	*16.42*	*4.98*	*4.86*	*0.12*	*2.47*	*U70E-04974*
U70F-04845	*Manzimtoti*	*C*	*28.50*	*4.74*	*4.62*	*0.12*	*2.51*	*U70F-04845*
U70F-04893	*Little Manzimtoti*	*C*	*8.67*	*1.44*	*2.37*	*-0.93*	*-64.34*	*U70F-04893*

5.10 LOVU (U70A - U70D)

The Lovu River catchment, shown in Figure 5.10 below, comprises of four quaternary catchments: U70A, U70B, U70C and U70D.

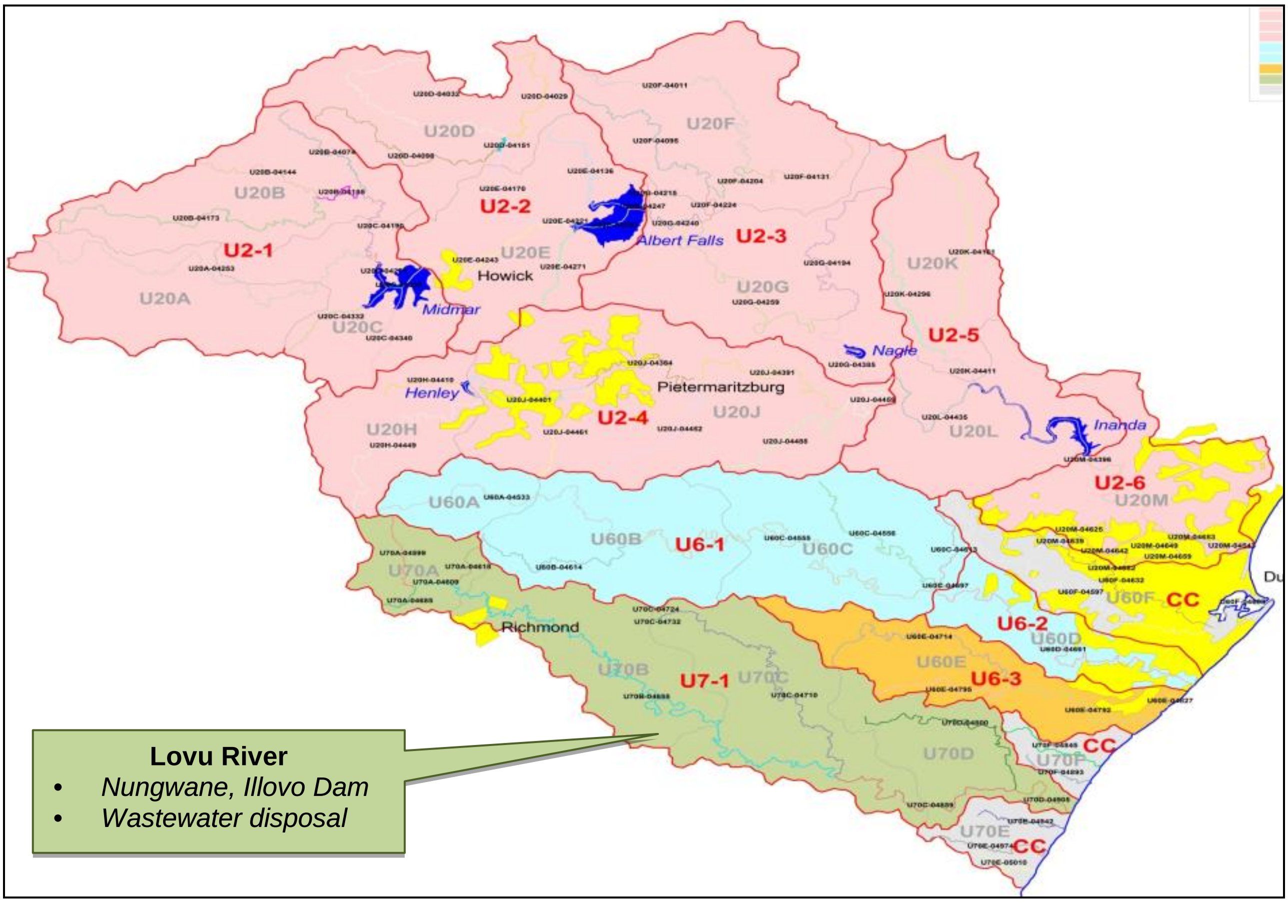

Figure 5.10 Lovu River Catchment

Ten DBNs were identified for the Lovu one of which was selected for a rapid EWR assessment (Lo_R_EWR1). The WR2012 hydrology and WRSM2000 configuration was used for the assessment of the Lovu River catchment. The hydrology is summarised in Table 5.36.

Table 5.36 Lovu (U70A – U70D): Summary of hydrology (1920 - 2009)

Quaternary catchment	Total catchment area (km^2)	Forestry area (km^2)	Alien vegetation area (km^2)	Irrigation area (km^2)	Farm Dams		NMAR (million m^3/a)
					Area (km^2)	Volume (million m^3)	
U70A	*114*	*73.00*	*9.40*	*4.25*	*0.06*	*0.29*	*23.67*
U70B	*272*	*110.50*	*6.30*	*4.25*	*0.43*	*1.07*	*28.33*
U70C	*350*	*22.80*	*2.70*	*4.25*	*0.32*	*1.07*	*37.80*
U70D	*208*	*0.00*	*2.60*	*2.55*	*-*	*-*	*29.55*

Quaternary catchment	Total catchment area (km^2)	Forestry area (km^2)	Alien vegetation area (km^2)	Irrigation area (km^2)	Farm Dams		NMAR (million m^3/a)
					Area (km^2)	Volume (million m^3)	
Total	**944**	**206.30**	**21.00**	**15.30**	**0.80**	**2.43**	**119.35**

Table 5.37 presents a breakdown of the portion of natural hydrology included at each DBN, as well as a summary of the average natural flow per node.

Table 5.37 Lovu (U70A – U70D): Details of natural flow development at DBNs

Node Name	Rivers	Hydrology reference and factor contributing to natural flow at node	Total catchment area (km^2)	NMAR (million m^3/a)
U70A-04599	Serpentine	U70A:0.4407	50.24	10.43
U70A-04609	Lovu	U70A:0.7523	85.76	17.81
U70A-04618		U70A:0.1462	16.67	3.46
U70A-04685	Lovu	U70A:0. 0702	8.00	1.66
U70B-04655	Lovu	U70A:1.0; U70B:1.0; U70C:0.2444	471.55	61.24
U70C-04710	Mgwahumbe	U70C:0.5874	205.58	22.20
U70C-04724		U70C:0.0024	0.85	0.09
U70C-04732		U70C:0.0012	0.43	0.05
Lo_R_EWR1 (U70C-04859)	Lovu	U70A:1.0; U70B:1.0; U70C:1.0; U70D:0.3649	811.91	100.58
U70D-04800	Nungwane	U70D:0.5131	106.72	15.16

The WRSM2000 configuration resulting from the WR2012 Study was adjusted to include modelling of the ten DBNs. As shown in Table 5.36 there is extensive forestry in the upper part of the catchment. The methodology described in Section 4.3 was applied to determine landuse and catchment development information relative to each of the DBNs. The simulated PD results for the DBNs are presented in Table 5.38.

Table 5.38 Lovu (U70A – U70D): Summary of Natural and PD flows at DBNs

Node Name	Rivers	REC	Total catchment area (km^2)	NMAR (million m^3/a)	PD MAR (million m^3/a)	Difference between NMAR and PD MAR		WRYM Channel No.
						(million m^3/a)	(%)	
U70A-04599	Serpentine	C	50.24	10.43	6.04	4.39	42.10	U70A-04599
U70A-04609	Lovu	B/C	85.76	17.81	10.51	7.30	40.98	U70A-04609
U70A-04618		C	16.67	3.46	2.16	1.30	37.59	U70A-04618
U70A-04685	Lovu	C	8.00	1.66	1.01	0.65	39.23	U70A-04685
U70B-04655	Lovu	C/D	471.55	61.24	37.21	24.03	39.24	U70B-04655
U70C-04710	Mgwahumbe	C	205.58	22.20	20.19	2.01	9.06	U70C-04710
U70C-04724		C	0.85	0.09	0.07	0.02	23.85	U70C-04724
U70C-04732		C	0.43	0.05	0.04	0.01	13.19	U70C-04732
Lo_R_EWR1 (U70C-04859)	Lovu	B	811.91	100.58	73.42	27.17	27.01	Lo_R_EWR1 (U70C-04859)
U70D-04800	Nungwane	B/C	106.72	15.16	9.32	5.84	38.52	U70D-04800

The PD water use and return flows are summarised in Table 5.39.

Table 5.39 Lovu (U70A – U70D): Summary of PD catchment development information

Catchment	Description	Water Use (million m^3/a)	Return Flow (million m^3/a)
U70A	*Reduction in runoff due to forestry and IAPs*	*9.29*	*-*
	Irrigation water use supplied from Dummy Dam	*2.16*	*-*
	Total for U70A	**11.45**	**0.00**
U70B	*Reduction in runoff due to forestry and IAPs*	*8.65*	*-*
	Irrigation water use supplied from Dummy Dam	*2.58*	*-*
	Richmond Abstraction	*0.38*	*-*
	Total for U70B	**11.61**	**0.00**
U70C	*Reduction in runoff due to forestry and IAPs*	*2.18*	*-*
	Irrigation water use supplied from Dummy Dam	*2.69*	*-*
	Richmond Return Flows	*-*	*0.31*
	Total for U70C	**4.87**	**0.31**
U70D	*Reduction in runoff due to forestry and IAPs*	*0.24*	*-*
	Irrigation water use supplied from Dummy Dam	*1.47*	*-*
	Illovo CG Smith Abstraction	*2.50*	*-*
	Umgeni WB Abstraction from Nungwane Dam	*5.81*	*-*
	Illovo CG Smith Return Flow	*-*	*0.29*
	Total for U70D	**10.02**	**0.29**
Total for Lovu catchment		**37.95**	**0.60**

5.11 MKOMAZI (U10A - U10M)

The Mkomazi River catchment comprises of secondary catchment U10 which includes twelve quaternary catchments (U10A to U10M). The Mkomazi catchment is shown in Figure 5.11.

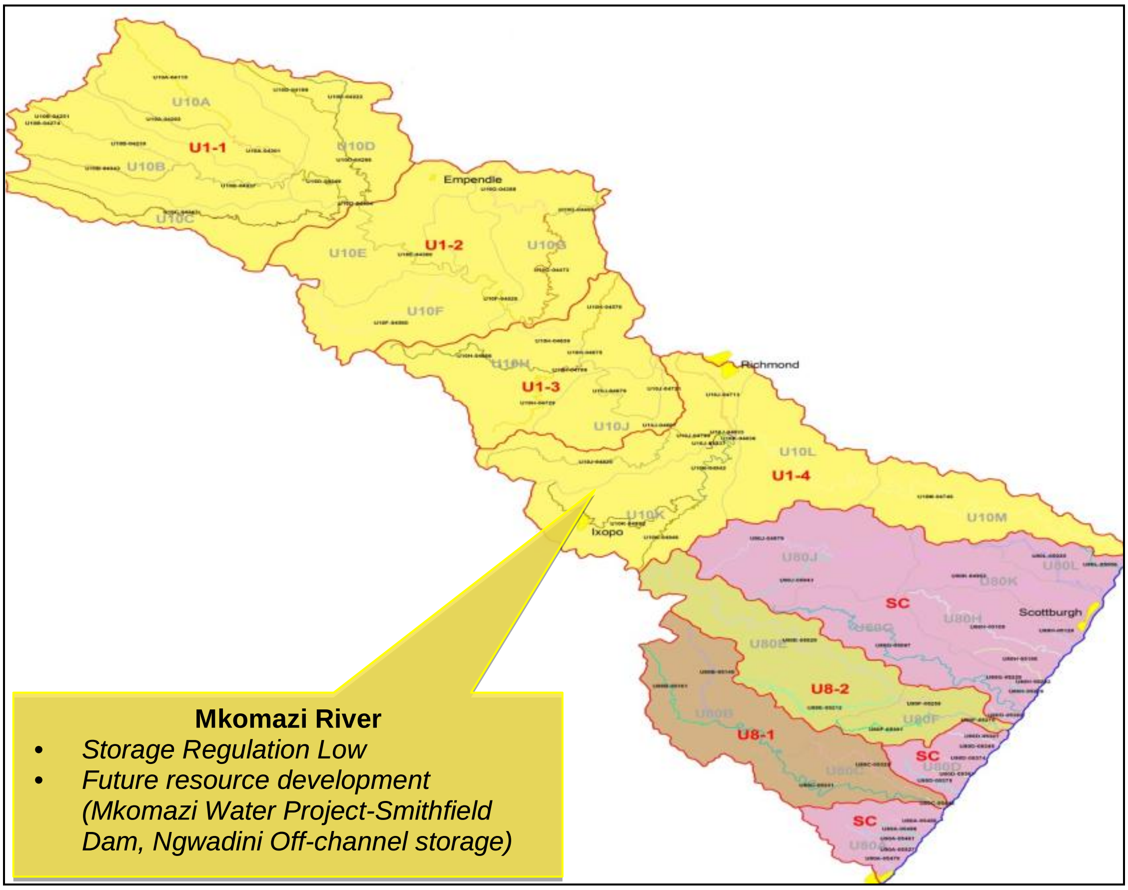

Figure 5.11 Mkomazi River Catchment

The hydrology and catchment development information obtained from the uMWP-1 Study (DWA, 2014) were used for the water resource assessment of this study. The available data set covers a period of 84 years from the 1925 to the 2008 hydrological year and was developed at a quaternary catchment scale.

The Mkomazi River catchment is currently fairly undeveloped, with the exception of large tracts of commercial forestry and irrigated areas in the central catchment areas around the towns of Richmond, Ixopo, Bulwer and Impendle, as well as water abstractions for the SAPPI SAICCOR mill located near the coastal town of Umkomaas. Other water users include small towns and rural settlements, stock watering, dry-land sugarcane and invasive alien plants. There are also numerous wetlands and small dams scattered throughout the catchment. The uMWP-1 entails the transfer of water from the Mkomazi River to the existing uMngeni system and two possible dam sites, Impendle and Smithfield, were evaluated within the Mkomazi catchment.

The hydrology and catchment development information is summarised in Table 5.40. It is important to note that the catchment development information presented in Table 5.40 is representative of 2008 conditions.

Table 5.40 Mkomazi (U10A – U10M): Hydrology and catchment development (1925 - 2008)

Quaternary catchment	Catchment area (km^2)	NMAR (million m^3/a)	Water use for 2008 conditions (million m^3/a)				Total water use (million m^3/a)
			Afforestation	IAPs	Irrigation	Urban, industrial and stockwatering	
U10A	418	209.52	0.88	0.38	0.00	0.36	1.62
U10B	392	164.49	4.26	1.46	0.00	-	5.72
U10C	267	96.7	3.29	0.81	1.70	-	5.80
U10D	337	98.22	0.42	0.87	1.12	0.29	2.70
U10E	327	100.92	4.82	0.66	0.00	0.48	5.96
U10F	379	67.1	4.7	0.32	0.59	0.26	5.87
U10G	353	70.12	5.55	0.36	6.87	0.27	13.05
U10H	458	82.66	14.39	0.41	12.62	-	27.42
U10J	505	77.99	13.35	0.42	8.71	0.30	22.78
U10K	364	40.42	7.53	0.35	5.92	0.90	14.70
U10L	307	29.56	1.99	0.15	0.17	-	2.31
U10M	280	40.1	0.18	0.18	0.00	53.00	53.36
Total	**4387**	**1077.74**	**61.36**	**6.37**	**37.70**	**55.86**	**161.29**

A total of 39 DBNs were identified in the Mkomazi catchment three of which were selected as key nodes for which intermediate EWR assessments were done. Table 5.41 presents a breakdown of the portion of natural hydrology included at each DBN, as well as a summary of the average natural flow per node.

Table 5.41 Mkomazi (U10A – U10M): Details of natural flow development at DBNs

Node Name	Rivers	Hydrology reference and factor contributing to natural flow at node	Total catchment area (km^2)	NMAR (million m^3/a)
U10A-04115	Lotheni	U10A:0.5398	224.83	113.09
U10A-04202	Nhlathimbe	U10A:0.2077	86.53	43.52
U10A-04301	Lotheni	U10A:0.9970	415.26	208.88

Node Name	Rivers	Hydrology reference and factor contributing to natural flow at node	Total catchment area (km^2)	NMAR (million m^3/a)
U10B-04239	Mkomazi	U10B:0.4744	184.66	78.03
U10B-04251	Mkomazi	U10B:0.0392	15.27	6.45
U10B-04274	Nhlangeni	U10B:0.0563	21.90	9.26
U10B-04337	Mkomazi	U10B:0.9973	388.23	164.05
U10B-04343	Mqatsheni	U10B:0.2268	88.27	37.30
U10C-04347	Mkhomazana	U10C:0.9933	264.20	96.05
U10D-04199	Nzinga	U10D:0.2325	78.30	22.84
U10D-04222	Rooidraai	U10D:0.1359	45.77	13.35
U10D-04298	Nzinga	U10D:0.8392	282.59	82.42
U10D-04349	Mkomazi	U10A:1.0; U10B:1.0; U10D:0.1498	860.43	388.72
U10D-04434	Mkomazi	U10A:1.0; U10B:1.0; U10C:1.0; U10D:0.1552	1129.27	485.96
Mk_I_EWR1 (U10E-04380)	Mkomazi	U10A:1.0; U10B:1.0; U10C:1.0; U10D:1.0; U10E:1.0; U10F:0.1985	1816.16	683.16
U10F-04528	Mkomazi	U10A:1.0; U10B:1.0; U10C:1.0; U10D:1.0; U10E:1.0; U10F:1.0; U10G:0.0306	2130.79	739.07
U10F-04560	Luhane	U10F:0.5412	204.93	36.30
U10G-04388	Elands	U10G:0.2692	94.96	18.87
U10G-04405		U10G:0.1234	43.55	8.66
U10G-04473	Elands	U10G:0.9575	337.81	67.14
U10H-04576	Tholeni	U10H:0.1702	77.85	14.07
U10H-04638	Mkomazi	U10A:1.0; U10B:1.0; U10C:1.0; U10D:1.0; U10E:1.0; U10F:1.0; U10G:1.0; U10H:0.1229	2529.21	817.21
U10H-04666	Ngudwini	U10H:0.2462	112.63	20.35
U10H-04675	Mkomazi	U10A:1.0; U10B:1.0; U10C:1.0; U10D:1.0; U10E:1.0; U10F:1.0; U10G:1.0; U10H:0.3211	2619.86	833.59
U10H-04708	Ngudwini	U10H:0.5711	261.23	47.21
U10H-04729	Mzalanyoni	U10H:0.2780	127.17	22.98
Mk_I_EWR2 (U10J-04679)	Mkomazi	U10A:1.0; U10B:1.0; U10C:1.0; U10D:1.0; U10E:1.0; U10F:1.0; U10G:1.0; U10H:1.0; U10J:0.0153	2938.75	890.91
U10J-04713	Mkobeni	U10J:0.1782	89.94	13.90
U10J-04721	Pateni	U10J:0.0798	40.30	6.23
U10J-04799	Mkomazi	U10A:1.0; U10B:1.0; U10C:1.0; U10D:1.0; U10E:1.0; U10F:1.0; U10G:1.0; U10H:1.0; U10J:0.7862	3327.79	951.03
U10J-04807	Mkomazi	U10A:1.0; U10B:1.0; U10C:1.0; U10D:1.0; U10E:1.0; U10F:1.0; U10G:1.0; U10H:1.0; U10J:0.3813	3123.46	919.45
U10J-04820	Lufafa	U10J:0.3345	168.85	26.09
U10J-04833	Mkomazi	U10A:1.0; U10B:1.0; U10C:1.0; U10D:1.0; U10E:1.0; U10F:1.0; U10G:1.0; U10H:1.0; U10J:0.8196	3344.66	953.63
U10J-04837		U10J:0.0050	2.50	0.39
U10K-04838	Mkomazi	U10A:1.0; U10B:1.0; U10C:1.0; U10D:1.0; U10E:1.0; U10F:1.0; U10G:1.0; U10H:1.0; U10J:1.0; U10K:0.0032	3437.18	967.83
U10K-04842	Nhlavini	U10IK:0.9941	361.99	40.18
U10K-04899	Xobho	U10K:0.4723	171.96	19.09
U10K-04946	Nhlavini	U10K:0.1646	59.95	6.65
Mk_I_EWR3 (U10M-04746)	Mkomazi	U10A:1.0; U10B:1.0; U10C:1.0; U10D:1.0; U10E:1.0; U10F:1.0; U10G:1.0; U10H:1.0; U10J:1.0; U10K:1.0; U10L:1.0; U10M:0.7706	4322.66	1068.55

The WRYM configuration obtained from the uMWP-1 Study (DWA, 2014) was adjusted to be representative of PD (2008) development conditions (i.e. future development schemes such as the *proposed Smithfield and Impendle dams were excluded). The resolution of the WRYM configuration was also refined to include modelling of 34 DBNs. The methodology described in Section 4.3 was applied to determine landuse and catchment development information relative to each of the DBNs. The simulated PD results for the DBNs are presented in Table 5.42.*

Table 5.42 Mkomazi (U10A – U10M): Summary of natural and PD flows at DBNs

Node name	Rivers	REC	Total catchment area (km^2)	NMAR (million m^3/a)	PD MAR (million m^3/a)	Difference between NMAR and PD MAR		WRYM Channel No.
						(million m^3/a)	(%)	
U10A-04202	Nhlathimbe	B	86.53	43.52	43.62	-0.10	-0.22	133
U10A-04301	Lotheni	B	415.26	208.88	208.16	0.72	0.35	3
U10B-04337	Mkomazi	B	388.23	164.05	158.86	5.19	3.16	7
U10B-04343	Mqatsheni	B	88.27	37.30	36.35	0.95	2.55	137
U10C-04347	Mkhomazana	B	264.20	96.05	91.71	4.34	4.52	16
U10D-04222	Rooidraai	B	45.77	13.35	12.93	0.42	3.15	149
U10D-04298	Nzinga	B	282.59	82.42	80.42	2.00	2.43	14
U10D-04349	Mkomazi	B	860.43	388.72	381.30	7.42	1.91	141
U10D-04434	Mkomazi	B	1129.27	485.96	474.07	11.89	2.45	142
Mk_I_EWR1	Mkomazi	C	1816.16	683.16	660.72	22.44	3.29	21
U10F-04528	Mkomazi	B	2130.79	739.07	712.72	26.35	3.57	184
U10F-04560	Luhane	B/C	204.93	36.30	33.08	3.22	8.87	25
U10G-04388	Elands	B	94.96	18.87	16.63	2.24	11.88	159
U10G-04405		C	43.55	8.66	6.94	1.72	19.82	171
U10G-04473	Elands	B	337.81	67.14	59.47	7.67	11.42	31
U10H-04576	Tholeni	B	77.85	14.07	10.69	3.38	24.02	192
U10H-04638	Mkomazi	B	2529.21	817.21	782.69	34.52	4.22	185
U10H-04666	Ngudwini	B	112.63	20.35	13.15	7.20	35.39	36
U10H-04675	Mkomazi	B	2619.86	833.59	794.30	39.29	4.71	193
U10H-04708	Ngudwini	B	261.23	47.21	35.64	11.57	24.51	204
U10H-04729	Mzalanyoni	B	127.17	22.98	19.63	3.35	14.58	203
Mk_I_EWR2	Mkomazi	B	2938.75	890.91	838.35	52.56	5.90	205
U10J-04713	Mkobeni	B	89.94	13.90	11.70	2.20	15.83	233
U10J-04721	Pateni	B	40.30	6.23	4.01	2.22	35.59	217
U10J-04799	Mkomazi	B	3327.79	951.03	881.04	69.99	7.36	224
U10J-04807	Mkomazi	B	3123.46	919.45	856.15	63.30	6.88	105
U10J-04820	Lufafa	B	168.85	26.09	21.53	4.56	17.46	218
U10J-04833	Mkomazi	B	3344.66	953.63	883.34	70.29	7.37	226
U10J-04837		A/B	2.50	0.39	0.32	0.07	16.89	225
U10K-04838	Mkomazi	B/C	3437.18	967.83	895.13	72.70	7.51	234
U10K-04842	Nhlavini	B	361.99	40.18	28.98	11.20	27.88	254
U10K-04899	Xobho	C/D	171.96	19.09	11.81	7.28	38.13	43
U10K-04946	Nhlavini	B/C	59.95	6.65	4.49	2.16	32.53	245
Mk_I_EWR3	Mkomazi	B	4322.66	1068.55	983.23	85.32	7.98	120

5.12 SOUTH COAST RIVERS (T40F, T40G, U80A, U80D, U80G, U80H, U80J, U80K AND U80L)

Nine of the coastal quaternaries in the southern part of the study area with similar properties (land use, small rivers originating within the quaternary) were grouped into the South Coast water resource zone. The catchments of the South Coast Rivers are shown in Figure 5.12. The storage *regulation in this water resource zone is low and the only dams in the area include a number of small farm dams in tributaries and a few instream dams. Land use activities in the water resources zones generally include cultivation (mostly sugarcane with some orchards) and some forestry plantations slightly inland. Rural settlements are usually located more inland with semi-urban and urban areas towards the coast. Return flows from a number of WWTW enter river systems affecting both the flow and quality of the relevant river systems.*

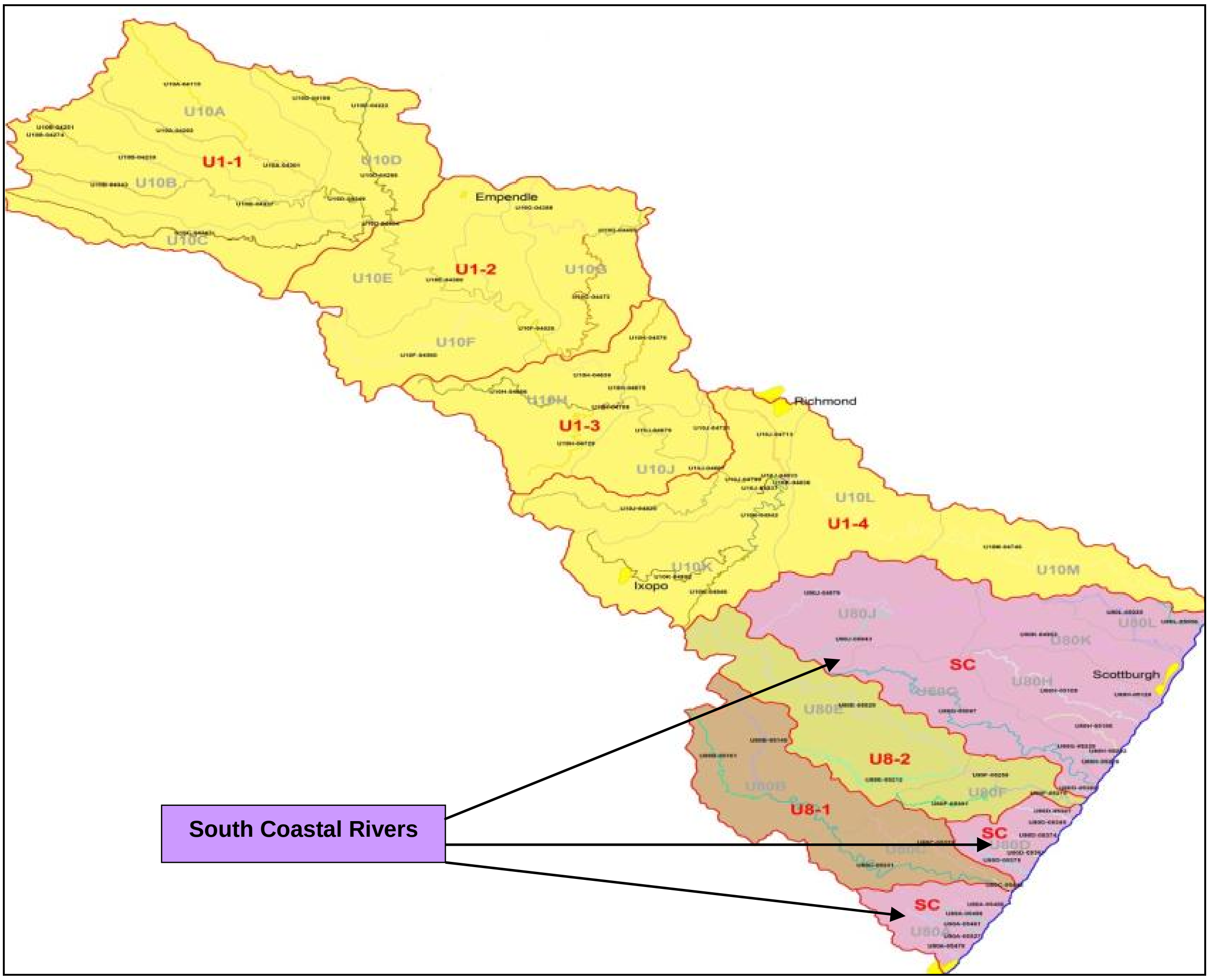

Figure 5.12 South Coast River Catchments

The hydrology resulting from the WR2005 Study was used for the assessment of these quaternary catchments. The WR2005 information is summarised in Table 5.43.

Table 5.43 South Coast Rivers: Summary of hydrology (1920 - 2004)

Quaternary catchment	Total catchment area (km^2)	Forestry area (km^2)	Alien vegetation area (km^2)	Irrigation area (km^2)	Farm Dams		NMAR (million m^3/a)
					Area (km^2)	Volume (million m^3)	
T40F	*335*	*2.80*	*7.60*	*0.00*	*0.41*	*0.21*	*87.46*
T40G	*300*	*0.00*	*12.40*	*0.00*	*1.50*	*0.83*	*74.96*
U80A	*158*	*25.00*	*14.19*	*0.60*	*0.13*	*0.34*	*29.44*
U80D	*120*	*0.00*	*4.41*	*3.00*	*0.75*	*0.27*	*23.08*
U80G	*261*	*43.80*	*2.80*	*2.00*	*0.02*	*0.08*	*49.94*
U80H	*243*	*30.16*	*2.19*	*0.00*	*0.05*	*0.34*	*42.11*

Quaternary catchment	Total catchment area (km²)	Forestry area (km²)	Alien vegetation area (km²)	Irrigation area (km²)	Farm Dams		NMAR (million m³/a)
					Area (km²)	Volume (million m³)	
U80J	371	36.32	3.70	0.00	0.02	0.13	36.17
U80K	184	0.78	1.74	0.00		0.06	26.54
U80L	107	0.00	1.48	0.00			16.79

No river DBNs were defined for quaternary catchments U80A and U80D. The remaining seven quaternary catchments included only 8 DBNs. Table 5.44 presents a breakdown of the portion of natural hydrology included at each of these DBNs, as well as a summary of the average natural flow per node.

Table 5.44 South Coast Rivers: Details of natural flow development at DBNs

Node Name	Rivers	Hydrology reference and factor contributing to natural flow at node	Total catchment area (km²)	NMAR (million m³/a)
T40F-05666	Mbizana	T40F:0.40	133.91	34.99
T40G-05616	Vungu	T40G:0.31	92.80	23.15
U80G-05097	Fafa	U80G:0.930	242.69	46.44
U80H-05109	Mzinto	U80H:0.544	132.15	22.90
U80J-04979	Mpambanyoni	U80J:0.349	129.46	12.62
U80J-05043	Ndonyane	U80J:0.180	66.86	6.52
U80K-04952	Mpambanyoni	U80J:1.0; U80K:0.821	522.07	57.96
U80L-05020	aMahlongwa	U80L:0.624	66.78	10.48

The WReMP (see Section 4.3) was used for the PD assessments of these estuaries. The catchment development information relating to the WReMP setups (as summarised in Table 5.45) was subsequently obtained and used for the PD assessments of the DBNs.

Table 5.45 South Coast Rivers: PD catchment development information

Node	Catchment area (km²)	Water use (million m³/a)				SFRA (million m³/a)		Return flows (million m³/a)	Dummy Dam	
		Rural	Urban	Industrial	Irrigation	Forestry	IAP		FSA (km²)	FSV (million m³)
T40F: Mbizana Estuary										
Estuary	138.52	0.50	0.00	0.00	0.00	0.00	0.273	0.00	-	-
T40G:Vungu Estuary										
Dummy Dam	11.98	0.00	0.00	0.00	0.00	0.00	0.009	0.00	0.25	0.79
Estuary	98.88	0.00	0.00	0.00	0.00	0.00	0.075	1.00	-	-
Total	**110.86**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.084**	**1.00**	**0.25**	**0.79**
U80G: Fafa Estuary										
Dummy Dam	13.06	0.00	0.00	0.00	0.000	0.316	0.034	0.00	0.03	0.08
Estuary	240.11	0.20	0.00	0.00	1.611	5.560	0.587	0.00	-	-
Total	**253.17**	**0.20**	**0.00**	**0.00**	**1.611**	**5.876**	**0.621**	**0.00**	**0.03**	**0.08**
U80H: Mzinto Estuary										
Dummy Dam	36.49	0.10	0.00	0.00	0.00	0.186	0.063	0.00	0.59	2.61
Node 1	24.32	0.00	2.50	0.00	0.00	0.000	0.042	0.00	-	-
Estuary	72.97	0.30	0.00	0.00	0.00	0.000	0.126	0.00	-	-
Total	**133.78**	**0.40**	**2.50**	**0.00**	**0.00**	**0.186**	**0.231**	**0.00**	**0.03**	**0.08**
U80J and U80K: Mpambanyoni Estuary										

Node	Catchment area (km^2)	Water use (million m^3/a)				SFRA (million m^3/a)		Return flows (million m^3/a)	Dummy Dam	
		Rural	Urban	Industrial	Irrigation	Forestry	IAP		FSA (km^2)	FSV (million m^3)
Dummy Dam	*18.57*	*0.00*	*0.00*	*0.00*	*0.00*	*0.126*	*0.066*	*0.00*	*0.22*	*0.33*
Node 1	*352.86*	*0.40*	*0.00*	*0.00*	*0.00*	*2.407*	*1.254*	*0.00*	-	-
Estuary	*165.19*	*0.40*	*0.00*	*0.00*	*0.00*	*0.111*	*0.135*	*0.00*	-	-
Total	**536.62**	**0.80**	**0.00**	**0.00**	**0.00**	**2.645**	**1.454**	**0.00**	**0.22**	**0.33**
U80L: aMahlongwa Estuary										
Dummy Dam	*10.74*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.000*	*0.00*	*0.08*	*0.15*
Estuary	*76.81*	*0.50*	*0.00*	*0.00*	*0.00*	*0.00*	*0.056*	*0.30*	-	-
Total	**87.55**	**0.50**	**0.00**	**0.00**	**0.00**	**0.00**	**0.056**	**0.30**	**0.08**	**0.15**

As shown in Table 5.45 the Mbizana catchment (T40F) only includes rural water use and flow reduction due to IAPs. The PD flow at the Mbizana DBN was, therefore, determined by means of a water balance calculation. The WRSM2000 was configured for the remaining South Coast catchments to simulate the PD flows at the DBNs and the WReMP catchment development information presented in Table 5.45 was used in the assessments. The methodology described in Section 4.3 was applied to determine landuse and catchment development information relative to each of the DBNs. The simulated PD results are presented in Table 5.46.

Table 5.46 South Coast Rivers: Summary of natural and PD flows at DBNs

Node name	Rivers	REC	Total catchment area (km^2)	NMAR (million m^3/a)	PD MAR (million m^3/a)	Difference between NMAR and PD MAR	
						(million m^3/a)	(%)
T40F-05666	*Mbizana*	*B*	*133.91*	*34.99*	*34.26*	*0.73*	*2.09*
T40G-05616	*Vungu*	*B*	*92.80*	*23.15*	*23.13*	*0.02*	*0.10*
U80G-05097	*Fafa*	*B*	*242.69*	*46.44*	*38.58*	*7.86*	*16.92*
U80H-05109	*Mzinto*	*C*	*132.15*	*22.90*	*19.89*	*3.01*	*13.15*
U80J-04979	*Mpambanyoni*	*B*	*129.46*	*12.62*	*10.21*	*2.41*	*19.11*
U80J-05043	*Ndonyane*	*B*	*66.86*	*6.52*	*5.67*	*0.85*	*13.02*
U80K-04952	*Mpambanyoni*	*B*	*522.07*	*57.96*	*53.11*	*4.85*	*8.37*
U80L-05020	*aMahlongwa*	*B*	*66.78*	*10.48*	*10.06*	*0.42*	*3.99*

5.13 MZUMBE (U80B AND U80C)

The Mzumbe River catchment comprises of quaternary catchments U80B and U80C. The Mzumbe catchment is shown in Figure 5.13.

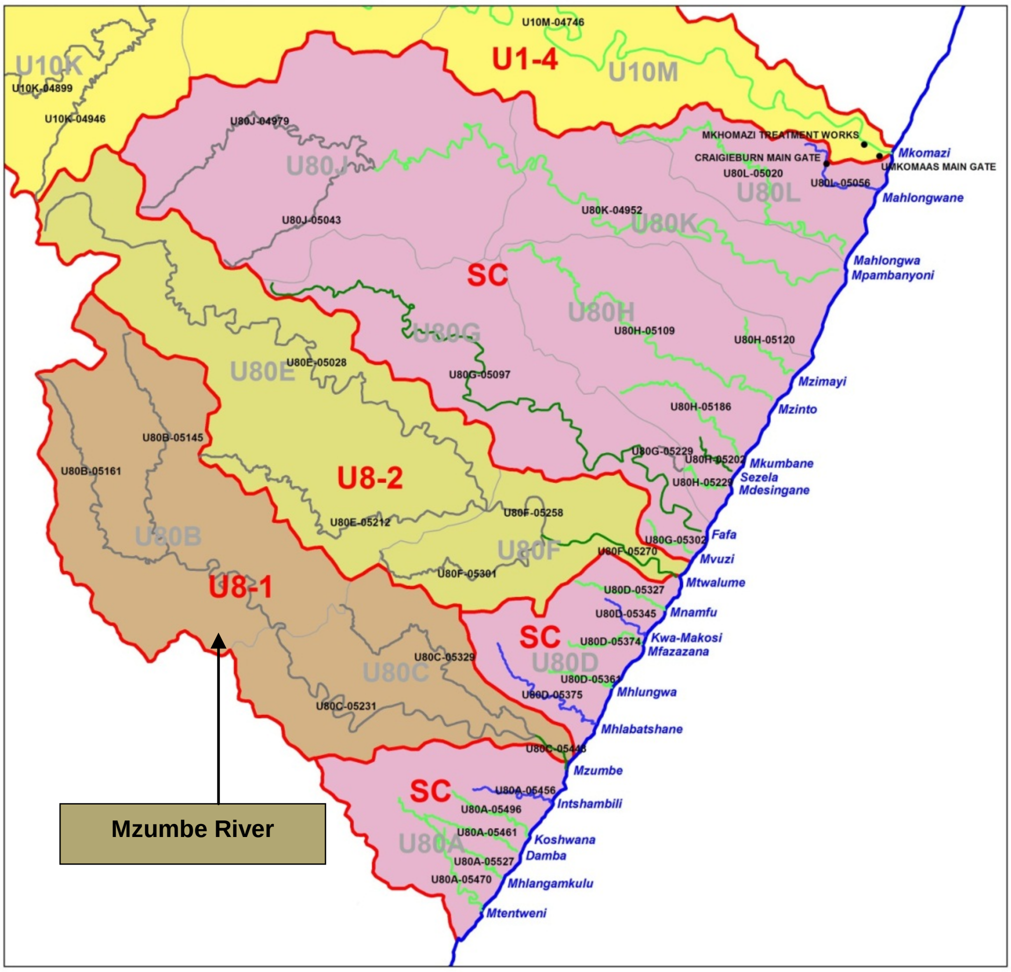

Figure 5.13 Mzumbe River Catchment

Four DBNs were defined within the catchment. The storage regulation in the catchment is low with no significant dams present. Rural villages are scattered throughout the catchment. There is some forestry and cultivation located in the upper reach of the Mzumbe River.

The hydrology resulting from the WR2005 Study was used for the assessment of the catchment. The WR2005 information is summarised in Table 5.47.

Table 5.47 Mzumbe (U80B and U80C): Summary of hydrology (1920 - 2004)

Quaternary catchment	Total catchment area (km^2)	Forestry area (km^2)	Alien vegetation area (km^2)	Irrigation area (km^2)	Farm Dams		NMAR (million m^3/a)
					Area (km^2)	Volume (million m^3)	
U80B	*339*	*0.00*	*0.00*	*0.00*	*0.14*	*0.48*	*28.25*
U80C	*202*	*0.00*	*0.00*	*0.00*	*0.08*	*0.00*	*30.28*
Total	**541**	**0.00**	**0.00**	**0.00**	**0.22**	**0.48**	**58.53**

Table 5.48 presents a breakdown of the portion of natural hydrology included at each of these DBNs, as well as a summary of the average natural flow per node.

Table 5.48 Mzumbe (U80B and U80C): Details of natural flow development at DBNs

Node Name	Rivers	Hydrology reference and factor contributing to natural flow at node	Total catchment area (km^2)	NMAR (million m^3/a)
U80B-05145	*Mzumbe*	*U80B:0.278*	*94.24*	*7.85*
U80B-05161	*Mhlabatshane*	*U80B:0.311*	*105.33*	*8.78*
U80C-05231	*Mzumbe*	*U80B:1.0; U80C:0.648*	*469.81*	*47.86*
U80C-05329	*Kwa-Malukaka*	*U80C:0.311*	*62.72*	*9.40*

The WReMP (see Section 4.3) was used for the PD assessment of the estuary. The catchment development information relating to the WReMP setups (as summarised in Table 5.49) was subsequently obtained and used for the PD assessments of the DBNs.

Table 5.49 Mzumbe (U80B and U80C): PD catchment development information

Node	Catchment area (km^2)	Water use (million m^3/a)				SFRA (million m^3/a)		Return flows (million m^3/a)	Dummy Dam	
		Rural	Urban	Industrial	Irrigation	Forestry	IAP		FSA (km^2)	FSV (million m^3)
Dummy Dam	*16.95*	*0.00*	*0.00*	*0.00*	*0.00*	*0.062*	*0.032*	*0.000*	*0.22*	*0.69*
Node2	*321.99*	*0.10*	*1.93*	*0.00*	*0.00*	*1.193*	*0.609*	*0.000*	*-*	*-*
Node3	*10.11*	*0.00*				*0.016*	*0.011*			
Node4	*192.13*	*0.10*	*0.00*	*0.00*	*0.00*	*0.321*	*0.215*	*0.965*	*-*	*-*
Total	**541.18**	**0.20**	**1.93**	**0.00**	**0.00**	**1.592**	**0.876**	**0.965**	**0.22**	**0.69**

The WRSM2000 was configured to simulate the PD flows at the DBNs and the WReMP catchment development information presented in Table 5.49 was used in the assessment. The methodology described in Section 4.3 was applied to determine landuse and catchment development information relative to each of the DBNs. The simulated PD results are presented in Table 5.50.

Table 5.50 Mzumbe (U80B and U80C): Summary of natural and PD flows at DBNs

Node name	Rivers	REC	Total catchment area (km^2)	NMAR (million m^3/a)	PD MAR (million m^3/a)	Difference between NMAR and PD MAR	
						(million m^3/a)	(%)
U80B-05145	*Mzumbe*	*B*	*94.24*	*7.85*	*6.42*	*1.43*	*18.25*
U80B-05161	*Mhlabatshane*	*B*	*105.33*	*8.78*	*8.08*	*0.70*	*7.94*
U80C-05231	*Mzumbe*	*B*	*469.81*	*47.86*	*44.68*	*3.18*	*6.64*
U80C-05329	*Kwa-Malukaka*	*B*	*62.72*	*9.40*	*9.10*	*0.30*	*3.21*

5.14 MTWALUME (U80E AND U80F)

The Mtwalume River catchment (shown in Figure 5.14) comprises of quaternary catchments U80E and U80F. The Mtwalume River has two main tributaries namely the Quha and uMngeni rivers. Four DBNs were defined within the catchment.

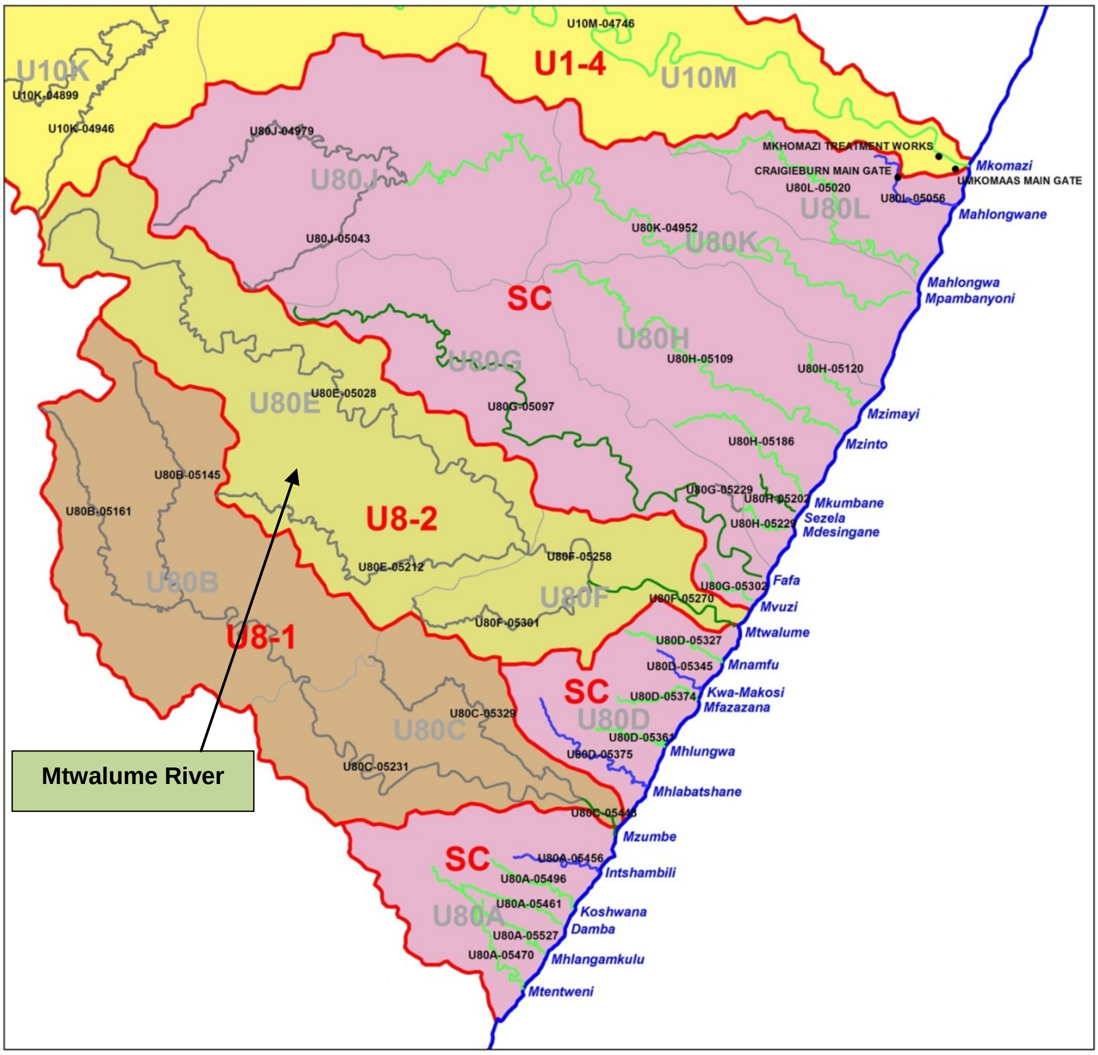

Figure 5.14 Mtwalume River Catchment

The storage regulation in this catchment is low and the only dams in the area include a number of small farm dams in tributaries and a few instream dams. Land use activities in the water resources zones generally include cultivation and some forestry in the middle and upper reaches of the river. Rural villages are also scattered throughout the catchment with semi-urban and urban areas located along the coast. The hydrology resulting from the WR2005 Study was used for the assessment of the Mtwalume catchment. The WR2005 information is summarised in Table 5.51.

Table 5.51 Mtwalume (U80E and U80F): Summary of hydrology (1920 - 2004)

Quaternary catchment	Total catchment area (km^2)	Forestry area (km^2)	Alien vegetation area (km^2)	Irrigation area (km^2)	Farm Dams		NMAR (million m^3/a)
					Area (km^2)	Volume (million m^3)	
U80E	*415*	*79.60*	*3.70*	*5.00*	*-*	*1.55*	*39.05*
U80F	*137*	*1.60*	*1.60*	*2.00*	*0.03*	*-*	*18.73*
Total	**552**	**81.20**	**5.30**	**7.00**	**0.03**	**1.55**	**57.78**

Table 5.52 presents a breakdown of the portion of natural hydrology included at each of the DBNs, as well as a summary of the average natural flow per node.

Table 5.52 Mtwalume (U80E and U80F): Details of natural flow development at DBNs

Node Name	Rivers	Hydrology reference and factor contributing to natural flow at node	Total catchment area (km^2)	NMAR (million m^3/a)
U80E-05028	*Mtwalume*	*U80E:0.713*	*295.71*	*27.83*
U80E-05212	*Quha*	*U80E:0.286*	*118.88*	*11.19*
U80F-05258	*Mtwalume*	*U80E:1.0; U80F:0.189*	*440.88*	*42.59*
U80F-05301	*uuMngeni*	*U80F:0.387*	*52.96*	*7.24*

The WReMP (see Section 4.3) was used for the PD assessment of the estuary. The catchment development information relating to the WReMP setup (as summarised in Table 5.53) was subsequently obtained and used for the PD assessments of the DBNs.

Table 5.53 Mtwalume (U80E and U80F): PD catchment development information

Node	Catchment area (km^2)	Water use (million m^3/a)				SFRA (million m^3/a)		Return flows (million m^3/a)	Dummy Dam	
		Rural	Urban	Industrial	Irrigation	Forestry	IAP		FSA (km^2)	FSV (million m^3)
Dummy Dam	*41.50*	*0.00*	*0.00*	*0.00*	*0.00*	*0.413*	*0.154*	*0.00*	*0.88*	*2.07*
Node2	*373.52*	*0.20*	*2.45*	*0.00*	*4.718*	*3.723*	*1.389*	*0.00*	*-*	*-*
Node3	*6.87*	*0.00*	*0.00*			*0.005*	*0.001*	*0.00*	*-*	*-*
Node4	*140.00*	*0.30*	*0.00*	*0.00*	*1.724*	*0.098*	*0.031*	*1.641*	*-*	*-*
Total	**561.89**	**0.50**	**2.45**	**0.00**	**6.442**	**4.239**	**1.575**	**1.641**	**0.88**	**2.07**

The WRSM2000 was configured to simulate the PD flows at the DBNs and the WReMP catchment development information presented in Table 5.53 was used in the assessment. The methodology described in Section 4.3 was applied to determine landuse and catchment development information relative to each of the DBNs. The simulated PD results are presented in Table 5.54.

Table 5.54 Mtwalume (U80E and U80F): Summary of natural and PD flows at DBNs

Node name	Rivers	REC	Total catchment area (km^2)	NMAR (million m^3/a)	PD MAR (million m^3/a)	Difference between NMAR and PD MAR	
						(million m^3/a)	(%)
U80E-05028	*Mtwalume*	*C*	*295.71*	*27.83*	*18.10*	*9.73*	*34.95*
U80E-05212	*Quha*	*B*	*118.88*	*11.19*	*10.64*	*0.55*	*4.88*
U80F-05258	*Mtwalume*	*B*	*440.88*	*42.59*	*32.21*	*10.38*	*24.37*
U80F-05301	*uuMngeni*	*B*	*52.96*	*7.24*	*7.14*	*0.10*	*1.39*

5.15 UMZIMKULU (T51 AND T52)

The Umzimkulu River catchment comprises of tertiary catchments T51 and T52. The main tributaries of the Umzimkulu River system are the Mzimkhulwane, Pholela, Bisi and Ngwangwane rivers. Agriculture and afforestation are the biggest water users (31% and 41% of the total water use respectively). Water use by alien vegetation represents 14% of the water use whilst rural and urban demands amount to 10% of the total water use. The Umzimkulu River catchment is shown in Figure 5.15.

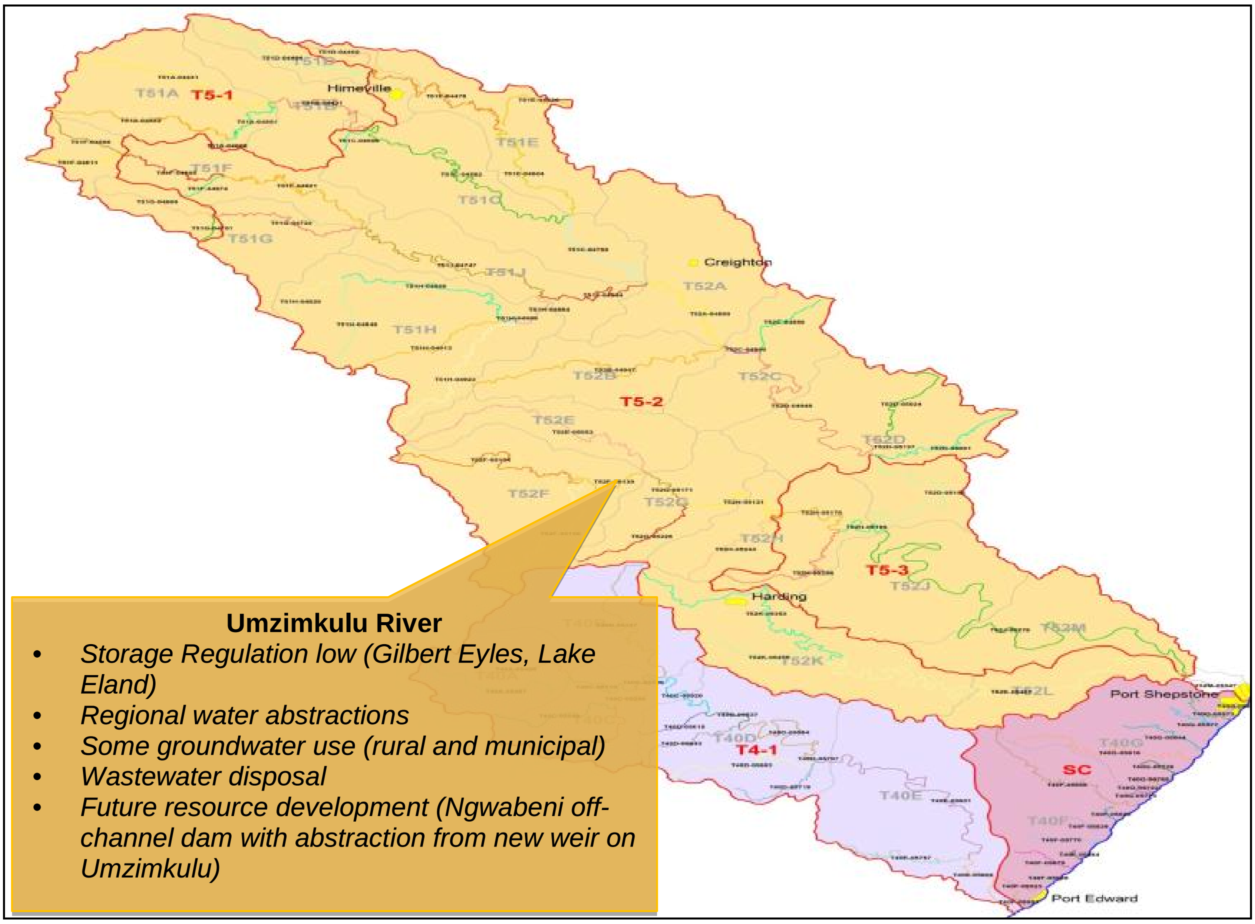

Figure 5.15 Umzimkulu River Catchment

The most recent study undertaken for this catchment is the Umzimkulu River Catchment Water Resources Study (DWA, 2011). The hydrology derived as part of the Umzimkulu Study covers the period 1920 to 2007 (88 years) and was used for the assessments undertaken for this study. Information on the hydrology and the reduction in runoff due to afforestation, as well as IAPs, resulting from the Umzimkulu Study (DWA, 2011) is summarised in Table 5.55.

Table 5.55 Umzimkulu (T51 and T52): Summary of hydrology (1920 - 2007)

Quaternary catchment	Total catchment area (km^2)	IAPs (million m^3/a)	Afforestation (million m^3/a)	NMAR (million m^3/a)
T51A	*328*	*1.05*	*1.40*	*157.04*
T51B	*210*	*0.63*	*3.91*	*87.35*
T51C	*462*	*3.19*	*12.33*	*116.97*
T51D	*142*	*0.59*	*2.75*	*65.93*
T51E	*256*	*1.64*	*5.56*	*59.93*
T51F	*307*	*2.01*	*3.96*	*116.67*
T51G	*256*	*1.68*	*3.68*	*91.44*
T51H	*520*	*3.36*	*5.20*	*123.43*
T51J	*265*	*1.93*	*2.50*	*51.69*
T52A	*382*	*3.90*	*12.14*	*93.94*
T52B	*256*	*2.28*	*2.91*	*50.24*
T52C	*261*	*2.46*	*10.27*	*48.09*
T52D	*531*	*1.92*	*3.19*	*28.88*
T52E	*233*	*1.66*	*10.08*	*56.49*
T52F	*418*	*2.75*	*20.69*	*96.55*

Quaternary catchment	Total catchment area (km^2)	IAPs (million m^3/a)	Afforestation (million m^3/a)	NMAR (million m^3/a)
T52G	221	3.72	4.21	64.98
T52H	344	1.20	0.65	27.63
T52J	368	1.23	0.97	34.54
T52K	426	1.15	6.42	33.27
T52L	179	0.30	0.14	14.94
T52M	313	1.07	0.00	32.51
Total	**6678**	**39.72**	**112.96**	**1425.51**

A total of 55 DBNs were defined within the Umzimkulu River catchment of which 5 represented key biophysical nodes (EWR sites). Table 5.56 presents a breakdown of the portion of natural hydrology included at each of the DBNs, as well as a summary of the average natural flow per node.

Table 5.56 Umzimkulu (T51 and T52): Details of natural flow development at DBNs

Node Name	Rivers	Hydrology reference and factor contributing to natural flow at node	Total catchment area (km^2)	NMAR (million m^3/a)
T51A-04431	Umzimkulu	T51A:0.617	202.32	96.87
T51A-04522	Mzimude	T51A:0.275	90.19	43.18
T51A-04608		T51A:0.010	3.29	1.57
T51A-04551	Mzimude	T51A:0.374	122.77	58.78
T51B-04421	Umzimkulu	T51A:1.0; T51B:1.0; T51C:0.015	545.13	246.19
T51C-04606		T51C:0.032	14.89	3.77
MzEWR2i (T51C-04582)	Umzimkulu	T51A:1.0; T51B:1.0; T51C:0.136	600.68	260.26
T51C-04760	Umzimkulu	T51A:1.0; T51B:1.0; T51C:1.0; T51D:1.0; T51E:1.0	1398.00	487.22
T51D-04404	Pholela	T51D:0.591	83.97	38.99
T51D-04460	Pholelana	T51D:0.046	6.52	3.03
T51E-04536		T51E:0.144	36.96	8.65
T51E-04478	Pholela	T51D:1.0; T51E:0.361	234.47	87.58
T51E-04604	Pholela	T51D:1.0; T51E:1.0	398.00	125.86
T51F-04566	Boesmans	T51F:0.0.117	35.96	13.67
T51F-04611	Ngwangwane	T51F:0.144	44.27	16.82
T51F-04674		T51F:0.024	7.48	2.84
T51F-04605	Ngwangwane	T51F:0..438	134.32	51.04
T51F-04621	Ngwangwane	T51F:0..991	304.27	115.63
T51G-04669	Ndawana	T51G:0. 274	70.09	25.04
T51G-04751		T51G:0. 033	8.38	2.99
T51G-04722	Ndawana	T51G:0.996	254.92	91.05
T51H-04828	Gungununu	T51H:0.075	38.92	9.24
T51H-04846	Lubhukwini	T51H:0.149	77.42	18.38
T51H-04913	Nonginqa	T51H:0.135	70.38	16.70
T51H-04923	Malenge	T51H:0.220	114.43	27.16
T51H-04808	Gungununu	T51H:0.550	285.75	67.83
T51H-04884	Gungununu	T51H:0.997	518.68	123.12
T51H-04908	Gungununu	T51H:0.691	359.46	85.32
T51J-04747	Ngwangwane	T51F:1.0; T51G:1.0; T51J:0.698	748.04	244.20

Node Name	Rivers	Hydrology reference and factor contributing to natural flow at node	Total catchment area (km^2)	NMAR (million m^3/a)
T51J-04844	Ngwangwane	T51F:1.0; T51G:1.0; T51H:1.0; T51J:0.996	1346.85	383.01
MzEWR3i (T52A-04690)	Umzimkulu	T51A:1.0; T51B:1.0; T51C:1.0; T51D:1.0; T51E:1.0; T51F:1.0; T51G:1.0; T51H:1.0; T51J:1.0; T52A:0.011	2750.39	871.53
T52B-04947	Cabane	T52B:0.995	254.73	49.99
T52C-04880		T52C:0.263	68.67	12.65
T52C-04960	Umzimkulu	T51A:1.0; T51B:1.0; T51C:1.0; T51D:1.0; T51E:1.0; T51F:1.0; T51G:1.0; T51H:1.0; T51J:1.0; T52A:1.0; T52B:1.0; T52C:0.048	3396.47	1016.93
T52D-05024	Ncalu	T52D:0.154	81.74	4.45
T52D-05061	Mgodi	T52D:0.187	99.53	5.41
T52D-04948	Umzimkulu	T51A:1.0; T51B:1.0; T51C:1.0; T51D:1.0; T51E:1.0; T51F:1.0; T51G:1.0; T51H:1.0; T51J:1.0; T52A:1.0; T52B:1.0; T52C:1.0; T52D:0.400	3857.55	1074.28
T52D-05137	Umzimkulu	T51A:1.0; T51B:1.0; T51C:1.0; T51D:1.0; T51E:1.0; T51F:1.0; T51G:1.0; T51H:1.0; T51J:1.0; T52A:1.0; T52B:1.0; T52C:1.0; T52D:0.568	3946.37	1079.11
MzEWR5i (T52D-05155)	Umzimkulu	T51A:1.0; T51B:1.0; T51C:1.0; T51D:1.0; T51E:1.0; T51F:1.0; T51G:1.0; T51H:1.0; T51J:1.0; T52A:1.0; T52B:1.0; T52C:1.0; T52D:0.762	4049.40	1084.71
T52E-05053	Upper Bisi	T52E:0.983	229.02	55.53
T52F-05104	Little Bisi	T52F:0.355	148.47	34.29
T52F-05190	Mbumba	T52F:0.490	204.78	47.30
T52F-05139	Little Bisi	T52F:0.995	415.98	96.08
T52G-05226	uMbumbane	T52G:0.296	65.32	19.21
T52G-05171	Bisi	T52E:1.0; T52F:1.0; T52G:0.279	712.66	171.17
T52H-05244	Mahobe	T52H:0.341	117.32	9.42
T52H-05295	Magogo	T52H:0.212	72.84	5.85
T52H-05121	Bisi	T52E:1.0; T52F:1.0; T52G:1.0; T52H:0.092	903.66	220.56
T52H-05178	Bisi	T52E:1.0; T52F:1.0; T52G:1.0; T52H:0.694	1110.90	237.21
T52H-05189	Bisi	T52E:1.0; T52F:1.0; T52G:1.0; T52H:0.998	1215.15	245.58
MzEWR6i (T52J-05467)	Umzimkulu	T51A:1.0; T51B:1.0; T51C:1.0; T51D:1.0; T51E:1.0; T51F:1.0; T51G:1.0; T51H:1.0; T51J:1.0; T52A:1.0; T52B:1.0; T52C:1.0; T52D:1.0; T52E:1.0; T52F:1.0; T52G:1.0; T52H:1.0; T52J:1.0; T52M:0.370	5875.72	1383.81
T52K-05353	Mzimkhulwana	T52K:0.397	169.18	13.21
T52K-05475	Nkondwana	T52K:0.196	83.34	6.51
MzEWR17i	Mzimkhulwana	T52K:1.0; T52L:0.622	537.37	42.57
T52M-05547 (Estuary)	Umzimkulu	T51A:1.0; T51B:1.0; T51C:1.0; T51D:1.0; T51E:1.0; T51F:1.0; T51G:1.0; T51H:1.0; T51J:1.0; T52A:1.0; T52B:1.0; T52C:1.0; T52D:1.0; T52E:1.0; T52F:1.0; T52G:1.0; T52H:1.0; T52J:1.0; T52K:1.0; T52L:1.0; T52M:1.0	6678.00	1452.51

The irrigation water demand and return flow information included in the PD assessments of the selected DBNs is summarised in Table 5.57. The irrigation water demands and return flows were modelled as time series files and, as indicated in the table below, distinction was made between *irrigation supplied from farm dams and those supplied from run-of-river abstractions. It should be noted that there are no major effluent return flows in the catchment.*

Table 5.57 Umzimkulu (T51 and T52): PD catchment development information

Quaternary catchment	Dummy dam irrigation abstractions		Run-of-river irrigation abstractions		Irrigation return flows	
	File name	Demand (million m^3/a)	File name	Demand (million m^3/a)	File name	Return flow (million m^3/a)
T51A	T51A-fdirr.dem	0.07	T51A-chirr.dem	1.63	T51A-irr.ret	0.42
T51B	T51B-fdirr.dem	4.18	T51b-chirr.dem	6.12	T51B-irr.ret	1.54
T51C	T51C-fdirr.dem	11.26	T51c-chirr.dem	1.90	T51c-irr.ret	3.04
T51D	T51d-fdirr.dem	3.61	-	-	T51d-irr.ret	0.73
T51E	T51e-fdirr.dem	5.37	T51e-chirr.dem	3.63	T51e-irr.ret	1.97
T51F	T51f-fdirr.dem	5.10	T51f-chirr.dem	3.54	T51f-irr.ret	1.58
T51G	T51g-fdirr.dem	1.02	T51g-chirr.dem	1.77	T51g-irr.ret	0.84
T51H	T51h-fdirr.dem	0.45	-	-	T51h-irr.ret	0.13
T51J	-	-	T51j-chirr.dem	0.06	T51j-irr.ret	0.00
T52A	T52a-fdirr.dem	4.70	T52a-chirr.dem	10.75	T52a-irr.ret	1.99
T52B	-	-	-	-	-	-
T52C	T52c-fdirr.dem	0.15	T52c-chirr.dem	3.14	T52c-irr.ret	0.66
T52D	T52d-fdirr.dem	2.52	T52d-chirr.dem	0.57	T52d-irr.ret	0.87
T52E	T52e-fdirr.dem	0.07	-	-	T52e-fd.ret	0.00
T52F	T52f-fdirr.dem	0.15	-	-	T52f-fd.ret	0.00
T52G			T52g-chirr.dem	0.00	T52g-ch.ret	0.00
T52H	T52h-fdirr.dem	0.00	-	-	T52h-fd.ret	0.00
T52J	T52j-fdirr.dem	0.00	-	-	T52j-fd.ret	0.00
T52K	T52k-fdirr.dem	0.21	T52k-chirr.dem	0.73	T52k-irr.ret	0.39
T52L	T52l-fdirr.dem	0.78	-	-	T52l-fd.ret	0.13
Total	**-**	**39.64**	**-**	**33.84**	**-**	**14.29**

There are no major storage structures in the Umzimkulu catchment. The Gilbert Eyles Dam situated on the Mzimkhulwane River in quaternary catchment T54L was decommissioned due to siltation problems. The numerous farm dams scattered throughout the catchment are used for supplying irrigation and have a combined storage of about 54 million m^3. Allowance was also made for the impact of wetlands that occur throughout the catchment. Wetland losses and wetland return flows included in the Umzimkulu Study water resource analyses amount to 101.7 million m^3/a and 75 million m^3/a respectively. Future resource development includes the Ncwabeni off-channel dam with an abstraction from a new weir on the Umzimkulu River.

The WRYM configuration compiled as part of the Umzimkulu Study was adjusted to be representative of the current water supply system (i.e. information on proposed future schemes were excluded). The setup was further refined to include modelling of the selected DBNs. The methodology described in Section 4.3 was applied to determine landuse and catchment development information relative to each of the DBNs. The simulated PD results are presented in Table 5.58.

Table 5.58 Umzimkulu (T51 and T52): Summary of natural and PD flows at DBNs

Node name	Rivers	REC	Total catchment area (km^2)	NMAR (million m^3/a)	PD MAR (million m^3/a)	Difference between NMAR and PD MAR		WRYM Channel No.
						(million m^3/a)	(%)	
T51A-04522	Mzimude	B	90.19	43.18	40.76	2.42	5.60	601
T51A-04608		B	3.29	1.57	1.55	0.03	1.79	600
T51A-04551	Mzimude	B	122.77	58.78	54.27	4.51	7.67	612
T51B-04421	Umzimkulu	B	545.13	246.19	224.32	21.88	8.89	619
T51C-04606		C	14.89	3.77	2.45	1.32	35.02	623
MzEWR2i	Umzimkulu	C	600.68	260.26	233.59	26.67	10.25	639
T51C-04760	Umzimkulu	C	1398.00	487.22	416.59	70.63	14.50	89
T51D-04404	Pholela	B	83.97	38.99	35.80	3.18	8.17	647
T51D-04460	Pholelana	D	6.52	3.03	2.88	0.15	4.89	648
T51E-04536		C	36.96	8.65	6.85	1.80	20.86	662
T51E-04478	Pholela	C	234.47	87.58	74.28	13.30	15.19	649
T51E-04604	Pholela	B/C	398.00	125.86	105.78	20.08	15.95	436
T51F-04674		C	7.48	2.84	1.69	1.15	40.43	679
T51F-04605	Ngwangwane	B	134.32	51.04	48.63	2.41	4.73	694
T51F-04621	Ngwangwane	B	304.27	115.63	100.76	14.87	12.86	111
T51G-04669	Ndawana	B	70.09	25.04	23.84	1.20	4.78	699
T51G-04751		B	8.38	2.99	2.46	0.53	17.73	702
T51G-04722	Ndawana	C	254.92	91.05	81.32	9.73	10.69	130
T51H-04913	Nonginqa	B/C	70.38	16.70	13.33	3.37	20.19	715
T51H-04923	Malenge	B	114.43	27.16	24.27	2.89	10.65	536
T51H-04808	Gungununu	B	285.75	67.83	63.08	4.74	6.99	709
T51H-04884	Gungununu	B/C	518.68	123.12	111.60	11.52	9.36	141
T51H-04908	Gungununu	B/C	359.46	85.32	77.14	8.19	9.60	716
T51J-04747	Ngwangwane	C	748.04	244.20	213.97	30.24	12.38	534
T51J-04844	Ngwangwane	C	1346.85	383.01	338.78	44.23	11.55	147
MzEWR3i	Umzimkulu	B	2750.39	871.53	756.15	115.38	13.24	718
T52B-04947	Cabane	B	254.73	49.99	43.33	6.66	13.32	171
T52C-04880		C	68.67	12.65	6.97	5.68	44.89	721
T52C-04960	Umzimkulu	B	3396.47	1016.93	862.97	153.95	15.14	720
T52D-05024	Ncalu	B	81.74	4.45	2.66	1.79	40.16	724
T52D-05061	Mgodi	B	99.53	5.41	3.39	2.02	37.40	726
T52D-04948	Umzimkulu	B	3857.55	1074.28	898.48	175.80	16.36	723
T52D-05137	Umzimkulu	B	3946.37	1079.11	901.44	177.67	16.46	725
MzEWR5i	Umzimkulu	B	4049.40	1084.71	905.01	179.71	16.57	727
T52E-05053	Upper Bisi	B	229.02	55.53	43.71	11.81	21.27	219
T52F-05104	Little Bisi	C	148.47	34.29	22.80	11.49	33.52	728
T52F-05190	Mbumba	B/C	204.78	47.30	35.24	12.06	25.49	732
T52F-05139	Little Bisi	B	415.98	96.08	71.82	24.26	25.25	228
T52G-05226	uMbumbane	B/C	65.32	19.21	16.92	2.28	11.88	742
T52G-05171	Bisi	B	712.66	171.17	131.38	39.79	23.24	738
T52H-05244	Mahobe	B/C	117.32	9.42	8.89	0.53	5.66	241
T52H-05295	Magogo	B	72.84	5.85	4.79	1.06	18.17	750
T52H-05121	Bisi	B/C	903.66	220.56	174.31	46.25	20.97	746
T52H-05178	Bisi	B	1110.90	237.21	189.51	47.70	20.11	747

Node name	Rivers	REC	Total catchment area (km²)	NMAR (million m³/a)	PD MAR (million m³/a)	Difference between NMAR and PD MAR		WRYM Channel No.
						(million m³/a)	(%)	
T52H-05189	*Bisi*	*B*	*1215.15*	*245.58*	*195.66*	*49.92*	*20.33*	*499*
MzEWR6i	*Umzimkulu*	*B*	*5875.72*	*1383.81*	*1149.26*	*234.54*	*16.95*	*546*
T52K-05353	*Mzimkhulwana*	*C*	*169.18*	*13.21*	*8.07*	*5.14*	*38.90*	*77*
T52K-05475	*Nkondwana*	*B/C*	*83.34*	*6.51*	*4.21*	*2.30*	*35.38*	*764*
T52M-05547 (Estuary)	*Umzimkulu*		*6678.00*	*1452.51*	*1182.37*	*270.14*	*18.60*	*305*

5.16 MTAMVUNA (T40A - T40E)

The Mtamvuna River catchment comprises of quaternary catchments T40A, T40B, T40C, T40D and T40E. The Mtamvuna River catchment is shown in Figure 5.16.

Figure 5.16 Mtamvuna River Catchment

Nineteen DBNs were defined within the catchment. The storage regulation in this catchment is low with no noticeable dams located in the area. The land use activities include extensive forestry in the upper reaches and some cultivation in the lower reaches. The catchment is predominantly rural with a large number of scattered rural and informal settlements supplied from regional water abstractions. The hydrology resulting from the WR2012 Study was used for the assessment of the Mtamvuna catchment. The WR2012 information is summarised in Table 5.60.

Table 5.59 Mtamvuna (T40A - T40E): Summary of hydrology (1920 - 2009)

Quaternary catchment	Total catchment area (km^2)	Forestry area (km^2)	Alien vegetation area (km^2)	Irrigation area (km^2)	Farm Dams		NMAR (million m^3/a)
					Area (km^2)	Volume (million m^3)	
T40A	*208*	*9.00*	*12.80*	*0.37*	-	-	*57.90*
T40B	*278*	*123.60*	*79.70*	*0.55*	-	-	*74.47*
T40C	*237*	*5.10*	*4.00*	*0.43*	-	-	*43.67*
T40D	*372*	*9.60*	*11.10*	*0.80*	*0.50*	*0.19*	*42.68*
T40E	*486*	*1.50*	*6.00*	*0.98*	*0.30*	*0.12*	*61.20*
Total	**1581**	**148.80**	**113.60**	**3.13**	**0.80**	**0.31**	**279.92**

Eighteen DBNs were defined within the Mtamvuna catchment one of which was selected for a rapid EWR assessment. Table 5.60 presents a breakdown of the portion of natural hydrology included at each of the DBNs, as well as a summary of the average natural flow per node.

Table 5.60 Mtamvuna (T40A - T40E): Details of natural flow development at DBNs

Node Name	Rivers	Hydrology reference and factor contributing to natural flow at node	Total catchment area (km^2)	NMAR (million m^3/a)
T40A-05450	*Mafadobo*	*T40A:0.4763*	*99.12*	*27.58*
T40A-05487	*Goxe*	*T40A:0.5183*	*107.85*	*30.01*
T40B-05337	*Weza*	*T40B:0.9989*	*277.33*	*74.47*
T40C-05510	*Mtamvuna*	*T40A:1.0; T40C:0.1627*	*246.64*	*65.00*
T40C-05520	*Mtamvuna*	*T40A:1.0; T40B:1.0; T40C:1.0; T40D:0.0836*	*753.77*	*179.61*
T40C-05530	*Mtamvuna*	*T40A:1.0; T40C:0.8685*	*413.91*	*95.83*
T40C-05566	*Ludeke*	*T40C:0.6576*	*155.84*	*28.72*
T40C-05589	*KuNtlamvukazi*	*T40C:0.2798*	*66.32*	*12.22*
T40C-05600	*Ludeke*	*T40C:0.3228*	*76.49*	*14.10*
T40D-05537	*Mtamvuna*	*T40A:1.0; T40B:1.0; T40C:1.0; T40D:0.2644*	*820.92*	*187.33*
T40D-05584	*Mtamvuna*	*T40A:1.0; T40B:1.0; T40C:1.0; T40D:0.6649*	*969.68*	*204.42*
T40D-05615	*Tungwana*	*T40D:0.0523*	*19.42*	*2.23*
T40D-05643	*Gwala*	*T40D:0.1318*	*48.95*	*5.62*
T40D-05683	*Ntelekweni*	*T40D:0.2089*	*77.59*	*8.91*
T40D-05707	*Mtamvuna*	*T40A:1.0; T40B:1.0; T40C:1.0; T40D:0.8833*	*1050.81*	*213.74*
T40D-05719	*Londobezi*	*T40D:0.1082*	*40.19*	*4.62*
Mt_R_EWR1 (T40E-05601)	*Mtamvuna*	*T40A:1.0; T40B:1.0; T40C:1.0; T40D:1.0; T40E:0.2928*	*1236.15*	*236.64*
T40E-05767	*Hlolweni*	*T40E:0.3685*	*178.69*	*22.55*
T40E-05869 (Estuary)	*Mtamvuna*	*T40A:1.0; T40B:1.0; T40C:1.0; T40D:1.0; T40E:1.0*	*1581*	*279.92*

The catchment development information relating to the quaternary catchments of the Mtamvuna as obtained from the WR2012 Study's WRSM2000 configuration is summarised in Table 5.61 and was used for the PD assessments of the DBNs.

Table 5.61 Mtamvuna (T40A - T40E): PD catchment development information

Quaternary catchment	SFRA: Forestry and IAP (million m^3/a)	Irrigation water use (million m^3/a)	Urban water use (million m^3/a)	Total water use (million m^3/a)	Irrigation return flows (million m^3/a)
T40A	*3.05*	*0.22*	*0.00*	*3.25*	*0.02*
T40B	*21.91*	*0.33*	*3.50*	*25.71*	*0.03*
T40C	*1.03*	*0.31*	*0.00*	*1.32*	*0.02*
T40D	*0.88*	*0.59*	*0.00*	*1.43*	*0.04*
T40E	*0.99*	*0.75*	*5.57*	*7.26*	*0.05*
Total	**27.86**	**2.20**	**9.07**	**38.97**	**0.16**

The WRSM2000 was configured to simulate the PD flows at the DBNs. The methodology described in Section 4.3 was applied to determine landuse and catchment development information relative to each of the DBNs. The simulated PD results are presented in Table 5.62.

Table 5.62 Mtamvuna (T40A - T40E): Summary of natural and PD flows at DBNs

Node name	Rivers	REC	Total catchment area (km^2)	NMAR (million m^3/a)	PD MAR (million m^3/a)	Difference between NMAR and PD MAR	
						(million m^3/a)	(%)
T40A-05450	*Mafadobo*	*B*	*99.12*	*27.58*	*26.23*	*1.35*	*4.89*
T40A-05487	*Goxe*	*B*	*107.85*	*30.01*	*28.42*	*1.59*	*5.29*
T40B-05337	*Weza*	*C*	*277.33*	*74.47*	*52.56*	*21.91*	*29.42*
T40C-05510	*Mtamvuna*	*B*	*246.64*	*65.00*	*61.25*	*3.75*	*5.78*
T40C-05520	*Mtamvuna*	*B/C*	*753.77*	*179.61*	*149.10*	*30.51*	*16.99*
T40C-05530	*Mtamvuna*	*B*	*413.91*	*95.83*	*91.46*	*4.37*	*4.56*
T40C-05566	*Ludeke*	*B*	*155.84*	*28.72*	*28.14*	*0.58*	*2.02*
T40C-05589	*KuNtlamvukazi*	*B*	*66.32*	*12.22*	*11.94*	*0.28*	*2.30*
T40C-05600	*Ludeke*	*B*	*76.49*	*14.10*	*13.64*	*0.46*	*3.23*
T40D-05537	*Mtamvuna*	*B*	*820.92*	*187.33*	*156.57*	*30.76*	*16.42*
T40D-05584	*Mtamvuna*	*B*	*969.68*	*204.42*	*173.15*	*31.27*	*15.30*
T40D-05615	*Tungwana*	*B*	*19.42*	*2.23*	*2.04*	*0.19*	*8.57*
T40D-05643	*Gwala*	*B*	*48.95*	*5.62*	*5.29*	*0.33*	*5.94*
T40D-05683	*Ntelekweni*	*B/C*	*77.59*	*8.91*	*8.55*	*0.36*	*4.09*
T40D-05707	*Mtamvuna*	*C*	*1050.81*	*213.74*	*182.12*	*31.62*	*14.79*
T40D-05719	*Londobezi*	*B*	*40.19*	*4.62*	*4.48*	*0.14*	*2.99*
Mt_R_EWR1 (T40E-05601)	*Mtamvuna*	*B*	*1236.15*	*236.64*	*203.74*	*32.90*	*13.90*
T40E-05767	*Hlolweni*	*B*	*178.69*	*22.55*	*22.25*	*0.30*	*1.34*
T40E-05869 (Estuary)	*Mtamvuna*		*1581*	*279.92*	*240.97*	*38.95*	*13.91*

6 EWR ASSESSMENTS: SELECTED EWR SITES

6.1 INTRODUCTION

Eleven EWR sites (key biophysical nodes) were selected for EWR determination. Rapid EWR assessments were undertaken for four of these EWR sites whilst seven of these sites were assessed using a revised and extended Intermediate Ecological Reserve Methodology.

The four Rapid EWR sites for which hydrological assessments were undertaken, are listed in Table 6.1. As indicated in Table 6.1 one rapid site was selected in each of the Mtamvuna and Lovu catchments while two of the rapid sites are located within the uMngeni catchment.

Table 6.1 Rapid EWR Sites identified in the study area

EWR site name	SQ reach	River	Quaternary catchment	Latitude	Longitude
Mt_R_EWR1	*T40E-05601*	*Mtamvuna*	*T40E*	*-30.85528*	*30.07333*
Mg_R_EWR1	*U20A-04253*	*uMngeni*	*U20A*	*-29.481085*	*30.142466*
Mg_R_EWR3	*U20E-04170*	*Karkloof*	*U20E*	*-29.441683*	*30.317831*
Lo_R_EWR1	*U70C-04859*	*Lovu*	*U70C*	*-30.087085*	*30.789081*

The seven Intermediate EWR sites are described in DWA (2013b) and listed below in Table 6.2. From Table 6.2 it is evident that Intermediate EWR sites were only selected within the Mvoti, uMngeni and Mkomazi catchments.

Table 6.2 EWR sites (Intermediate level) selected in the study area

EWR site name	SQ reach	River	Quaternary catchment	Latitude	Longitude	Management Resource Unit (MRU)
Mv_I_EWR1	*U40B-03770*	*Heinespruit*	*U40B*	*-29.13054*	*30.64002*	*MRU Heyns A*
Mv_I_EWR2	*U40H-04064*	*Mvoti*	*U40H*	*-29.26398*	*31.03513*	*MRU Mvoti C*
Mg_I_EWR2	*U20E-04243*	*uMngeni*	*U20E*	*-29.46184*	*30.29832*	*MRU uMngeni B*
Mg_I_EWR5	*U20L-04435*	*uMngeni*	*U20L*	*-29.64521*	*30.74556*	*MRU uMngeni D*
Mk_I_EWR1	*U10E-04380*	*Mkomazi*	*U20F*	*-29.74338*	*29.91165*	*MRU Mkomazi B*
Mk_I_EWR2	*U10J-04679*	*Mkomazi*	*U20J*	*-29.921*	*30.08448*	*MRU Mkomazi C*
Mk_I_EWR3	*U10M-04746*	*Mkomazi*	*U10M*	*-30.132*	*30.66245*	*MRU Mkomazi D*

Natural and PD time series files were produced for the above-mentioned eleven EWR sites and were provided to the Ecological team for further assessment.

6.2 HYDROLOGICAL ASSESSMENT OF RAPID EWR SITES

The natural and PD flow results for the rapid sites are summarised in Table 6.3. Graphical comparisons were made between the natural and PD monthly flow distributions and a mass plot (plot of cumulative annual flows) was produced for each of these sites.

Table 6.3 Rapid EWR Sites: Natural and PD flow results

EWR site name	SQ Reach	River	Total catchment area (km²)	NMAR (million m³/a)	PD MAR (million m³/a)	Difference between NMAR and PD MAR (million m³/a)	Difference between NMAR and PD MAR (%)
Mt_R_EWR1	T40E-05601	Mtamvuna	1236.15	236.64	203.74	32.90	13.90
Mg_R_EWR1	U20A-04253	uMngeni	361.58	78.76	60.46	18.30	23.24
Mg_R_EWR3	U20E-04170	Karkloof	388.62	70.11	56.50	13.61	19.41
Lo_R_EWR1	U70C-04859	Lovu	811.91	100.58	73.42	27.17	27.01

The flow comparisons for the Mtamvuna rapid Mt_R_EWR1 are shown in Figure 6.1. The 14% difference in MAR is due to catchment development. The hydrology was derived from information obtained from the WR2012 study currently being undertaken. Although records have been extended no recalibration of the WRSM2000 has been done yet (i.e. interim results were used for this assessment). The high resolution WRSM2000 system configuration obtained from the WR2012 Study was refined to include simulation of flows at Mt_R_EWR1. Catchment developments (forestry, alien vegetation and irrigation water use) were disaggregated based on catchment area scaling. The confidence in the natural and PD hydrology derived for this catchment is considered to be low.

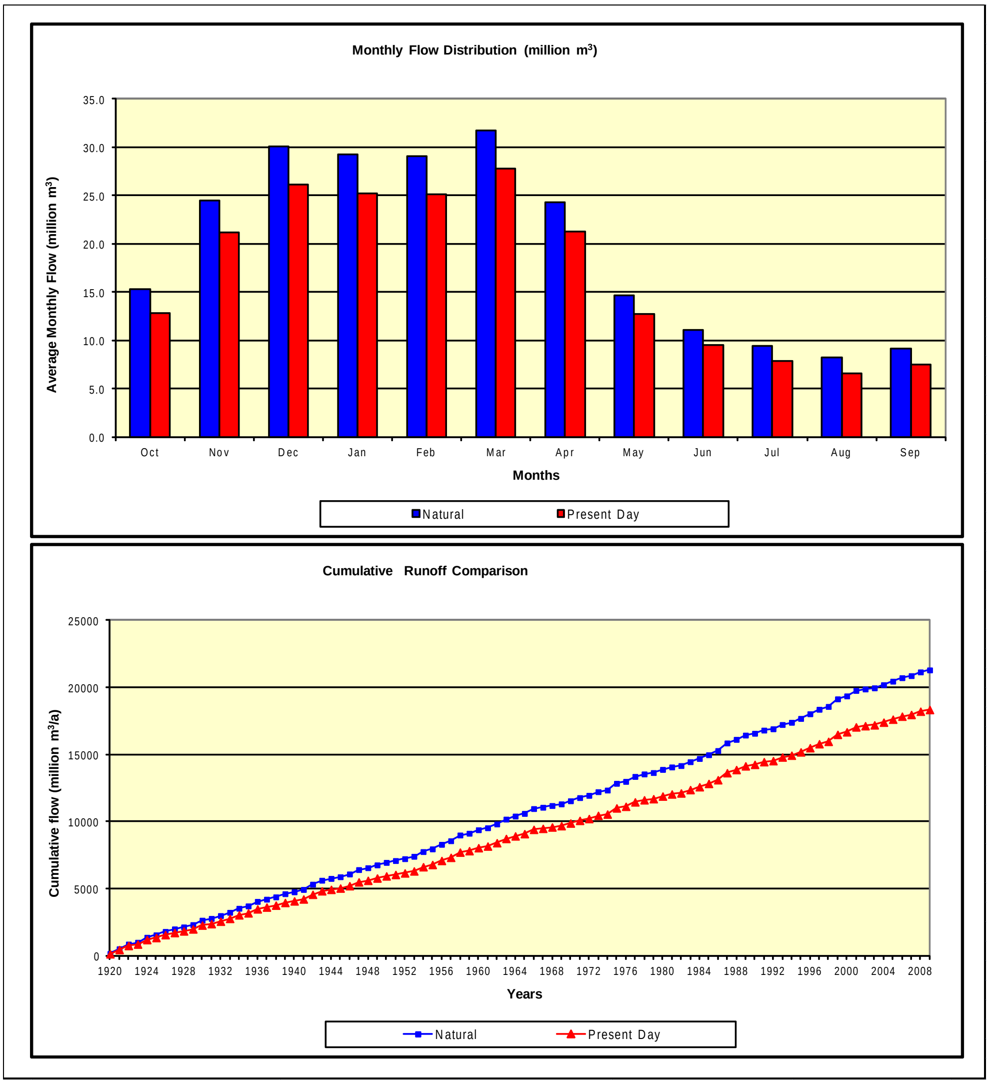

Figure 6.1 Mt_R_EWR1: Natural and PD flow comparisons

The flow comparison results for the two uMngeni rapid EWR sites are shown in Figure 6.2 and Figure 6.3 respectively. The hydrology was derived from a detailed hydrological assessment (see Section 5.6). The high resolution WRPM system configuration was refined to include simulation of flows at the EWR sites. Catchment developments (forestry, small dams and irrigation water use) were disaggregated based on information obtained from the WR2005 Study and catchment area scaling. The 23% and 19% differences in MAR found for Mg_R_EWR1 and Mg_R_EWR1 respectively are due to the impact of catchment development (afforestation, farm dams and irrigation water use). Although the assessments are based on high confidence hydrology, the overall confidence of the EWR site results is reduced by the disaggregation of catchment development information (refer to Section 4.3 for adopted methodology) as well as the refinement of the DSS.

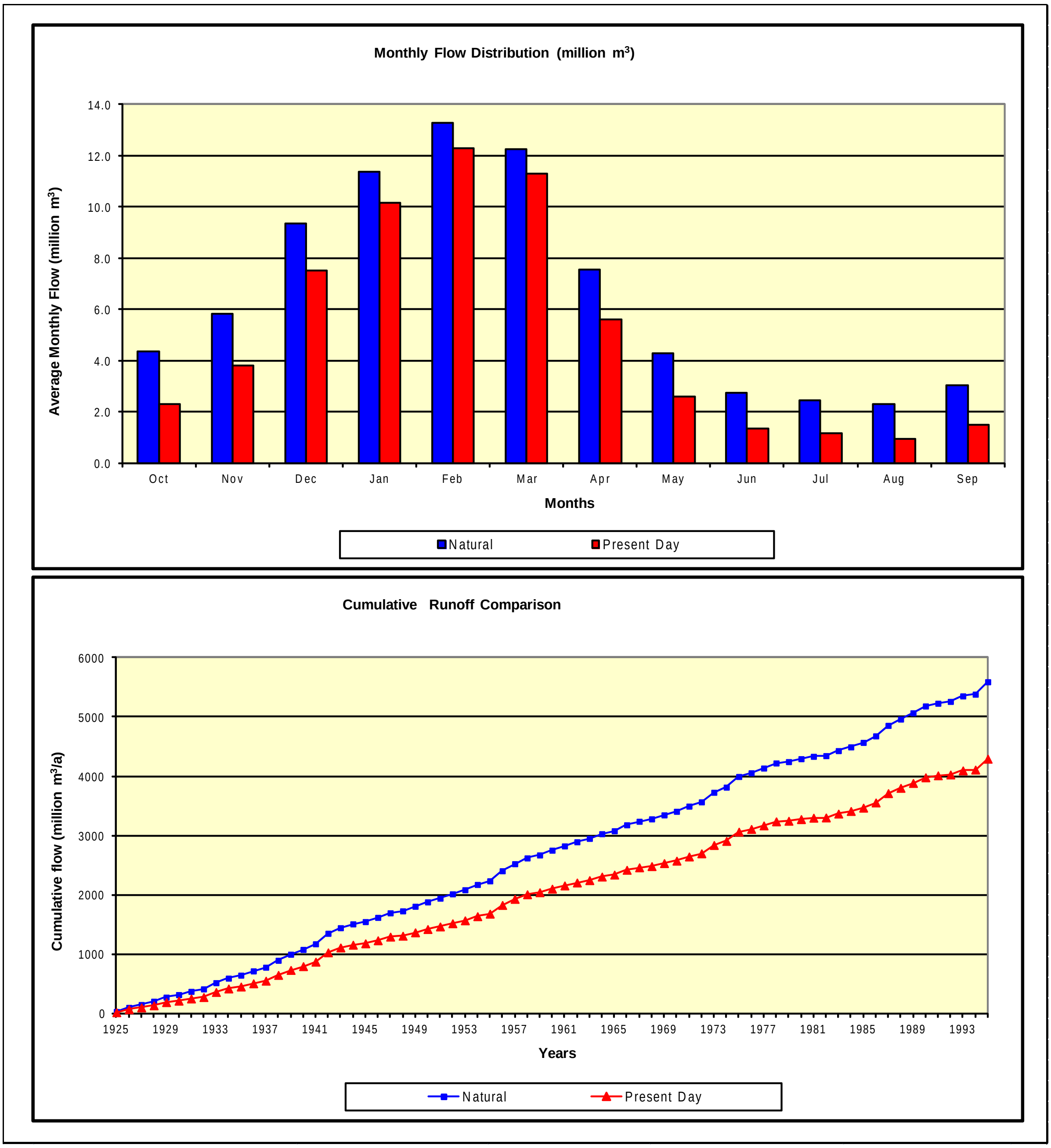

Figure 6.2 Mg_R_EWR1: Natural and PD flow comparisons

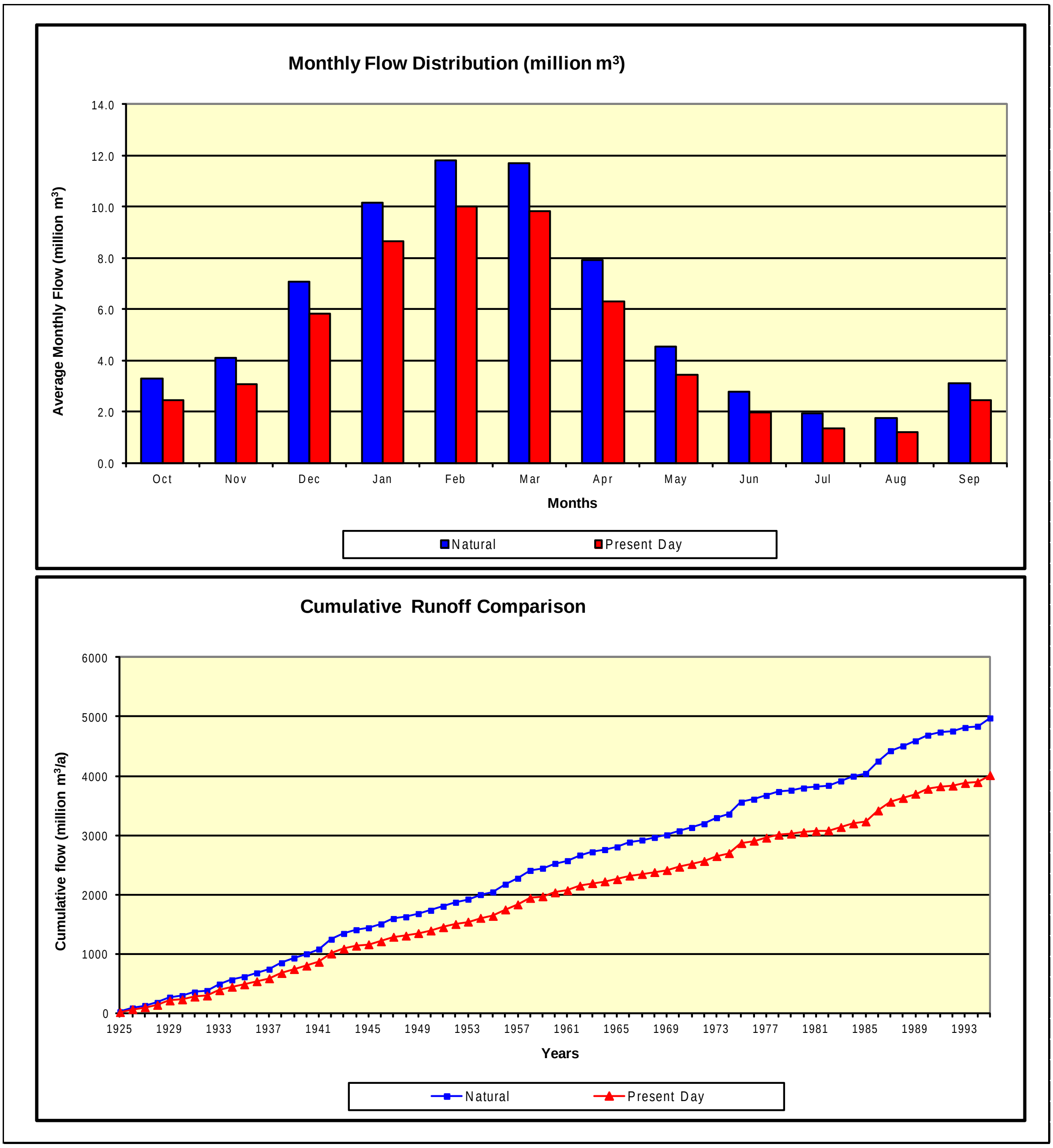

Figure 6.3 Mg_R_EWR3: Natural and PD flow comparisons

The flow comparisons for the Lovu rapid Lo_R_EWR1 are shown in Figure 6.4. As mentioned in Section 5.10 the hydrology used for the Lovu catchment was derived from information obtained from the WR2012 study currently being undertaken. Although small dams have been included in the system configuration no recalibration of the WRSM2000 model has been done yet (i.e. interim results were used). The high resolution WRSM2000 system configuration obtained from the WR2012 Study was refined to include simulation of flows at the EWR site. Catchment development information was disaggregated based on catchment area scaling. The 27% difference in MAR (see Table 6.3) is due to catchment development (afforestation, alien vegetation, small dams, urban and irrigation water use). The confidence in the natural and PD hydrology derived for this catchment is therefore considered to be low.

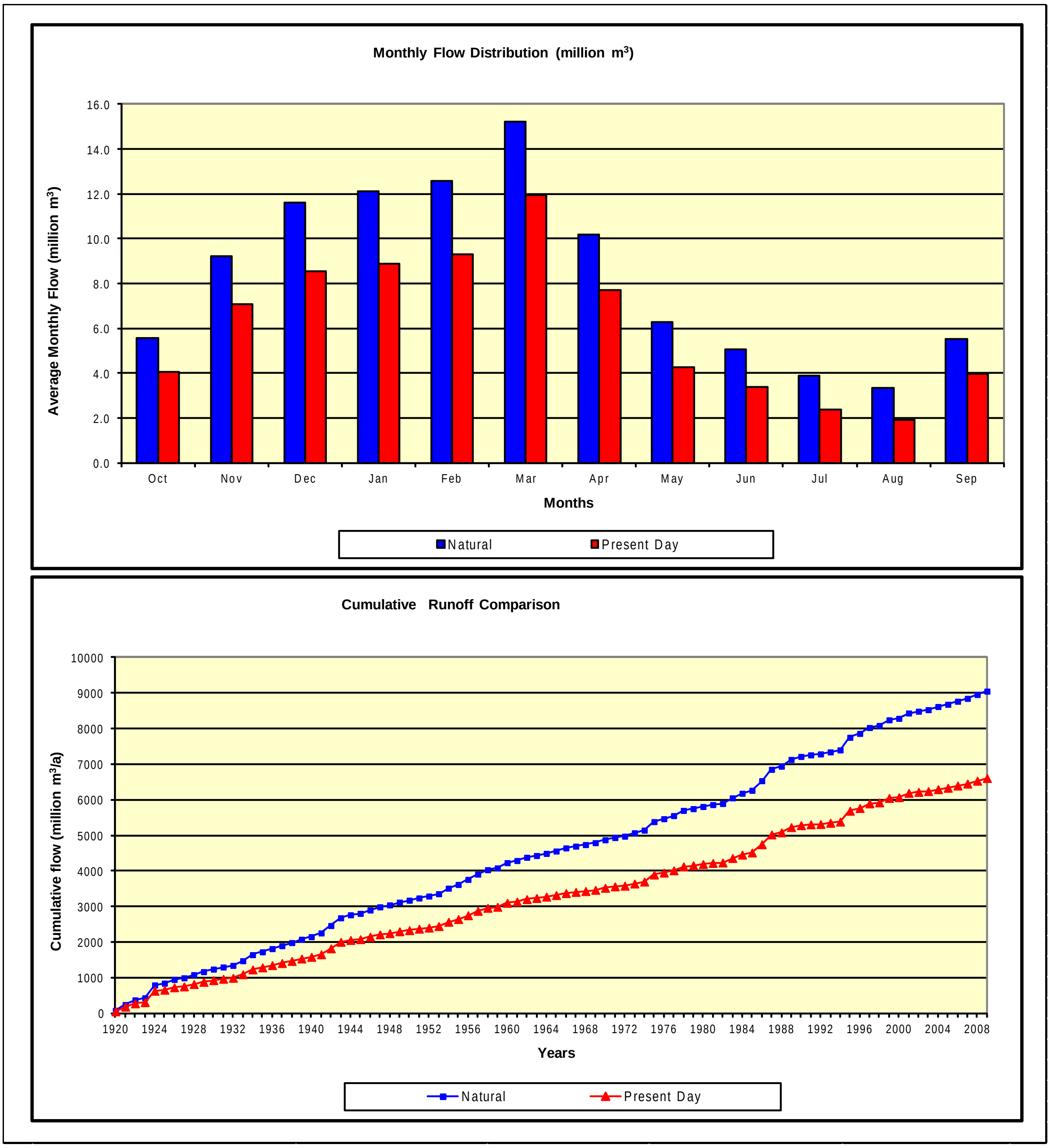

Figure 6.4 Lo_R_EWR1: Natural and PD flow comparisons

6.3 EWR QUANTIFICATION

EWR quantifications were undertaken for the seven intermediate EWR sites. The final flow requirements are expressed as a percentage of the nMAR. The summarised results are presented in Table 6.4 and detailed information for each EWR site can be found in the study report entitled Volume 3: EcoClassification and EWR assessment on the Mkomazi, uMngeni, and Mvoti Rivers (DWA, 2014d).

Table 6.4 Intermediate EWR Sites: Summarised EWR results

EWR site	Ecological Category	nMAR (MCM)	pMAR (MCM)	Low flows (MCM)	Low flows (%)	High flows (MCM)	High flows (%)	Total flows (MCM)	Total (%)
Mv_I_EWR1	*PES/REC[1]: C*	*17.36*	*7.08*	*3.16*	*18.2*	*1.69*	*9.7*	*4.85*	*27.9*
	AEC: D			*2.26*	*13*	*1.6*	*9.2*	*3.85*	*22.2*
Mv_I_EWR2	*PES/REC instream: B/C*	*273.96*	*168.84*	*48.3*	*17.6*	*19.4*	*7.1*	*67.7*	*24.7*
	AEC instream: C/D			*33.4*	*12.2*	*17.6*	*6.4*	*51*	*18.6*
Mk_I_EWR1	*PES/REC instream: B/C*	*683.17*	*660.72*	*171.78*	*25.1*	*67.31*	*9.9*	*239.09*	*35*
	AEC: C/D			*88.96*	*13*	*57.57*	*8.4*	*146.53*	*21.4*
Mk_I_EWR2	*PES/REC: B*	*890.91*	*838.35*	*220.59*	*24.8*	*94.44*	*10.6*	*315.03*	*35.4*
	AEC: C			*166.69*	*18.7*	*81.6*	*9.2*	*248.29*	*27.9*
Mk_I_EWR3	*PES/REC instream: B*	*1068.6*	*983.23*	*223.42*	*20.9*	*104.6*	*9.8*	*328.02*	*30.7*
	AEC: C			*151.2*	*14.2*	*90.35*	*8.4*	*241.55*	*22.6*
Mg_I_EWR2	*PES/REC: C/D (RDRM C)*	*228.19*	*105.4*	*33.5*	*14.7*	*12.1*	*5.3*	*45.6*	*20*
Mg_I_EWR5	*PES/REC instream: C/D*	*583.7*	*245.3*	*133.57*	*22.9*	*17.03*	*2.9*	*150.6*	*25.8*

1 Recommended Ecological Category

6.4 EWR STRUCTURES REQUIRED FOR MODELLING

Detailed EWR results are provided in the RDRM generated report compiled for each EWR site. The EWR report includes an EWR table and an EWR rule for each Ecological Category (EC). Furthermore, both a total flow and a low flow EWR rule table are provided for each EC. The low flow EWR rule table is useful for operating the system, whereas the total flow EWR rule table must be used for the operation of high flows. The RDRM detailed output for all the EWR sites can be found in Appendix C of the report Volume 3: EcoClassification and EWR assessment on the Mkomazi, uMngeni, and Mvoti Rivers (DWA, 2014d).

The WRYM and WRPM include a control mechanism developed to model the EWR in a water resource system. This procedure applies a user defined relationship between selected incremental inflows and specified releases to simulate the EWR. The information required for the EWR structure is a list of nodes with incremental inflow that serves as the reference according to which the ER releases are made. For each of the twelve months of the year, a data table is defined relating the EWR releases to the sum of the inflows of the reference nodes.

The following three sets of EWR data structures were determined for each of the EWR sites included in the WRYM and WRPM configurations:

- **Low Flow (LF) EWR structure:** *Based on the REC EWR maintenance low flows only.*
- **Total Flow (TF) EWR structure:** *Based on the REC EWR total flows comprising of maintenance low flows including freshets and specified floods; and*
- **Low Flow+ (LF+) EWR structure:** *Based on a combination of the REC EWR total flows for selected high flow months and the REC EWR maintenance low flows for the remaining months.*

The reasoning behind the selection of the alternative EWR scenario (Low Flow+) is to evaluate the impact of implementing an EWR that is somewhere between the Low and Total Flow EWR scenarios. The strategy followed for determining the alternative Low Flow+ EWR scenario was to identify only two or three of the high flow months within the specific catchment and to allow for releasing EWR floods during the selected high flow months only.

The corresponding EWR structures incorporated in the WRYM and WRPM configurations for the modelling of the specified EWR scenario are included in Appendix B.

6.5 EWR OPERATING RULES

In terms of the scenario analyses described in Section 8 the following basic assumptions were adopted for the operational scenarios which included modelling of the EWRs:

- *The EWRs were given priority over all other demands;*
- *Dummy dams (combination of small dams) were assumed not to contribute towards supplying the EWRs; and*
- *Principles of "equality" and "minimum proportional flow in a river reach" were applied. This means that each tributary or river reach within the water resource system should contribute its fair share towards supplying the ER and this contribution should remain in the downstream river reaches (i.e. downstream water users should not be allowed access to these EWR releases).*

7 OPERATIONAL SCENARIOS

7.1 GENERAL

A key component of the Water Resources Classification System (WRCS) is to find the appropriate balance between protection of the ecology and using water to sustain the desired socio-economic activities that depend on the water resources. The WRCS guidelines spell out that this evaluation should occur in line with prevailing integrated water resource management practices that are taking place in the catchments or river systems.

Therefore the approach to derive this desirable balance is to identify and analyse a range of different scenarios, where each scenario results in a certain level of protection and use. Generally the higher the water use, the lower is the level of protection achieved. These relationships are, however, complex and opportunities to find optimal solutions are usually possible.

Scenarios, in context of water resource management and planning are plausible definitions (settings) of all the factors (variables) that influence the water balance and water quality in a catchment and the system as a whole. The scale (resolution) of the analysis requires the aggregation of land use effects and therefore individual and localised small scale developments will not significantly influence the classification of a water resource. However significant small scale impacts on priority water resources should be managed by setting the RQO at the specific point to protect the said water resource, especially in the case of sensitive wetlands.

Possible variables that make up scenarios have been identified for the various catchments in the Mvoti to Umzimkulu WMA. These variables have been combined into different scenarios. The variables and scenarios are illustrated in matrices which show the scenario numbers and which variables are applicable to each scenario. The operational scenarios are based on flow and water quality related aspects and not on non-flow related aspects. Mitigation measures to address non-flow related aspects will be identified and will be addressed as part of the RQO identification process.

7.2 IDENTIFICATION OF OPERATIONAL SCENARIOS

Scenarios were identified from different sources of information and ongoing planning processes undertaken by the Department of Water Affairs and Municipalities as described below.

The study "Water Reconciliation Strategy Study for the KwaZulu-Natal Coastal Metropolitan Areas" was undertaken by DWA with the main purpose to identify priority areas where shortfalls in water resource availability occur and confirm the intervention options required to reconcile the water requirements with the available water resources in the study area at current and future development levels. The study area extended from the Mvoti to the Mkomazi River System and a simplified schematic of the water resources and supply area is illustrated in Figure 12.1 of Appendix A. The following possible interventions defined in the strategy will be considered as scenarios:

- *Isithundu Dam on the Mvoti River to supply the North Coast and Kwadakuza areas.*
- *The raising of Hazelmere Dam on the Mdloti River.*
- *The MMTS2 providing additional water transfers into Midmar Dam.*
- *Development of the proposed Smithfield Dam on the Mkomazi River and its associated conveyance infrastructure to augment the water supply of eThekwini.*

- *Development of the proposed Bulwer Dam on the Luhane River, a tributary of the Mkomazi River situated upstream of the Smithfield Dam site to supply water to the Greater Bulwer Donnybrook regional water supply area.*
- *Ngwadini off-channel storage dam on the lower Mkomazi River to augment water supply of the Middle South Coast Area.*
- *Re-use of treated wastewater in the eThekwini Municipality.*
- *Re-use of treated wastewater in Msunduzi Municipality (Darvill WWTW).*

Other relevant studies included:

- *Mkomazi Feasibility Study (DWA, 2014).*
- *Southern KwaZulu-Natal Water Resources Pre-Feasibility Study.*
- *Ngwabeni Off-channel Storage Dam Feasibility Study (on the Umzimkulu River).*
- *Umzimkulu River Catchment Water Resource Study: Riverine Ecological Water Requirements.*
- *WRC: The resilience of South Africa's estuaries to future water resource development based on a provisional ecological classification of these systems; and*
- *DWA All Towns Reconciliation Strategy Study.*

A large portion of the river systems in the study area are impacted on by return flows generated from WWTW. This is most prominent in the eThekwini Municipal Area, where waste water is currently disposed through 25 Waste Water Treatment Works (WWTW) into 16 rivers (see Figure 7.1 below). The location of the eThekwini Municipality WWTW in the Tongati, Mdloti and Mhlanga River Catchments, the uMngeni to the Ngane River Catchments and the Mkomazi and Mahlongwane River Catchments are illustrated in Figure 12.2, Figure 12.3 and Figure 12.4 respectively. These figures are included in Appendix A.

An Ultimate Waste Water Scenario (UWS) has been derived for the eThekwini WWTWs (projected waste water discharges for 2040) in accordance with the eThekwini Spatial Development Framework. An evaluation of the estuarine health was conducted for the estuaries in the study area that will or are currently impacted on by the operations/upgrading of the WWTWs. The ECs were derived for the Present Ecological State (PES), REC and the UWS as part of the Pilot Study: "Evaluation of eThekwini Wastewater Scenarios and the Estuarine Health" undertaken as part of this classification study. The results and the recommended management actions for each of the rivers and estuaries were incorporated into the possible operational scenarios.

Based on the information from the above studies and processes the preliminary operational scenarios for each of the rivers are presented as a matrix in this report. The various scenarios consist of a range of scenario drivers that are included in some scenarios and not in others. Together, the ranges of scenario drivers that are activated for a scenario define the scenario.

The scenarios presented in Section 8 are for the main river systems that are influenced by operational activities namely the Mvoti, Lovu, uMngeni and Mkomazi River systems.

Figure 7.1 Rivers and estuaries affected by eThekwini WWTW discharges

8 MAIN RIVER SYSTEMS INFLUENCED BY OPERATIONAL ACTIVITIES

8.1 MVOTI RIVER CATCHMENT (U40A - U40D)

The natural and PD flow assessments undertaken for Mvoti River Catchment is described in Section 5.2 and the catchment is illustrated in Figure 5.2. The proposed scenarios for the Mvoti system are summarised in Table 8.1 and each scenario and its associated variables are described in the sub-sections that follow. The PES and the REC for the EWR sites on the Mvoti River System and the estuary can be summarised as follows:

- *Mv_I_EWR1 (Heinespruit downstream (d/s) of Greytown): PES = C = REC*
- *Mv_I_EWR2 (d/s of Hlambitwa confluence): PES = BC = REC*
- *Estuary: PES = D = REC*

Table 8.1 Summarised description of Mvoti Scenarios

Scenario	Scenario Variables				
	Update water demands	Ultimate development demands and return flows (2040)	EWR	MRDP[1]	Imvutshane Dam
MV1	Yes	No	No	No	No
MV21	Yes	No	REC tot[2]	No	No
MV22	Yes	No	REC low[3]	No	No
MV3	Yes	Yes	No	Yes	Yes
MV41	Yes	Yes	REC tot[2]	Yes	Yes
MV42	Yes	Yes	REC low[3]	Yes	Yes
MV43	Yes	Yes	REC low+[4]	Yes	Yes

1 Mvoti River Development Project (Isithundu Dam). 2 Recommended Ecological Category (Total Flows)
3 Recommended Ecological Category (Low Flows).
4 Recommended Ecological Category (Total Flows for January, February, March and Low Flows for remaining months).

The EWR structures presented in Appendix B were included in the WRYM configuration and the monthly time series of demands were simulated for each EWR site. The average annual demands as simulated at each EWR site for the various EWR scenarios are presented in Table 8.2. This information was used to assess EWR compliance. It is important to note that both the EWR supply and the total flow at the EWR site are monitored during the scenario simulation.

Table 8.2 Mvoti: Summary of simulated EWRs

EWR site name	SQ reach	River	REC	EWR:1921 - 1994 (million m^3/a)			WRYM Channel No. (demand)
				REC tot	REC low	REC low+	
Mv_I_EWR1	U40B-03770	Heinespruit	C	4.83	3.16	4.16	154
Mv_I_EWR2	U40H-04064	Mvoti	B/C	67.73	48.26	58.57	156

8.1.1 Scenario MV1: Present Day

The WRYM from the original DWS Mvoti River Dam Feasibility Study was updated with the latest information available to produce the best possible estimate of present day flow (refer to Section 5.2 for details). Information from the DWS All Towns Reconciliation Strategies and the Water Reconciliation Strategy Study for the Kwazulu Natal Coastal Metropolitan Areas was used to define the urban and industrial water requirements and return flows to present day levels (2007).

8.1.2 Scenarios MV21 and MV22: Present Day and REC EWR

*For these scenarios, both the total flow EWRs set to achieve the REC (***MV21***) and the low flow EWRs set to achieve the REC (***MV22***) were included in the model and the modelled flows at the EWR sites were assessed for present day conditions.*

*The purpose of these scenarios is to determine to what degree both the two EWR flow scenarios (***MV21*** and ***MV22***) with the tributary inflows will achieve the REC and whether curtailments in the upstream water use are required under present day conditions bearing in mind that there is currently minimal storage regulation in the Mvoti River System, with the only noticeable dam being Lake Merthley in the upper reaches of the catchment (which supports Greytown).*

In view of the adopted EWR operating rules (see Section 6.5) no upstream releases can be made in support of Mv_I_EWR1 and Mv_I_EWR2. Restrictions can be implemented on two user groups supplied from run-of-river abstractions to meet the EWR at Mv_I_EWR2. The total demand for these two irrigation water user groups amounts to only 4.47 million m³/a and support towards the EWR was found to be limited. The socio-economic implications of meeting the EWR through curtailments in upstream water use will therefore not be significant. The simulated average annual results for the two EWR sites and the estuary are summarised in Table 8.3.

Table 8.3 Mvoti: Results for MV21 and MV22

EWR site name	SQ reach	MV21 Results :1921 - 1994				MV22 Results :1921 - 1994			
		EWR supply (Mm³/a)	WRYM Cannel No.	Total Flow (Mm³/a)	WRYM Cannel No.	EWR supply (Mm³/a)	WRYM Cannel No.	Total flow (Mm³/a)	WRYM Cannel No.
Mv_I_EWR1	U40B-03770	4.17	154	7.17	103	2.39	154	7.17	103
Mv_I_EWR2	U40H-04064	71.33	156	169.05	141	48.26	156	169.02	141
Estuary	-	-	-	225.76	58	-	-	225.67	58

8.1.3 Scenario MV3: Ultimate Development, Mvoti River Development Project and Imvutshane Dam

This scenario included estimates of increased water use and return flows for the domestic sector (Greytown and Kwadukuza). The increase was due to population growth and improved service delivery for the ultimate development scenario. Information on estimated increase in domestic use was sourced from the DWA's All Towns Strategies. Since Greytown's PD water use already exceeded the yield of Lake Merthley, it was assumed that the town's increased water use will be supplied from groundwater resources. To this end, adjustments were made to the natural surface runoff from the incremental catchment affected by the increased groundwater use. The runoff from simulation catchment MC3 was subsequently reduced by 2.1%. The projected 2040 return flows included for Greytown and Kwadukuza amounted to 1.578 and 7.26 million m³/a respectively.

This scenario also included the implementation of the Mvoti River Development Project (Isithundu Dam with a gross storage capacity of 51.8 million m³) and the Imvutshane Dam (located on a tributary of the Hlimbitwa River just above the Mvoti and Hlimbitwa confluence).

Information on the Imvutshane Dam was obtained from the Initial Feasibility Study for the Proposed Imvutshane Dam (Umgeni Water, 2009). The Imvutshane Dam is currently in construction and is situated on the Imvutshane River approximately 10km from Mapumulo. The purpose of the Imvutshane Water Supply Scheme (WSS) is to augment the water supply to

Mapumulo and Maqumbi. The initial total demand for Mapumulo and Maqumbi is estimated at 6Ml/d with an ultimate demand of 23 Ml/d by 2045. Umgeni Water (personal communication with Mr. P Sithole on 24 July 2014) confirmed that Phase 3 of the project, which involves an upgrade of the abstraction works to 12Ml/d (4.38 million m^3/a) should be implemented around 2040. The supply from the Imvutshane Dam will also be augmented with an abstraction from the Hlimbitwa River. Information on environmental releases from the dam was sourced from the relevant licence application.

The following information relating to the Imvutshane WSS was adopted for inclusion in the WRYM configuration:

- *Imvutshane Dam catchment area: 42.86 km^2.*
- *Imvutshane Dam Natural MAR: 8.80 million m^3/a.*
- *Full Supply Capacity (FSC) of dam: 3.11 million m^3.*
- *Buffer storage reserved for environmental releases: 0.311 million m^3 (10% of FSC).*
- *Abstraction from dam in 2040: 12Ml/d (4.38 million m^3/a).*
- *Maximum capacity for diversion from Hlimbitwa: 0.1 m^3/s.*
- *Environmental releases: 0.054 m^3/s May – October; 0.069 m^3/s November – April.*

As indicated in Table 8.1 scenario **MV3** *excluded the Mvoti EWRs and to be consistent no environmental releases were made from Imvutshane Dam for this scenario as well. The purpose of this scenario was to determine the Excess Firm Yield (EFY) at Isithundu Dam for the 2040 development conditions and to assess the modelled flows at the EWR sites with the system operated at the EFY (i.e. the EFY is imposed as a direct abstraction from Isithundu Dam. All downstream water users were supported from the proposed Isithundu Dam which means that the water resources of the Mvoti were fully utilised for this scenario.*

The Excess Firm Yield was found to be 34.88 million m^3/a. The scenario **MV3** *simulated storage levels of the Isithundu and Imvutshane dams are shown in Figure 8.1 and Figure 8.2 respectively. As shown in Figure 8.1 the critical period is from June 1991 to October 1993 and covers a period of 28 months. The simulated flows at the EWR sites and the estuary are summarised in Table 8.4.*

Table 8.4 Mvoti: Simulation results for MV3

EWR site name	SQ reach	MV3: Results :1921 - 1994 Total Flow (Mm^3/a)	WRYM Channel No.
Mv_I_EWR1	*U40B-03770*	*6.93*	*103*
Mv_I_EWR2	*U40H-04064*	*128.88*	*141*
Estuary	*-*	*187.78*	*58*

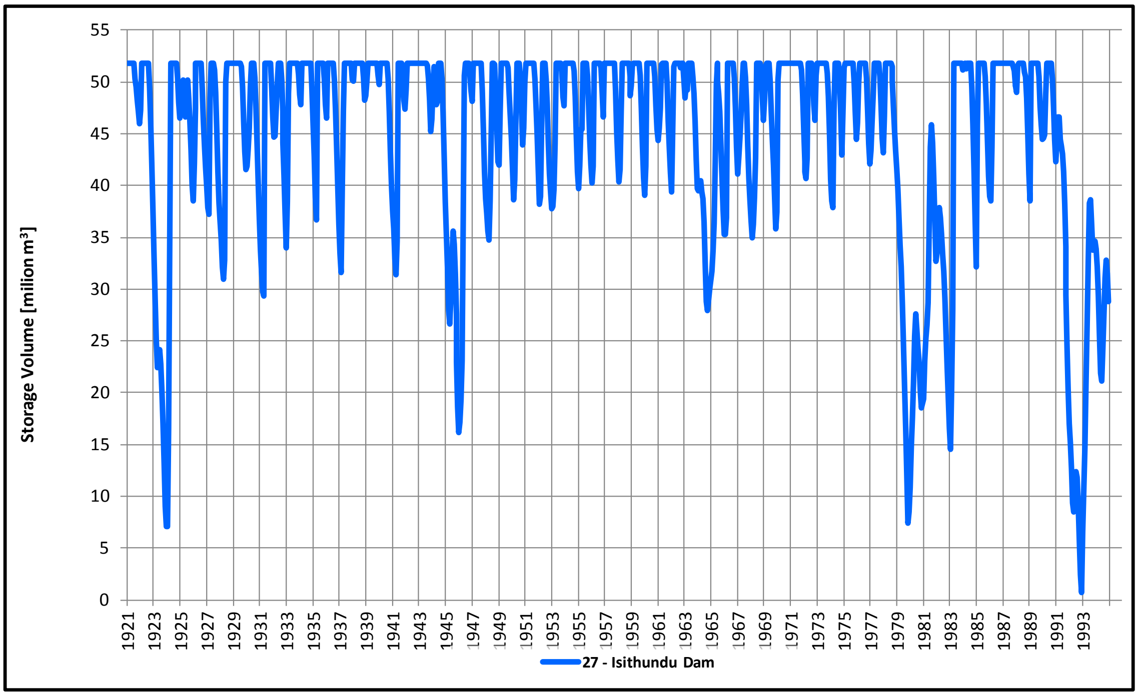

Figure 8.1: MV3: Simulated storage levels for Isithundu Dam

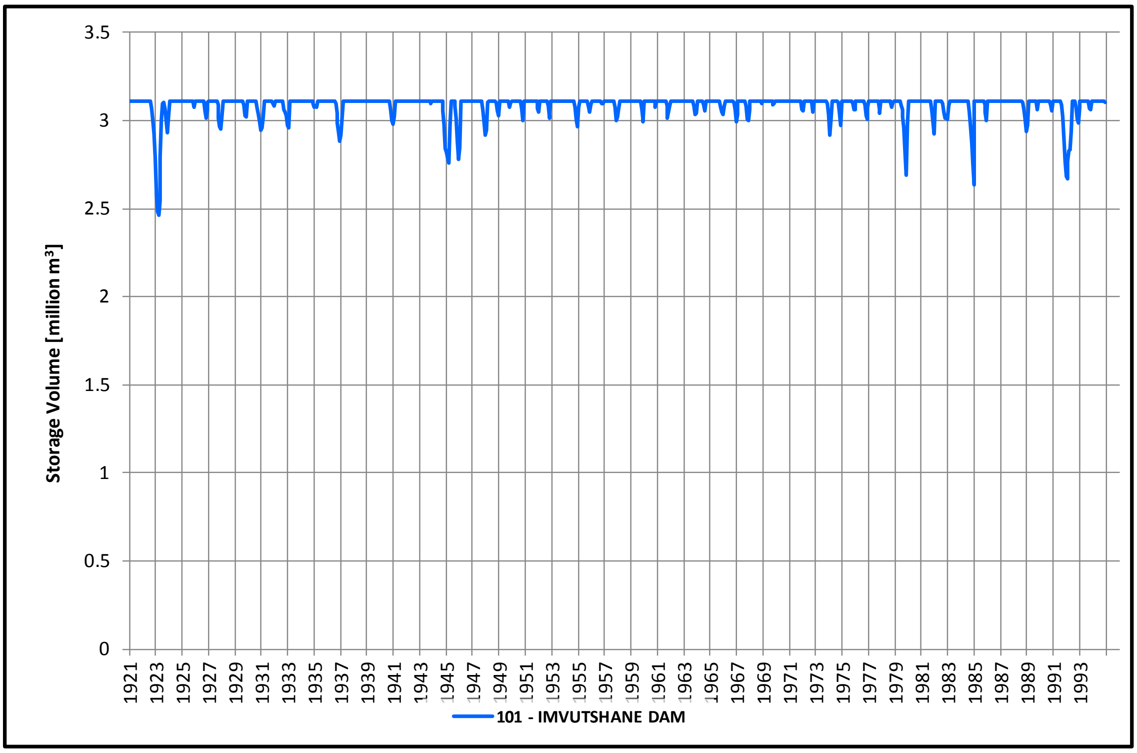

Figure 8.2 MV3: Simulated storage levels for Imvutshane Dam

8.1.4 Scenario MV41, MV42 and MV43: Ultimate Development, REC EWR and MRDP

These scenarios are based on Scenario **MV3** *but the flows at the EWR sites are assessed for the implementation of the following alternative EWRs:*

- *Total flow EWRs set to achieve the REC (***MV41***).*
- *Low flow EWRs set to achieve the REC (***MV42***).*
- *Total Flows for January, February and March and Low Flows for the remaining months set to achieve the REC (***MV43***).*

The purpose of these scenarios is to determine to what degree the total flow, low flow and the in between flow (low+) EWRs together with the dam spills and tributary inflows will achieve the REC EWRs. It is important to note that the Imvutshane environmental releases, as specified in Section 8.1.3, were implemented for all three of these scenarios.

The 'cost' of releasing an EWR from the future Isithundu Dam (and possibly Imvutshane Dam) can then be determined as an impact on the current socio-economics. To facilitate this, the EFY was determined for all three scenarios and the results are compared against the EFY of scenario **MV3** *(considered as baseline) to evaluate the impact of implementing the alternative EWRs. The yield results are summarised in Table 8.5.*

Table 8.5 Mvoti: Summary of Excess Firm Yield results

Scenario	EWR	Isithundu EFY (million m^3/a)	Reduction in yield due to EWR (million m^3/a)
MV3	No	34.88	-
MV41	REC tot	8.02	26.86
MV42	REC low	15.22	19.66
MV43	REC low+	13.77	21.11

The flows at the EWR sites and the estuary, as simulated for the three scenarios, are summarised in Table 8.6. As expected, the results for Mv_I_EWR1 are identical for all three scenarios. The simulated time series of flows were provided to the Ecological team for further assessment.

Table 8.6 Mvoti: Simulated results for scenarios MV41, MV42 and MV43

EWR site name	SQ reach	Total Flow: 1921 - 1994 (million m^3/a)			WRYM Channel No.
		MV41	MV42	MV43	
Mv_I_EWR1	U40B-03770	6.93	6.93	6.93	103
Mv_I_EWR2	U40H-04064	156.12	148.86	150.40	141
Estuary	-	217.02	209.13	211.12	58

The scenario **MV41** *simulated storage levels of the Isithundu and Imvutshane dams are shown in Figure 8.3 and Figure 8.4 respectively. From Figure 8.3 it can be seen that the critical period for scenario* **MV41** *is from May 1979 to November 1983 covering a period of 54 months. Comparison between Figure 8.3 and Figure 8.1 shows that the implementation of the total EWR has caused a shift in the critical period. The critical period for scenario MV41 is also longer than that of scenario MV3. The response of Imvutshane Dam is the same for scenarios* **MV41***,* **MV42** *and* **MV43***. The impact of environmental releases is reflected in the simulated storage levels of Imvutshane Dam shown in Figure 8.4.*

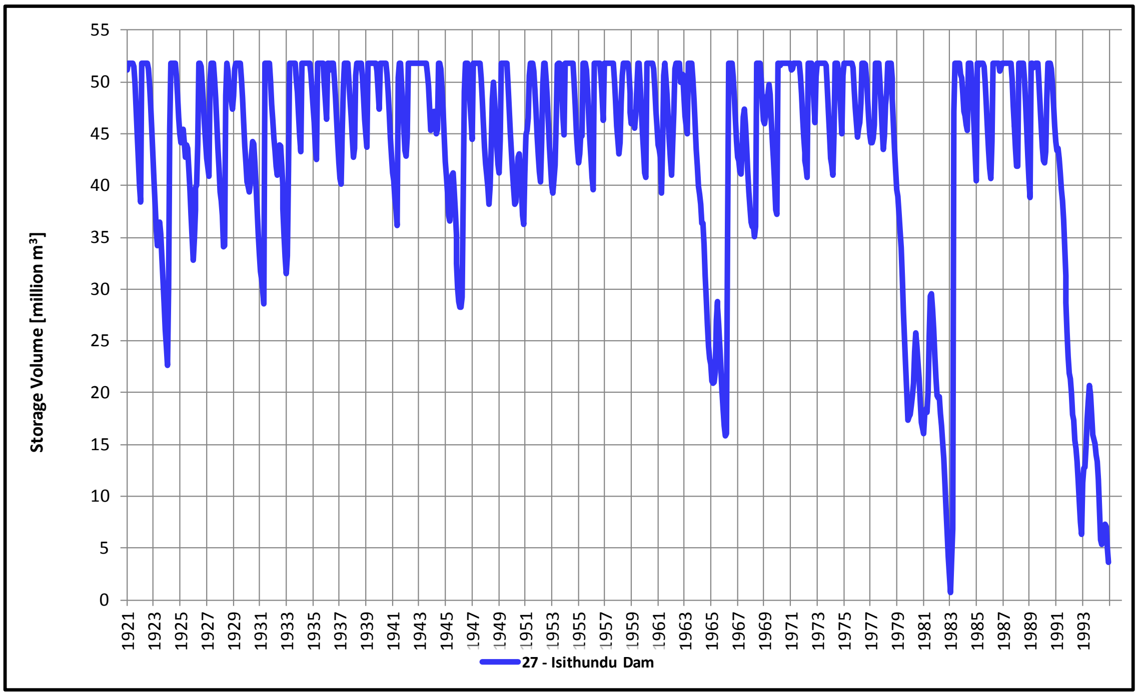

Figure 8.3 MV41: Simulated storage levels for Isithundu Dam

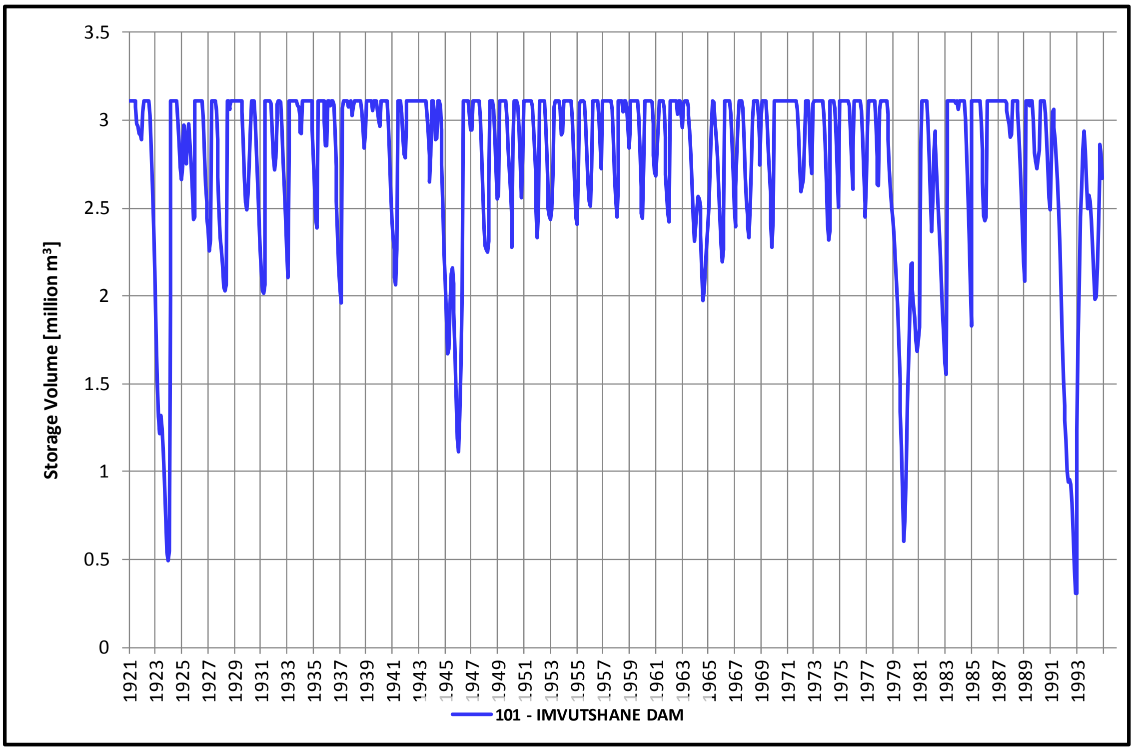

Figure 8.4 MV41: Simulated storage levels for Imvutshane Dam

8.2 LOVU RIVER CATCHMENT (U70A - U70D)

The location of the Lovu River Catchment is illustrated in Figure 5.10. The proposed scenarios for the Lovu catchment are summarised in Table 8.7 and each scenario and its associated variables are described in the sub-sections that follow. As indicated in Figure 8.7 the EWR for the rapid EWR1 site was not included in any of the operational scenarios and the flow simulated at Lo_R_EWR1 was merely evaluated against the EWR. The PES and the REC for the estuary can be summarised as follows:

- *Estuary: PES = C, REC = A/B or Best Attainable State (BAS).*

Table 8.7 Lovu: Summary of operational scenarios

Scenario	Scenario variables			
	Update water demands	Ultimate development demands and return flows (2040)	EWR	Reduced abstraction and afforested areas
LO1	*Yes*	*No*	*No*	*No*
LO2	*Yes*	*Yes*	*No*	*No*
LO3	*Yes*	*Yes*	*No*	*Yes (25% reduction)*
LO4	*Yes*	*Yes*	*No*	*Yes (50% reduction)*

8.2.1 Scenario LO1: Present Day

Details of the assumptions adopted for the PD flow assessment, as well as the results, are discussed in Section 5.10. As mentioned, information from the WR2012 Study was used for the WRSM2000 configuration. Updated information on the water abstractions from Nungwane Dam was also source from Umgeni Water and included in the analysis.

8.2.2 Scenario LO2: Ultimate Development (2040)

This scenario includes estimates of increased water use and return flows for the domestic sector due to population growth and improved service delivery for the ultimate development scenario. The return flows are from WWTW situated higher up in the catchment (U70B, Richmond and township). Information on increased water use and return flows for the domestic sector was sourced from the DWS All Towns Strategy Study and other sources such as available municipal documents.

The water requirements and return flow information for the Lovu catchment is summarised in Table 8.8. The 2040 development information was adopted for scenario LO2.

Table 8.8 Lovu: Water use and return flows for LO2

Description	2008 (million m^3/a)	2040 (million m^3/a)
Water Requirements		
Richmond	*2.00*	*3.27*
Illovo CG Smith	*2.50*	*2.50*
Umgeni (Nungwane Dam)	*5.81*	*5.81*
Total water requirements	**10.31**	**11.58**
Return Flows		
Richmond	*0.31*	*0.51*
Illovo CG Smith	*0.29*	*0.29*
Total return flows	**0.60**	**0.80**

The purpose of this scenario is to monitor the flows at the EWR sites for the ultimate development scenario. The simulated results for Lo_R_EWR1 and the Lovu estuary are presented in Table 8.9.

8.2.3 Scenario LO3: Ultimate Development, Reduced Abstraction and Afforestation Areas (25%)

This scenario is based on Scenario **LO2** *with a reduction in abstraction from Lovu Dam in the upper part of the catchment as well as a reduction in the afforested areas in order to increase base flows by 25%. The 'cost' of reducing the current abstractions and reducing the afforested areas* *can also be determined as an impact on the current socio-economics. This scenario will also need to be considered in a process of determining possible trade-offs with other adjacent estuaries.*

The simulated results for Lo_R_EWR1 and the Lovu estuary are presented in Table 8.9.

8.2.4 Scenario LO3: Ultimate Development, Reduced Abstraction and Afforestation Areas (25%)

This scenario is based on Scenario **LO2** *with a reduction in abstraction from Lovu Dam in the upper part of the catchment as well as a reduction in the afforested areas in order to increase base flows by 50%. The 'cost' of reducing the current abstractions and reducing the afforested areas can also be determined as an impact on the current socio-economics. This scenario will also need to be considered in a process of determining possible trade-offs with other adjacent estuaries.*

The simulated results for Lo_R_EWR1 and the Lovu estuary are presented in Table 8.9.

Table 8.9 Lovu: Summary of simulated results for operational scenarios

EWR site name	Average annual flow for indicated operational scenarios: 1921 - 1994 (million m^3/a)				WRSM2000 route number
	LO1	LO2	LO3	LO4	
Lo_R_EWR1	*73.42*	*70.84*	*77.40*	*84.03*	*18*
Estuary	*82.77*	*80.19*	*89.18*	*98.02*	*25*

8.3 uMNGENI RIVER CATCHMENT (U20A - U20M)

The location of the uMngeni River Catchment is shown in Figure 5.6. The proposed operational scenarios for the uMngeni catchment are summarised in Table 8.10 and each scenario and its associated variables are described in the sub-sections that follow. It is important to note that the EWRs were not included in any of the operational scenarios.

The PES and the REC for the two intermediate EWR sites and the estuary can be summarised as follows:

- *Mg_I_EWR2 (between Midmar and Albert Falls): PES = C = REC*
- *Mg_I_EWR5 (between Nagle and Inanda): PES = C/D = REC*
- *Estuary: PES= E, REC = D*

Table 8.10 uMngeni Summary of operational scenarios

Scenario	Scenario Variables							
	Update water demands	Update demands and return flows (2022)	Ultimate development demands and return flows (2040)	EWR	MMTS2	uMWP-1	Darvill re-use	eThekwini re-use
UM1	*Yes*	*No*	*No*	*No*	*No*	*No*	*No*	*No*
UM2	*No*	*Yes*	*No*	*No*	*Yes*	*No*	*No*	*No*
UM41	*Yes*	*No*	*Yes*[1]	*No*	*Yes*	*No*	*No*	*No*
UM42	*Yes*	*No*	*Yes*[2]	*No*	*Yes*	*No*	*No*	*No*
UM51	*Yes*	*No*	*Yes*[1]	*No*	*Yes*	*No*	*Yes*	*Yes*
UM52	*Yes*	*No*	*Yes*[2]	*No*	*Yes*	*No*	*Yes*	*Yes*

1 All future return flows from Phoenix and Mhlanga WWTW to the uMngeni System: Total return flows of 282 Ml/d.
2 All future return flows from Phoenix, Umhlanga and Tongati WWTW to the uMngeni System: Total return flows of 408 Ml/d.

8.3.1 Scenario UM1: Present Day without MMTS2

The latest WRPM configuration used by Umgeni Water for the annual operating analysis of the uMngeni River System was utilised for the present day scenario as described in Section 5.6. The purpose of the scenario was to monitor the flows at the EWR sites for present day (2012) conditions. The simulated flow results are summarised in Table 8.11.

8.3.2 Scenario UM2: 2022 Development Level and MMTS2

Scenario **UM1** *was updated to include the MMTS2 (Spring Grove Dam) inter-basin transfer as well as the estimates of increased water use and return flows for the domestic sector due to population growth and improved service delivery to represent the 2022 development level (i.e. one year before the implementation of Mkomazi Water Project). The MMTS2 inter-basin transfer discharges into the Mpofana River, which is a tributary of the Lions River that flows into the Midmar Dam catchment and will mainly impact on these two rivers.*

This scenario also includes a maximum load shift volume from the Upper to the Lower uMngeni River System via the Western Aqueduct (direct support from Midmar Dam to the eThekwini Durban Heights WTW) while maintaining a 3 months available storage in Midmar Dam as a buffer storage for supplying the Upper UMngeni Demand Centres. Midmar (with support provided from MMTS2) is the only water source to most of the demand centres in the Upper UMngeni System, including Pietermaritzburg. A buffer storage should thus remain in Midmar Dam as a safety factor. A buffer storage in the order of 68 million m^3 was set as target for scenario **UM2** *and the load shift volume was determined through iteration. The final analysis for scenario* **UM2** *included a maximum load shift of 55.23 million m^3/a with a resulting buffer storage of 68.45 million m^3 in Midmar Dam.*

The following WWTW discharges representative of 2022 development conditions were included in scenario **UM2***:*

- *Howick WWTW: 2.468 million m^3/a.*
- *Darvill WWTW: 23.51 million m^3/a.*
- *Cato Ridge WWTW: 0.25 million m^3/a; and*
- *eThekwini WWTW: 61.87 million m^3/a.*

The purpose of the scenario is to monitor the flows at the EWR sites for the 2022 development scenario (i.e. before the implementation of the uMWP-1). The simulated flow results for the EWR sites and the estuary are summarised in Table 8.11. The simulated storage levels for the major dams within the Mooi-UMngeni system are shown in Figure 8.5 and Figure 8.6.

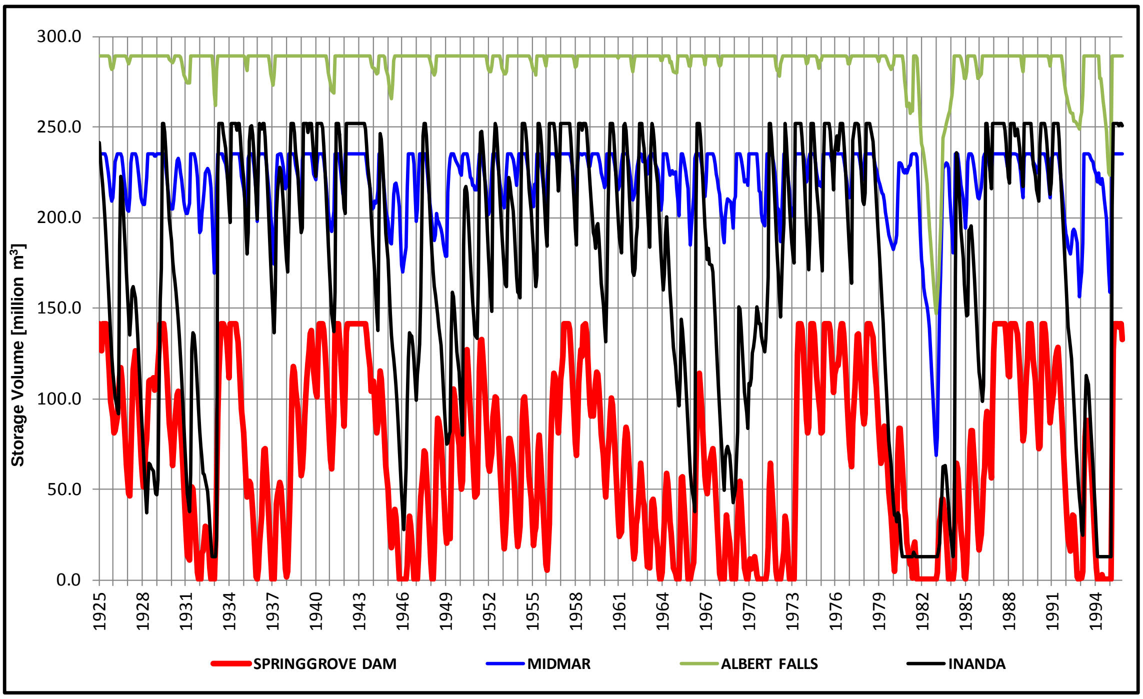

Figure 8.5 uMngeni Scenario UM2: Simulated storage levels for large dams

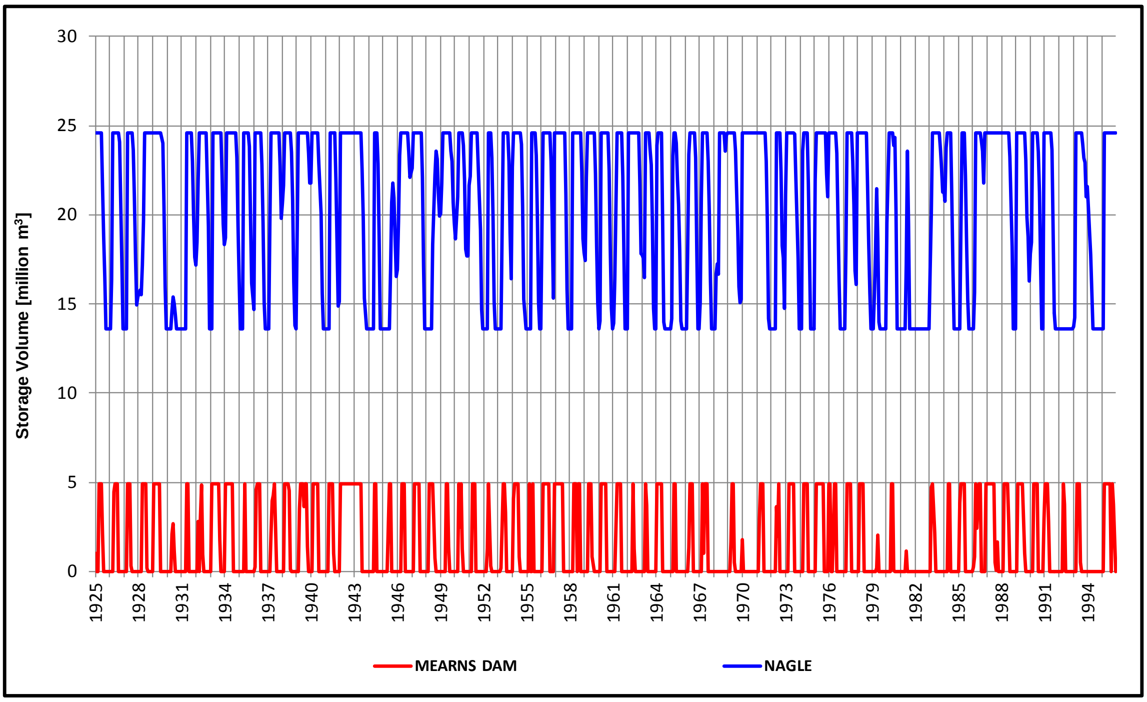

Figure 8.6 uMngeni Scenario UM2: Simulated storage levels for Nagle and Mearns dams

8.3.3 Scenario UM41 and UM42: Ultimate Development and MMTS2

These scenarios are based on scenario **UM2** *but no allowance was made for load shift from the Upper to Lower uMngeni. As for scenario UM2, water use and return flows for the domestic sector was set at 2022 development conditions. The uMWP-1 was not included in the scenario but demands were set to run the uMngeni system at a firm yield development level (i.e. the demands were adjusted to ensure full utilization of the existing uMngeni water resources).*

Return flows were set at 2040 development level:

- *Howick WWTW: 3.170 million m³/a.*

- *Darvill WWTW: 34.46 million m^3/a.*
- *Cato Ridge WWTW: 0.25 million m^3/a; and*
- *eThekwini WWTW: Ultimate Waste Water Generation (2 alternatives as described below).*

There are several existing and planned WWTW in the uMngeni catchment and water is also transferred from the Mhlanga River (Phoenix WWTW) to a tributary (Piesangs River) of the uMngeni River. The eThekwini WWTW ultimate waste water generation was included for the diversion of return flows from neighbouring catchments and the following two alternatives were considered:

- *Scenario* **UM41:** *All future return flows from Phoenix and Mhlanga WWTW discharged to the uMngeni System with total return flows amounting to 282 Ml/d (103 million m^3/a).*
- *Scenario* **UM42:** *All future return flows from Phoenix, Umhlanga and Tongati WWTW discharged to the uMngeni System with total return flows of 408 Ml/d (149 million m^3/a).*

*The purpose of these scenarios is to monitor the flows at the EWR sites for the ultimate development scenario with the implementation of MMTS2 and for the two return flow cases (***UM41** *and* **UM42***). The simulated flow results for the EWR sites and the estuary are summarised in Table 8.11. The scenario simulated storage levels for the major dams within the Mooi-uMngeni system are shown in Figure 8.7 and Figure 8.8.*

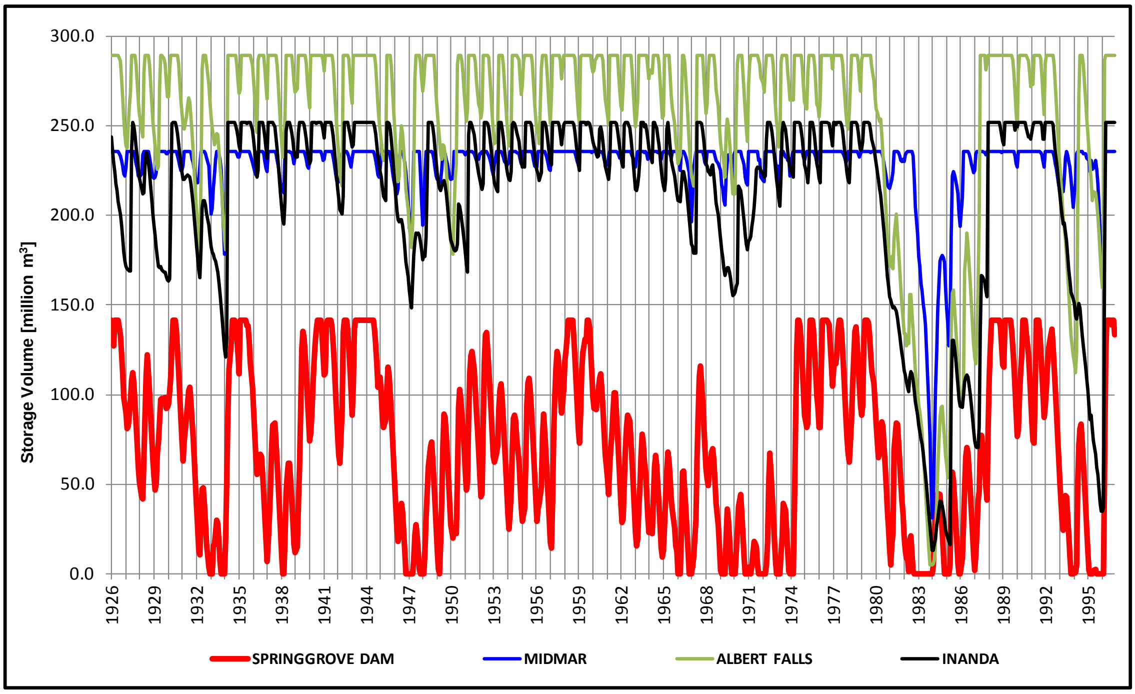

Figure 8.7 uMngeni Scenario UM41: Simulated storage levels for large dams

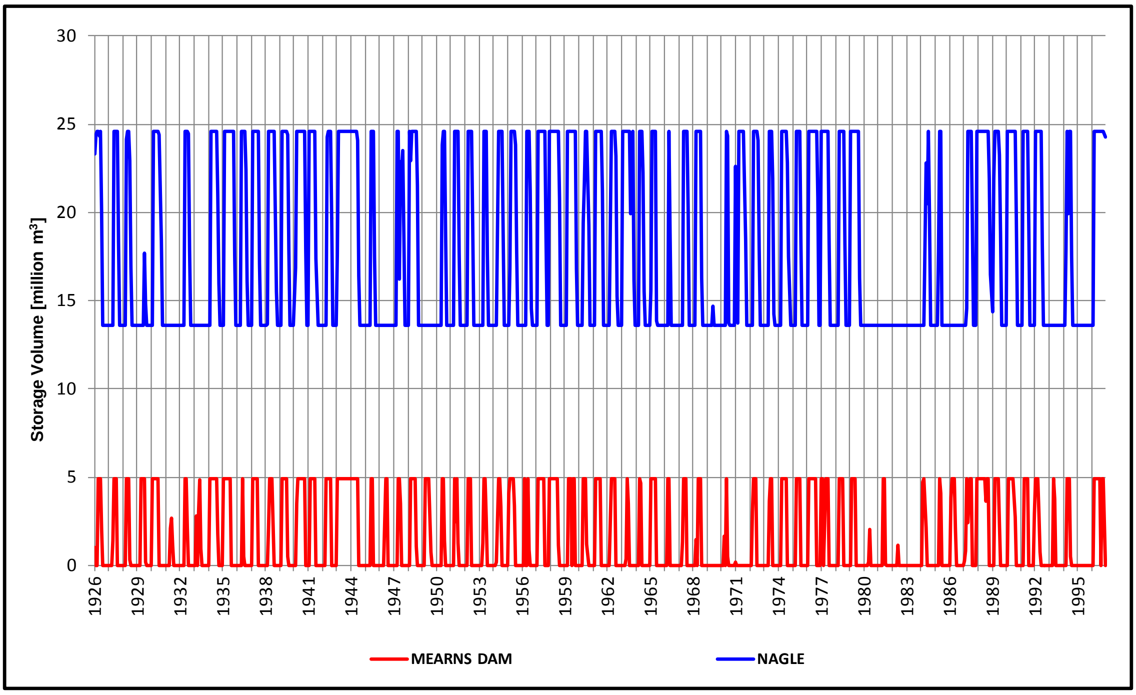

Figure 8.8 uMngeni Scenario UM41: Simulated storage levels for Nagle and Mearns dams

8.3.4 Scenario UM51 and UM52: Ultimate Development, MMTS2, Darvill Re-use and eThekwini Direct Re-use

As for Scenarios **UM41** *and* **UM42** *with the Darvill Re-use and the eThekwini Direct Re-use options included. Discharges from the Darvill WWTW (Pietermaritzburg area) enter the Msunduze River and affect the flow and especially the water quality of the river. Umgeni water is currently investigating the potential of re-using effluent from the Darvill WWTW, which could have a future impact on the Msunduze River and the uMngeni River after the Msunduze/uMngeni confluence. The eThekwini Municipality has conducted a feasibility study for the re-use of treated effluent in the eThekwini metropolitan area. The implementation of the investigated re-use schemes will have an impact on the WWTW return flows entering the uMngeni River System in the future. The locations of the WWTWs discharging into the uMngeni River are illustrated in Figure 12.3 of Appendix A.*

*The purpose of the scenarios is to monitor the flows at the EWR sites for the ultimate development scenario with the implementation of MMTS2, Darvill Re-use and eThekwini Re-use included for the two return flow cases (***UM51** *and* **UM52***) defined as follows:*

- *Scenario* **UM51***: Darvill Re-use of 60 Ml/d (21.915 million m^3/a), i.e. reduce the Darvill return flows by 60 Ml/d.*
- *Scenario* **UM52***: eThekwini Re-use of 41 million m^3/a, i.e. reduce the eThekwini return flows which enter the uMngeni River system just above the estuary by 41 million m^3/a.*

The simulated flow results for the EWR sites and the estuary are summarised in Table 8.11. The scenario **UM51** *simulated storage levels for the major dams within the Mooi-uMngeni system are shown in Figure 8.9 and Figure 8.10.*

Table 8.11 uMngeni: Summary of simulated results for operational scenarios

EWR site name	SQ reach	Average Annual flow for indicated operational scenarios: 1921 - 1994 (million m³/a)						WRPM Channel No.
		UM1	UM2	UM41	UM42	UM51	UM52	
Mg_I_EWR2	*U20E-04243*	*105.40*	*96.82*	*131.62*	*131.62*	*131.55*	*131.55*	*572*
Mg_I_EWR5	*U20L-04435*	*245.25*	*273.78*	*261.00*	*261.00*	*240.12*	*240.12*	*649*
Estuary	-	*199.13*	*259.50*	*340.00*	*386.01*	*299.92*	*345.93*	*841 & 825*

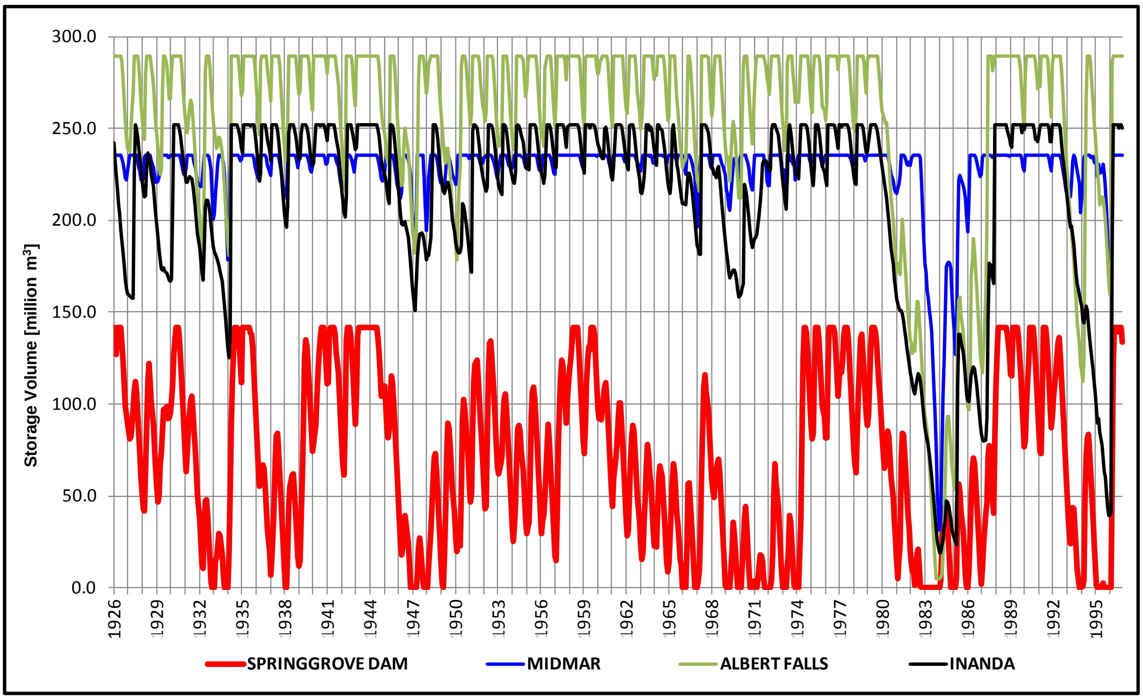

Figure 8.9 uMngeni Scenario UM51: Simulated storage levels for large dams

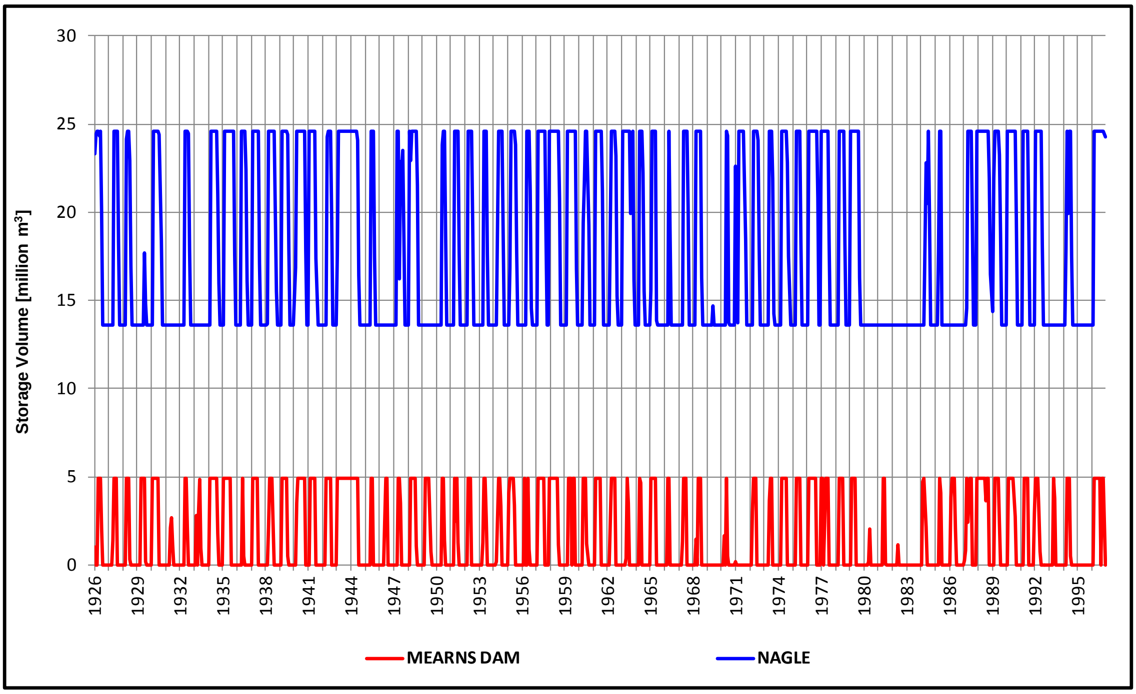

Figure 8.10 uMngeni Scenario UM51: Simulated storage levels for Nagle and Mearns dams

8.3.5 Summary of scenario results

In summary the following should be noted in terms of the uMngeni operational scenarios:

- *EWRs were not included as demands on the water resource system and the resulting flows at the selected EWR sites were merely evaluated. The EWR structures included in Appendix B were applied in the WRPM to assess the simulated EWR demands which are summarised in Table 8.12. This information was only used for the evaluation of flows at the EWR sites.*
- *Assumptions in terms of the Darvill WWTW return flows impact on the flow at Mg_R_EWR4 (situated on Msunduze River) and Mg_I_EWR5 (uMngeni River) as well as on the water supply from the downstream Inanda Dam.*
- *Assumptions regarding the eThekwini WWTW discharges do not impact on the water supply of the uMngeni system, but affect the inflow to the uMngeni estuary.*

Table 8.12 uMngeni: Summary of simulated EWRs

EWR site name	SQ reach	River	REC	EWR:1920 - 1994 (million m^3/a)			WRYM Channel No. (demand)
				REC tot	REC low	REC low+	
Mg_I_EWR2	*U20E-04243*	*uMngeni*	*C*	*45.05*	*33.10*	*41.68*	*664*
Mg_I_EWR5	*U20L-04435*	*uMngeni*	*C/D*	*134.32*	*118.32*	*130.06*	*666*

The operating rule adopted for the analyses of scenarios **UM41, UM42, UM51** *and* **UM52** *was to ensure full utilization of the uMngeni water resources. This was achieved by iterative adjustment of the demands up to the point where no supply failures occur. The gross water requirements of the demand centres, as projected at the 2022 development level, formed the basis of the assessments and are summarised in Table 8.13 together with the firm supply results obtained for the relevant operational scenarios. Scenarios* **UM42** *and* **UM52** *are based on scenarios* **UM41** *and* **UM51** *respectively and differences between the scenarios only include changes to the eThekwini WWTW discharges that impact on the inflow to the estuary and not on the supply from the system.*

Table 8.13 uMngeni: Demand and supply results for operational scenarios

Description of demand centre	Gross demand for 2022 (million m^3/a)	Firm supply for indicated operational scenarios (million m^3/a)		Difference in supply: UM41 vs UM51 (million m^3/a)
		UM41	UM51	
Durban Heights	*219.73*	*219.71*	*219.71*	*0.00*
Wiggins	*107.50*	*25.4*	*3.25*	*22.15*
Pietermaritzburg and Others	*146.33*	*149.48*	*149.48*	*0.00*
North Industrial re-use	*8.80*	*8.8*	*8.8*	*0.00*
Total	**482.35**	**403.39**	**381.24**	**22.15**

It is important to note that the Wiggins demand centre was randomly selected for the demand adjustment and that the focus should be on the total reduction in supply. The difference between the firm supply for the scenarios **UM41** *and* **UM51** *was found to be equal to the Darvill re-use of about 22 million m^3/a. In essence there is, therefore, only an impact on the flow passing through the two downstream EWR sites (Mg_R_EWR4 and Mg_I_EWR5).*

8.4 MKOMAZI RIVER CATCHMENT (U10A – U10M)

The location of the Mkomazi River Catchment is illustrated in Figure 5.11. The proposed scenarios for the Mkomazi catchment are summarised in Table 8.14 and each scenario and its associated variables are described in the sub-sections that follow.

The PES and the REC for the EWR sites and the estuary can be summarised as follows:

- *Mk_I_EWR1 (Lundy's Hill near Bulwer): PES = C = REC*
- *Mk_I_EWR2 (Hela Hela at start of gorge): PES = B = REC*
- *Mk_I_EWR3 (u/s Sappi offtake and gauging weir): PES = C = REC*
- *Estuary: PES= C, REC = B*

Table 8.14 Mkomazi: Summary of operational scenarios

Scenario	Scenario Variables				
	Update water demands	Ultimate development demands and return flows (2040)	EWR	uMWP-1	Ngwadini OCD[1]
MK1	Yes	No	No	No	No
MK2	Yes	Yes	No	Yes	Yes (no support)
MK21	Yes	Yes	REC tot[2] (EWR 2)	Yes	Yes (no support)
MK22	Yes	Yes	REC low[3] (EWR 2)	Yes	Yes (no support)
MK23	Yes	Yes	REC low+[4] (EWR 2)	Yes	Yes (no support)
MK31	Yes	Yes	REC tot[2] (EWR 3)	Yes	Yes (no support)
MK32	Yes	Yes	REC low[3] (EWR 3)	Yes	Yes (no support)
MK33	Yes	Yes	REC low+[4] (EWR 3)	Yes	Yes (no support)
MK4	Yes	Yes	No	Yes	Yes (with support)
MK41	Yes	Yes	REC tot[2] (EWR 2)	Yes	Yes (with support)
MK42	Yes	Yes	REC low[3] (EWR 2)	Yes	Yes (no support)

1 Off-channel Dam.
2 Recommended Ecological Category (Total Flows).
3 Recommended Ecological Category (Low Flows).
4 Recommended Ecological Category (Total Flows for January, February, March and Low Flows remaining months).

The EWR structures compiled for the two EWR sites modelled as part of the operational scenarios are included in Appendix B and were applied in the WRYM to assess the simulated EWR demands which are summarised in Table 8.16. Since Mk_I_EWR1 is situated upstream of the proposed Smithfield Dam the EWR for this site was not included in any of the operational scenarios.

Table 8.15 Mkomazi: Summary of simulated EWRs

EWR site name	SQ reach	River	REC	EWR:1920 - 1994 (million m^3/a)			WRYM Channel No. (demand)
				REC tot	REC low	REC low+	
Mk_I_EWR1	U10E-04380	Mkomazi	C	242.71	174.40	-	256
Mk_I_EWR2	U10J-04679	Mkomazi	B	318.95	223.50	273.03	109
Mk_I_EWR3	U10M-04746	Mkomazi	C	332.75	226.85	281.56	111

8.4.1 Scenario MK1: Present Day

The latest WRYM configuration was sourced from the uMWP- 1: Module 1: Technical Feasibility Study Raw Water (DWA, 2014c). The WRYM setup representing the 2008 development level was refined to include modelling of the DBNs. The adjusted WRYM configuration was used for analysing the present day scenario as discussed in Section 5.11.

8.4.2 Information relevant to 2040 operational scenarios

Water use and catchment development

Information on catchment development and water use that are representative of the 2040 conditions was sourced from the uMWP- 1 Study (DWA, 2014b). The 2040 landuse information included additional farm dams, expansion of forestry areas, increased stockwatering and irrigation water use. The 2040 catchment development information is summarised in Table 8.16. The 2040 eThekwini WWTW discharges to the Lower Mkomazi River were projected to be in the order of 7.67 million m^3/a (21 Ml/d) and these return flows were assumed to enter the river system just downstream of the SAPPI-SAICCOR abstraction. The water use for SAPPI-SAICCOR was taken as 53 million m^3/a and is included as an industrial demand in quaternary catchment U10M.

Table 8.16 Mkomazi: Hydrology and catchment development for 2040 conditions

Quaternary catchment	Catchment area (km^2)	NMAR (million m^3/a)	Water use for 2040 conditions (million m^3/a)				Total water use (million m^3/a)
			Afforestation	IAPs	Irrigation	Urban, industrial & stockwatering	
U10A	418	209.52	3.00	0.38	1.85	0.41	5.64
U10B	392	164.49	4.42	1.46	1.75	0.12	7.75
U10C	267	96.7	4.41	0.81	2.42	0.03	7.67
U10D	337	98.22	3.80	0.87	2.61	0.33	7.61
U10E	327	100.92	6.80	0.66	0.88	0.26	8.60
U10F	379	67.1	5.61	0.32	1.18	0.30	7.41
U10G	353	70.12	6.22	0.36	8.34	0.31	15.23
U10H	458	82.66	14.39	0.41	12.78	0.25	27.83
U10J	505	77.99	13.35	0.42	11.69	0.34	25.80
U10K	364	40.42	7.53	0.35	6.79	0.46	15.13
U10L	307	29.56	3.00	0.15	1.17	0.22	4.54
U10M	280	40.1	0.18	0.18	0.23	53.00	53.59
Total	**4387**	**1077.74**	**72.71**	**6.37**	**51.69**	**56.03**	**186.80**

8.4.3 Mkomazi Water Project

The uMWP-1, as proposed by the DWA Water Reconciliation Strategy Study for the Kwazulu Natal Coastal Metropolitan Areas as a required augmentation option to meet the projected future water requirements of the uMngeni River System, was included in all the operational scenarios. This means that the proposed Smithfield Dam, with a FSC of 236.94 million m^3, was included in the assessment of the 2040 operational scenarios. The uMWP-1 will impact directly on the flows of the Mkomazi due to the Smithfield Dam impoundment and abstraction to support the eThekwini municipality's projected water requirements and will hence contribute to projected increase in return flows of the Mkomazi WWTW and also in neighbouring rivers that the eThekwini WWTW discharge into. Alternative operating rules can be considered for Smithfield Dam in terms of support to existing downstream users and new proposed development options by means of river releases.

Bulwer Water Supply Scheme

The Sisonke District Municipality is planning the Greater Bulwer Donnybrook Regional Water Supply Project aimed at providing a reliable source of water for several communities in the vicinity of Bulwer Town and Donnybrook. The proposed Bulwer WSS involves the construction of Bulwer Dam on the Luhane River in quaternary catchment U10F. This proposed WSS was also included in the 2040 assessments of the Mkomazi Study (DWA, 2014c) and the same assumptions were applied for the purposes of the classification study. The planned water supply area of the dam covers the majority of communities located in the central Mkomazi River catchment (U10E to U10K) where all urban and rural users with significant water requirements are located. Consequently it was decided that all urban and rural users would be excluded for the 2040 setup of the WRYM. Instead the yield of Bulwer Dam, estimated in the Sisonke Feasibility Study to be in the order of 3.0 million m^3/a, was imposed on the dam as a fixed abstraction. Since this abstraction far exceeds the projected urban and rural demands from surface water across the entire Mkomazi catchment, this approach was considered acceptable as it would give more conservative results. The proposed Bulwer Dam situated on the Luhane River, a tributary of the Mkomazi River, has a catchment area of 46 km^2, a nMAR of 8 million m^3/a and a FSC of 9.92 million m^3. A Rapid Level III EWR assessment was also undertaken as part of the recent Sisonke District Municipality Study. The average EWR based on a B EC is 3.0 million m^3/a. The inclusion of the Bulwer WSS will impact on the inflow to the proposed Smithfield Dam.

Ngwadini Dam WSS

Umgeni Water has recently commissioned the Lower Mkomazi Bulk Water Supply Scheme: Service Provider for the Detailed Feasibility Study and Preliminary Design which includes the Ngwadini OCD in the lower Mkomazi River. The Ngwadini OCD will rely largely on water diverted from the lower Mkomazi River. This option is included in the 2040 operational scenarios and will also impact directly on the flows of the Mkomazi due to the proposed weir construction and abstraction from the main stem of the Mkomazi River. Smithfield Dam may be operated to support Ngwadini Dam by making river leases for downstream abstraction. The Mkomazi Study investigated alternative options for the operation of the Ngwadini OCD and allowed for river losses in the order of 10% should support be given to Ngwadini. A FSC of 10.66 million m^3 was assumed for the proposed Ngwadini Dam and the diversion will be from the Mkomazi River upstream of Mk_I_EWR3.

SAPPI-SAICCOR abstraction

SAPPI-SAICCOR abstracts water from the Lower Mkomazi at the inflow to the estuary. Return flows from SAPPI-SAICCOR are discharged to the sea via a pipeline. A small volume of backwash water amounting to 2.65 million m^3/a is discharged directly into the estuary. SAPPI-SAICCOR is licensed to abstract 53 million m^3/a from the Mkomazi which is currently its only source of supply. The estuary has a water requirement of 1 m^3/s and SAPPI-SAICCOR is allowed to abstract all flow exceeding this environmental requirement. The assurance of supply to SAPPI-SAICCOR will be negatively impacted by any upstream development. The operating policy adopted for the MWP as part of the Mkomazi Study was to maximise the yield from Smithfield Dam for supply to the uMngeni catchment with no support given to SAPPI-SAICCOR. The reasoning was that SAPPI-SAICCOR should find an alternative source such as from the Natal South Coast Scheme. Although due consideration was given to the assumptions of the Mkomazi Study it was argued that the Natal South Coast Scheme would not be a viable alternative source of supply. For the purposes of the classification study it was therefore assumed that the supply to SAPPI-SAICCOR will be augmented with releases from the proposed Smithfield Dam. Allowance was made for river losses amounting to 10% of the required river releases. For the scenarios where the EWR is implemented it was assumed that SAPPI-SAICCOR (due to the location of their abstraction point) will have access to the EWR implying that less support will be required from Smithfield Dam.

Supply to downstream irrigators

It was argued that the supply to irrigators abstracting water from the main stem of the Mkomazi River downstream of Smithfield Dam should not be negatively impacted by the implementation of the uMWP-1. To this end, an assessment was made of the supply situation prior to the commissioning of the uMWP-1 and it was assumed that the same assurance of supply should be maintained once Smithfield Dam is operational.

The dam characteristics applied for the proposed Smithfield, Bulwer and Ngwadini dams are summarised in Table 8.17.

Table 8.17 Mkomazi: Dam characteristics applied for proposed dams

Dam name	Dead Storage Conditions			Full Supply Conditions		
	Level (m)	Storage (million m^3)	Surface area (km^2)	Level (m)	Storage (million m^3)	Surface area (km^2)
Smithfield	*887.20*	*22.46*	*2.172*	*930.00*	*236.94*	*9.527*
Bulwer	*1486.20*	*0.903*	*0.258*	*1500.50*	*9.919*	*1.079*
Ngwadini	*92.60*	*0.60*	*0.109*	*118.00*	*10.66*	*0.740*

8.4.4 Scenario MK2: Ultimate Development, MWP and Ngwadini OCD (No MWP Support)

The purpose of this scenario is to determine the system yield prior to the implementation of the EWRs and to assess the flows at the selected two EWR sites (Mk_I_EWR2 and Mk_I_EWR3).

The scenario **MK2** *analysis was based on the following assumptions:*

- *Catchment development was set to reflect the ultimate development level (2040).*
- *The MWP was implemented with Smithfield Dam operated at its HFY.*
- *Ngwadini OCD implemented with no support from Smithfield Dam and operated at its HFY.*
- *EWRs not implemented.*
- *Modelling of Bulwer WSS, SAPPI-SAICCOR and main stem irrigators as described in* **Section 8.4.2**.

As indicated above, the Ngwadini OCD was configured in the WRYM in such a way that no support was provided from Smithfield Dam. The strategy adopted for the assessment of Scenario **MK2,** *was firstly to determine the HFY for Smithfield Dam and secondly to determine the HFY for Ngwadini Dam whilst Smithfield is operated at its HFY. The system was finally run with both dams operated at their respective HFYs to get the final simulated flows for scenario* **MK2***.*

The HFYs for Smithfield and Ngwadini dams were found to be 196.0 million m^3/a and 11.99 million m^3/a respectively. The simulated storage trajectories of the two dams are shown in Figure 8.11 and Figure 8.12. The simulated flow results are summarised in Table 8.18.

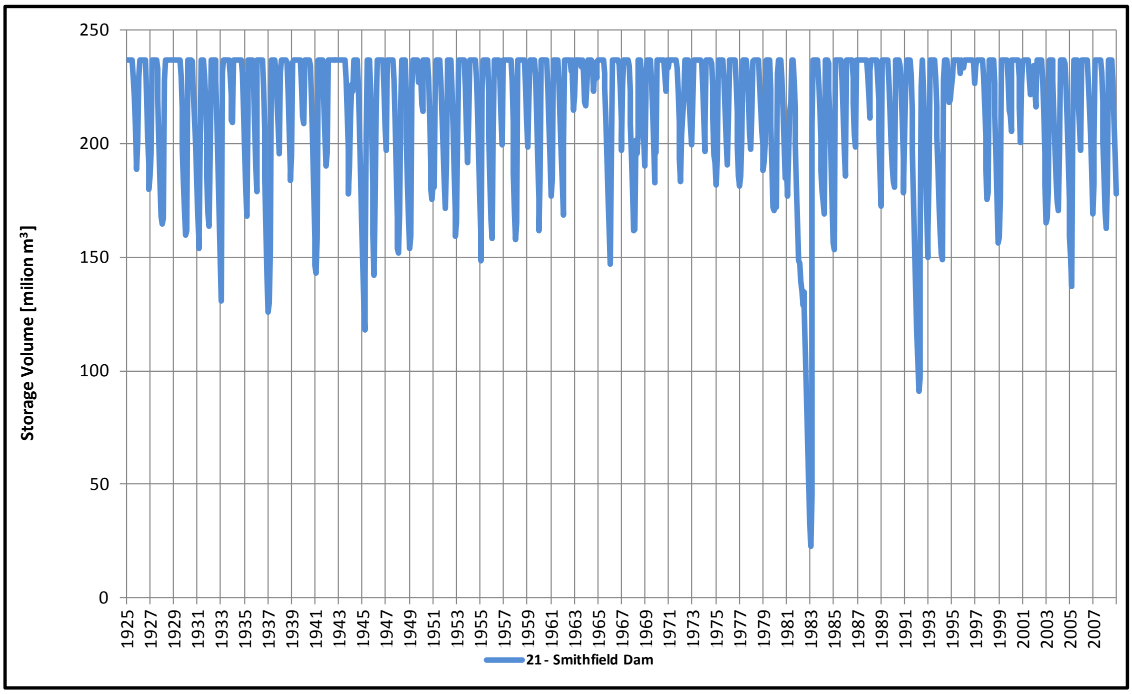

Figure 8.11 Mkomazi Scenario MK2: Simulated storage levels for Smithfield Dam

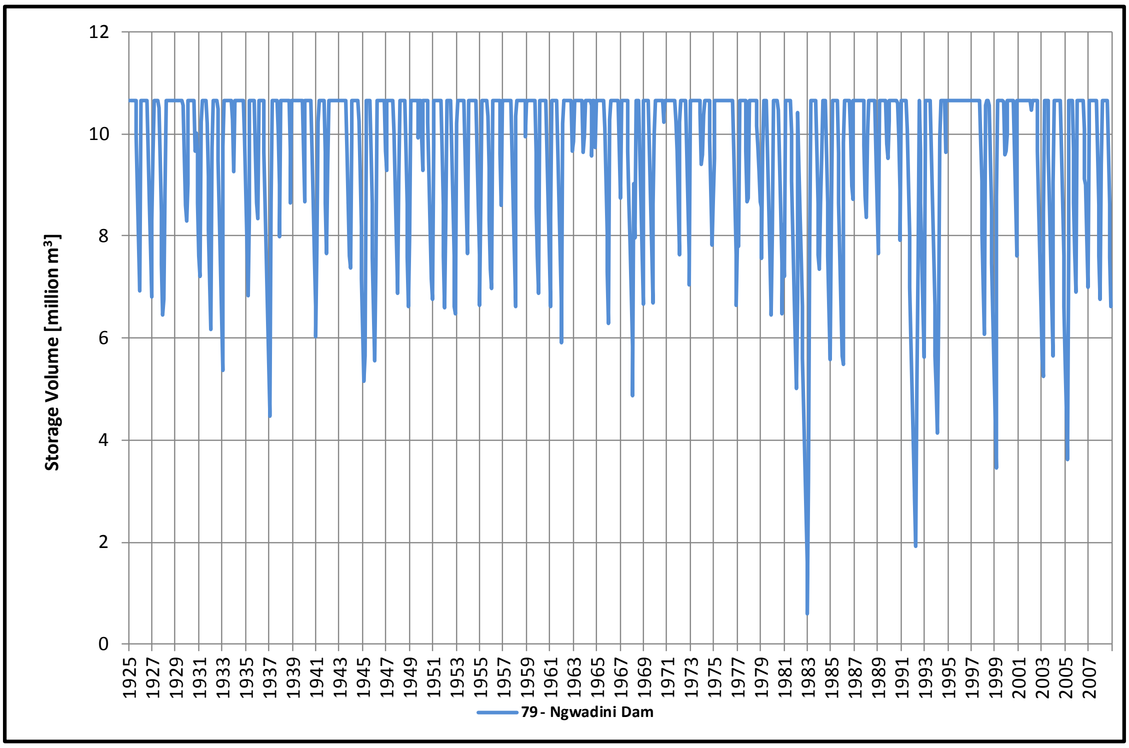

Figure 8.12 Mkomazi Scenario MK2: Simulated storage levels for Ngwadini Dam

8.4.5 Scenario MK21, MK22, MK23: Ultimate Development, REC EWR (Mk_I_EWR2), MWP and Ngwadini OCD (No MWP Support)

These scenarios were based on Scenario **MK2** *where the flows at the EWR sites were assessed for the following EWR flows:*

- *Total flow EWRs (Mk_I_EWR2) set to achieve the REC (***MK21***).*
- *Low flow EWRs (Mk_I_EWR) set to achieve the REC (***MK22***).*
- *Total Flows for January, February, March and Low Flows remaining months (Mk_I_EWR2) set to achieve the REC (***MK23***).*

The purpose of these scenarios was to determine to what degree the total flow, low flow and the in between flow EWRs together with the dam spills and tributary inflows from the dam will achieve the REC at EWR Site 2. The HFYs of Smithfield and Ngwadini were also assessed to determine the affect of implementing the EWR. The 'cost' of releasing an EWR from the future Smithfield Dam can then be determined as an impact on the current socio-economics.

The simulated flow results are summarised in Table 8.18 and the HFY results for the three scenarios are presented in Table 8.19. Since the Scenario **MK21** *EWR has the biggest impact on the system yield, the simulated storage trajectories for Smithfield (Figure 8.13) and Ngwadini (Figure 8.14) are presented for this scenario only. From Figure 8.13 it is evident that Smithfield Dam is operated at lower levels when releases are made for the EWR.*

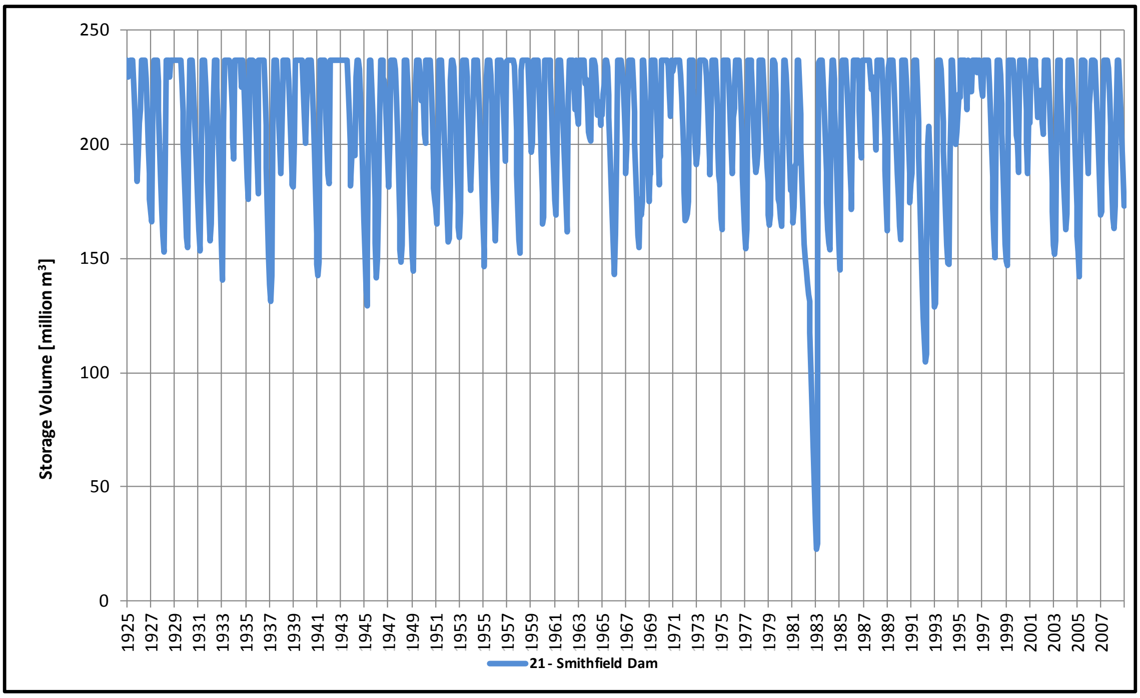

Figure 8.13 Mkomazi Scenario MK21: Simulated storage levels for Smithfield Dam

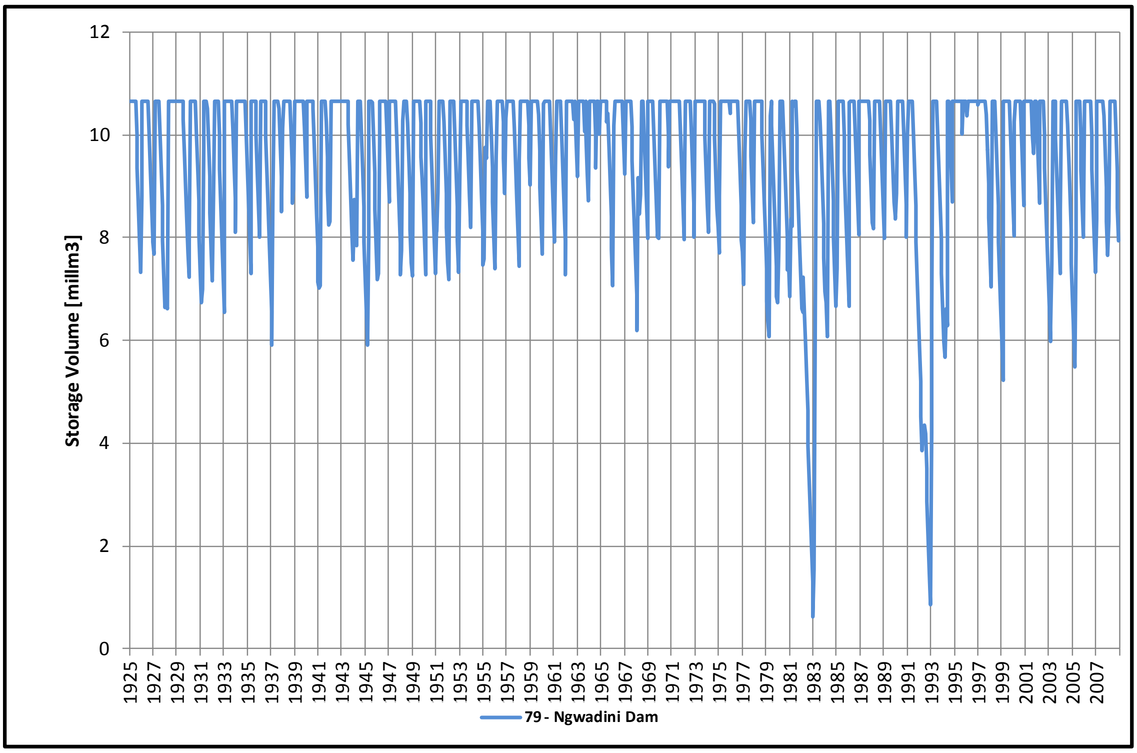

Figure 8.14 Mkomazi Scenario MK21: Simulated storage levels for Ngwadini Dam

8.4.6 Scenario MK31, MK32, MK33: Ultimate Development, REC EWR (Mk_I_EWR3), MWP and Ngwadini OCD (No MWP Support))

These scenarios are based on **Scenario MK2** *where the flows at the EWR sites will be assessed for the following EWR flows:*

- *Total flow EWRs (Mk_I_EWR3) set to achieve the REC (***MK31***).*
- *Low flow EWRs (Mk_I_EWR3) set to achieve the REC (***MK32***).*
- *Total flows for January, February, March and low flows remaining months (Mk_I_EWR3) set to achieve the REC (***MK33***).*

The purpose of these scenarios is to determine to what degree the total flow, low flow and the in between flow EWRs together with the dam spills and tributary inflows from the dam will achieve the REC at Mk_I_EWR3. The HFYs of Smithfield and Ngwadini were also assessed to determine the affect of implementing the EWR. The 'cost' of releasing an EWR from the future Smithfield Dam can also be determined as an impact on the current socio-economics.

The simulated flow results are summarised in Table 8.18 and the HFY results for the three scenarios are presented in Table 8.19.

8.4.7 Scenario MK4: Ultimate Development, MWP and Ngwadini OCD (No MWP Support)

This scenario is based on Scenario **MK2** *with the only change being that the Ngwadini OCD was configured in the WRYM in such a way that support is provided from Smithfield Dam. The strategy adopted for the assessment of Scenario* **MK4,** *was firstly to determine the HFY for Ngwadini Dam and secondly to determine the HFY for Smithfield Dam whilst Ngwadini is operated at its HFY. The system was finally run with both dams operated at their respective HFYs to get the final simulated flows for scenario* **MK4.**

The purpose of this scenario is to assess the flows at the EWR sites for the ultimate development level with MWP and Ngwadini OCD (with support provided from Smithfield Dam) in place. The HFYs of Smithfield and Ngwadini were assessed to determine the affect of implementing the EWR. The 'cost' of releasing an EWR from the future Smithfield Dam can also be determined as an impact on the current socio-economics.

The simulated flow results for Scenario **MK4** *are summarised in Table 8.18 and the HFY results for Smithfield and Ngwadini are presented in Table 8.19. The simulated storage trajectories of Smithfield and Ngwadini dams are shown in Figure 8.15 and Figure 8.16 respectively.*

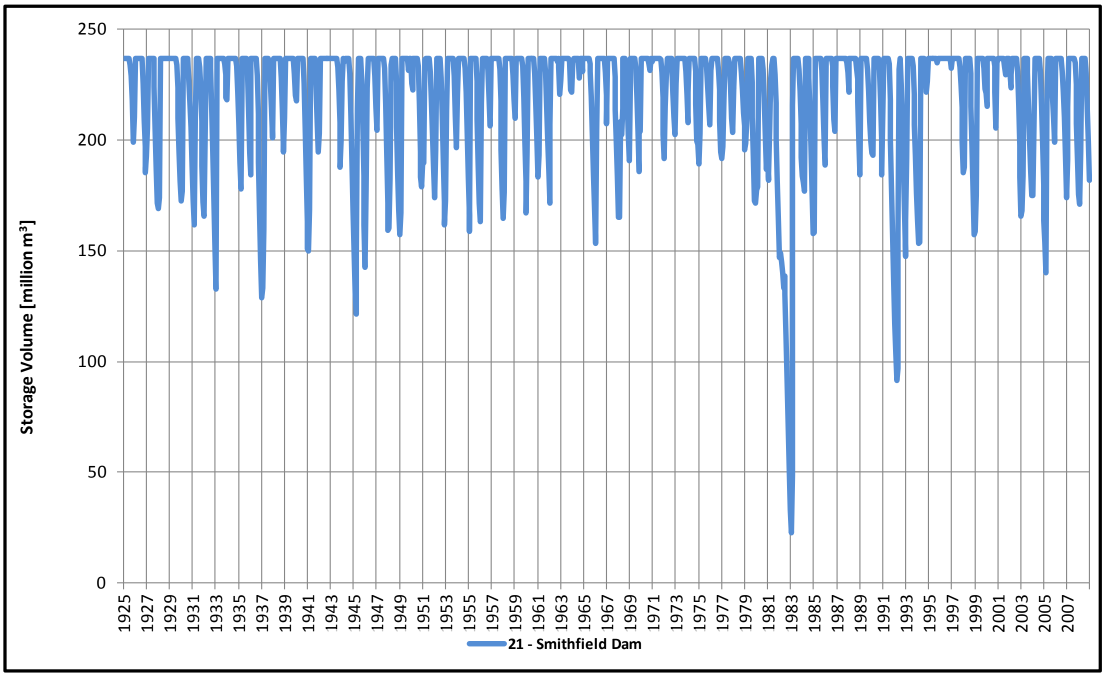

Figure 8.15 Mkomazi Scenario MK4: Simulated storage levels for Smithfield Dam

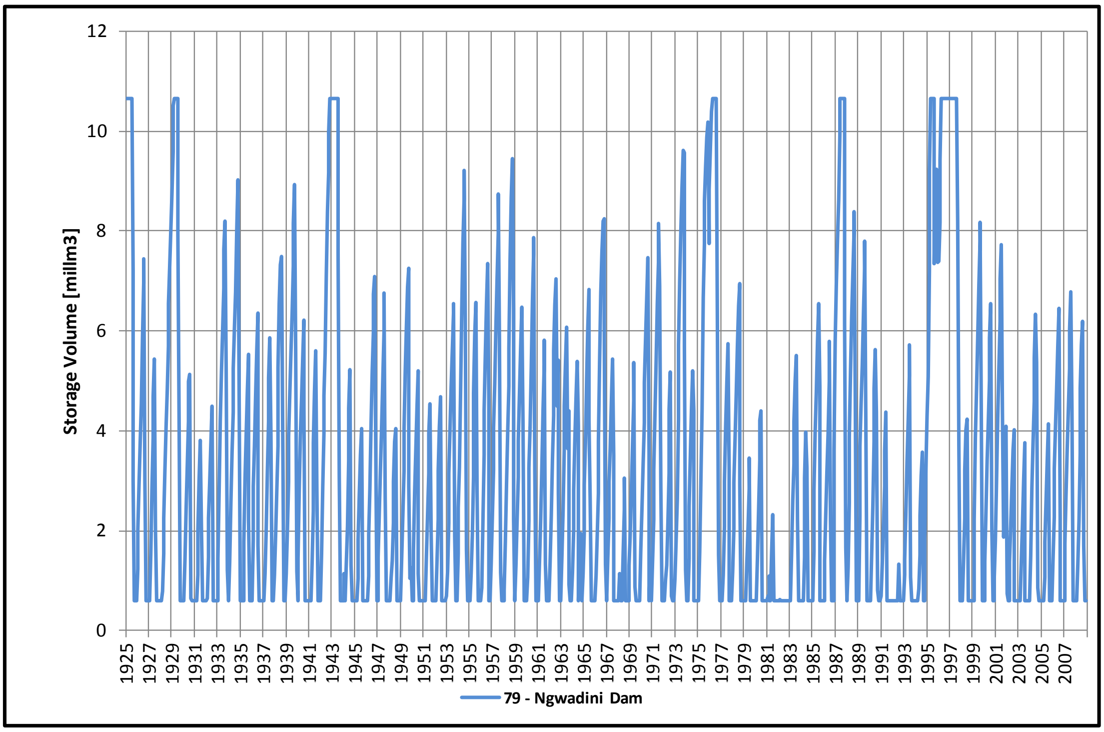

Figure 8.16 Mkomazi Scenario MK4: Simulated storage levels for Ngwadini Dam

8.4.8 Scenario MK41, MK42, MK43: Ultimate Development, REC EWR (Mk_I_EWR2), MWP and Ngwadini OCD (With MWP Support)

These scenarios are based on Scenario **MK4** *and the flows at the EWR sites were assessed for the following EWR flows:*

- *Total flow EWRs (Mk_I_EWR2) set to achieve the REC (***MK41***).*
- *Low flow EWRs (Mk_I_EWR2) set to achieve the REC (***MK42***).*

The purpose of these scenarios is to determine to what degree the total flow and low flow EWRs (Mk_I_EWR2) together with the dam spills and tributary inflows from the dam will achieve the REC at the EWR sites.

The simulated flow results are summarised in Table 8.18 and the HFY results for the two scenarios are presented in Table 8.19. The Scenario **MK41** *simulated storage trajectories of Smithfield and Ngwadini dams are shown in Figure 8.17 and Figure 8.18 respectively.*

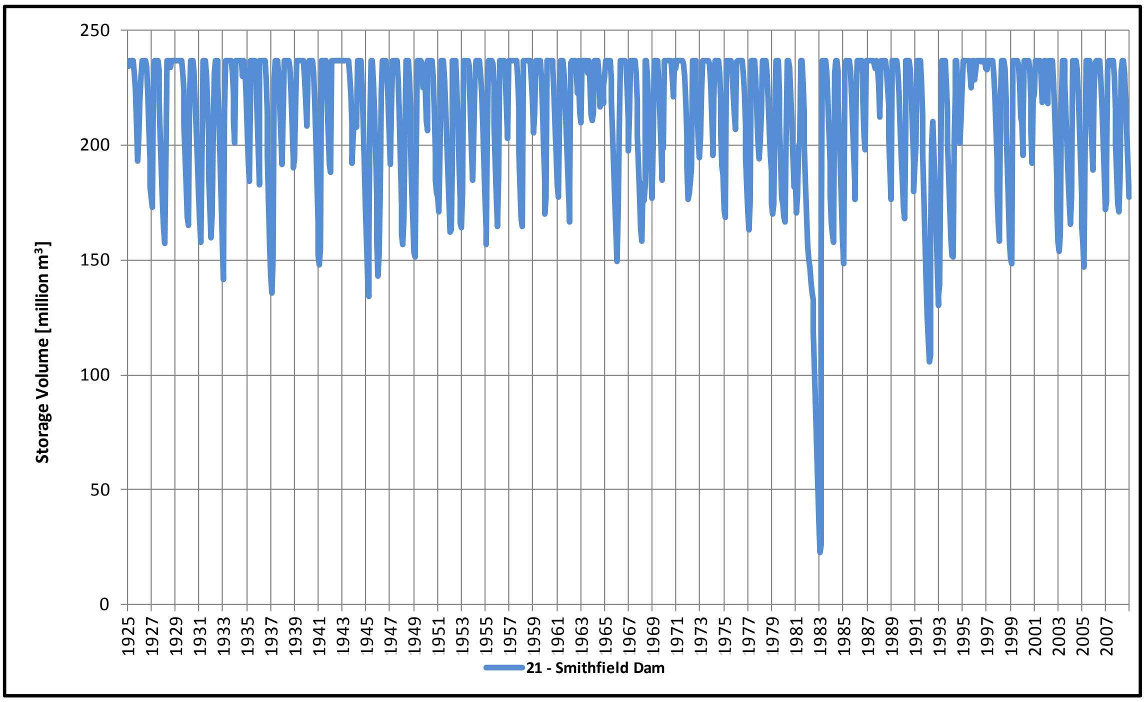

Figure 8.17 Mkomazi Scenario MK41: Simulated storage levels for Smithfield Dam

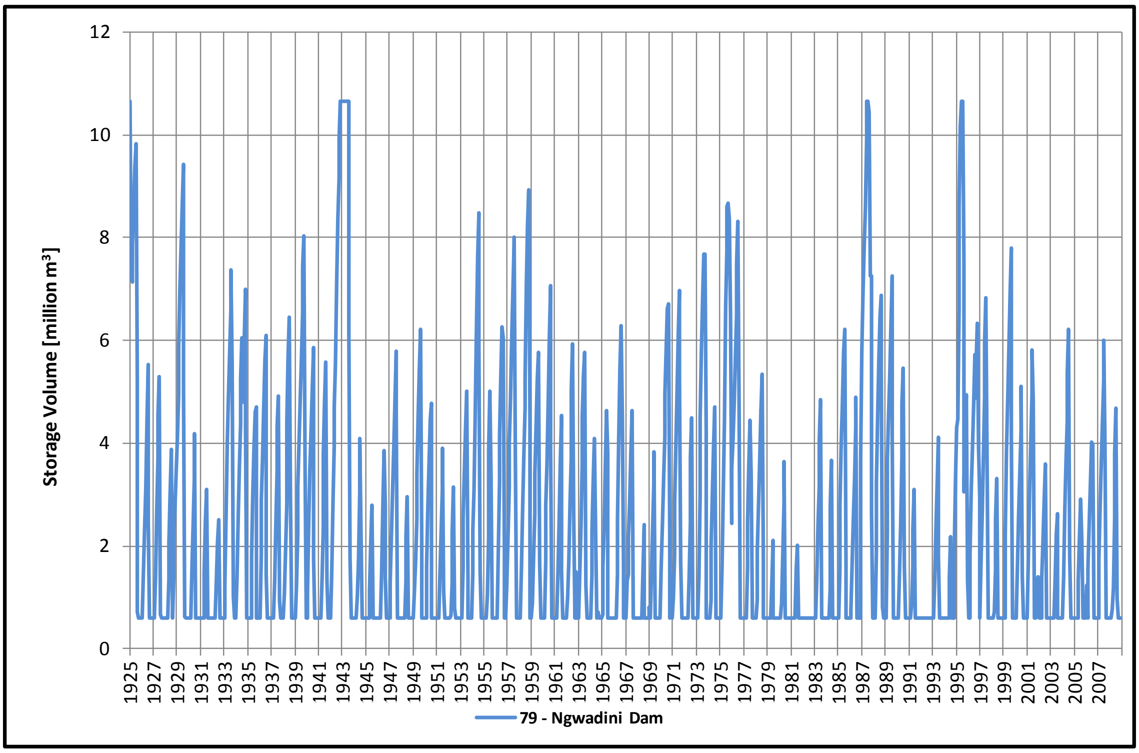

Figure 8.18 Mkomazi Scenario MK41: Simulated storage levels for Ngwadini Dam

8.4.9 Summary of scenario results

The flows simulated at the two selected EWR sites (Mk_I_EWR2 and Mk_I_EWR3), as well as the inflow to the Mkomazi estuary, were monitored for each of the operational scenarios. In additional to these three sites, a fourth site situated just downstream of Smithfield Dam, referred to as EWR_Site_1b, was also included in the evaluation. EWR_Site_1b relates to an EWR site that was analysed as part of the Mkomazi Study (DWA, 2014c), but for the purposes of the classification study the site was merely monitored due to its location. The relevant time series of flow files generated for the four sites of interest were provided to the Ecological team for further evaluation. The corresponding average annual flow results are summarised in Table 8.18.

Table 8.18 Mkomazi: Summary of simulated results for operational scenarios

EWR site name	SQ reach	Average annual flow for indicated operational scenarios: 1920 - 2008 (million m^3/a)										WRYM Channel No.
		MK2	MK21	MK22	MK23	MK31	MK32	MK33	MK4	MK41	MK42	
EWR_Site_1b	-	486.4	540.4	532.1	532.6	532.5	521.7	521.7	539.8	598.5	590.1	278
Mk_I_EWR2	U10J-04679	621.0	677.0	668.7	669.2	669.0	658.2	658.2	672.8	732.6	724.3	205
Mk_I_EWR3	U10M-04746	755.5	813.5	805.1	805.6	807.5	796.0	796.0	764.7	822.6	814.3	120
Estuary	-	719.1	779.1	770.8	771.2	773.1	761.6	761.6	728.2	788.1	779.8	118

The yield results obtained from the operational scenario analyses are presented in Table 8.19. The yield results are important from a water resources point of view as it provides an indication of how the water supply capability of the system is affected by the implementation of additional system components (such as the EWR) or by changing an operating rule (e.g. support to Ngwadini). The yield results can also be applied to assess the socio-economic implications of releasing water to meet the EWR.

Table 8.19 Mkomazi: Summary of yield results for operational scenarios

Scenario	Description	Smithfield HFY (million m^{3}/a)	Ngwadini HFY (million m^{3}/a)	Total HFY (million m^{3}/a)	Difference in total HFY due to EWR (million m^{3}/a)
MK2	*No EWR; No support to Ngwadini*	*196.0*	*11.99*	*207.99*	*-*
MK21	*Total Flow EWR (EWR2); No support to Ngwadini*	*142.2*	*8.03*	*150.23*	*57.76*
MK22	*Low Flow EWR (EWR2); No support to Ngwadini*	*150.6*	*8.03*	*158.63*	*49.36*
MK23	*Low Flow+ EWR (EWR2); No support to Ngwadini*	*150.6*	*8.03*	*158.63*	*49.36*
MK31	*Total Flow EWR (EWR3); No support to Ngwadini*	*150.1*	*5.98*	*156.08*	*51.91*
MK32	*Low Flow EWR (EWR3); No support to Ngwadini*	*161.0*	*6.63*	*167.63*	*40.36*
MK33	*Low Flow+ EWR (EWR3); No support to Ngwadini*	*161.0*	*6.63*	*167.63*	*40.36*
MK4	*No EWR; Support to Ngwadini*	*142.5*	*54.8*	*197.3*	*-*
MK41	*Total Flow EWR (EWR2) ; Support to Ngwadini*	*84.1*	*54.8*	*138.9*	*58.40*
MK42	*Low Flow EWR (EWR2); Support to Ngwadini*	*92.5*	*54.8*	*147.3*	*50.00*

Since scenarios **MK2** *and* **MK4** *do not include EWRs, the yield results of these scenarios are used as benchmark for assessing the impacts of implementing alternative EWRs for a specific EWR site or to determine which EWR site is the driver within the system. The impact on the yield due to the implementation of the various EWRs is indicated in Table 8.19.*

The following conclusions are made based on the results presented in Table 8.19:

- *Implementation of the Total Flow EWR at Mk_I_EWR2 (***MK21***) reduces the total yield of the system by 27.8% (57.8 million m^3/a).*
- *Implementation of the Total Flow EWR at Mk_I_EWR3 (***MK31***) reduces the total yield of the system by 25% (51.9 million m^3/a).*
- *Evaluation of the Scenario* **MK21** *and* **MK31** *yield results show that the implementation of the total EWR at Mk_I_EWR2 is causing the total HFY to be about 5.85 million m^3/a less compared to the when the total EWR at Mk_I_EWR3 is implemented.*
- *In general, the inclusion of the EWR at Mk_I_EWR2 has a higher impact on the total yield compared to the EWR at Mk_I_EWR3.*
- *Although the HFY for Ngwadini Dam increases by 42.81 million m^3/a when it is supported from Smithfield Dam (Scenario* **MK4***), Smithfield's HFY decreases resulting in a lower total HFY compared to that of Scenario* **MK2***. The difference in total yield between scenarios* **MK2** *and* **MK4***, which amounts to 10.69 million m^3/a, is therefore due to the change in operating rule whereby support is given to Ngwadini. It is important to note that additional river losses (10%) are included with the Ngwadini support.*
- *The increase in yield at Ngwadini due to support from Smithfield Dam (***MK4***) should thus be evaluated within the context of the total yield which is 5% lower than that of scenario* **MK2***.*

9 CONCLUSIONS AND RECOMMENDATIONS

In summary, the following should be noted in terms of the hydrological data and models applied in the water resource assessments of this study:

- *High resolution and high confidence models were available for only two catchments (Mkomazi and Umzimkulu).*
- *There are four catchments (uMngeni, Mvoti, Mdloti and Tongati) with relatively old high confidence hydrology and high resolution high confidence models.*
- *The remaining twelve catchments have low confidence hydrology (WR2005 Study information) and no water resource assessment models configured. The WRSM2000 was applied for these catchments.*
- *The hydrological time periods differ for the catchments.*
- *Groundwater surface water interaction was not accounted for in the assessment of the catchments.*
- *Various assumptions were made in terms of the disaggregation of hydrological and catchment development information to enable modelling of DBNs impacting on the confidence associated with DBN results.*

With reference to the natural and PD assessments described in Section 5 the following should be noted:

- *Data sets of natural time series of flows were generated for 244 DBNs.*
- *Low confidence PD time series of flows were simulated for 219 DBNs.*
- *The above-mentioned time series of flows were provided to the Ecological team for further assessment and for use in the quantification of the EWR.*

The following conclusions are made based on the results of the operational scenarios presented in Section 8:

- *Implementation of the EWR in the Mvoti River catchment will have a significant impact on the yield available from the proposed Isithundu Dam. The reduction in excess yield varies from 77% for the total flow EWR to 56% for the low flow EWR.*
- *Conclusions in terms of operational scenario results for the Lovu catchment can only be made by evaluation of simulated flows at the EWR site and the estuary. It was noted that a 25% reduction in abstractions (Scenario* **LO3***) has caused a 9% increase in average annual flow at Lo_R_EWR1. A more significant impact should, however, be observed in the base flows.*
- *Operational scenario results for the uMngeni River system should be evaluated in terms of the flows simulated at the selected EWR sites. The re-use from Darvill WWTW has no impact on the supply from the system, but influences the flows at the downstream EWR sites (Mg_R_EWR4 and Mg_I_EWR5).*
- *As expected, the implementation of the EWR in the Mkomazi catchment has a significant impact on the firm yield of the system. For scenarios excluding support to Ngwadini OCD the reduction in firm yield varies from 29.7% for Scenario* **MK21** *to 19.4% for Scenario MK33.*
- *The firm yield of the Mkomazi system is reduced by 5% when support to Ngwadini OCD is allowed from Smithfield Dam (comparison of scenarios* **MK2** *and* **MK4***). The increase in yield at Ngwadini due to support from Smithfield Dam (***MK4***) should thus be evaluated within the context of the total firm yield of the system.*

- *Evaluation of the Scenario* **MK21** *and* **MK31** *yield results show that the implementation of the total EWR at Mk_I_EWR2 is causing the total HFY of the Mkomazi system to be about 5.85 million m3/a less compared to the when the total EWR at Mk_I_EWR3 is implemented.*
- *In general, the inclusion of the EWR at Mk_I_EWR2 has a higher impact on the total firm yield of the Mkomazi system compared to the implementation of the EWR at Mk_I_EWR3.*

It is recommended that:

- *The information provided in this report is used for further assessment and decision making but that due cognisance be taken of the confidence associated with the results.*
- *The firm yield results provided for the Mvoti and Mkomazi catchments are used to determine the impact of implementation of the EWR on the current socio-economics.*

10 INFORMATION REPOSITORY

All the relevant information utilised and generated as part of the water resource analyses of the Classification Study is provided electronically with this report for future use. The electronic data directory structure used for this purpose is as follows:

- *[1. Documentation]: This Document and the Appendices*
- *[2. Water Resources Database]:*
  - *[2.1 Natural Flow for Biophysical Nodes]:*
    - *[2.1.1 Hydrological Data]*
    - *[2.1.2 Natural Flow Time Series Files]*
  - *[2.2 Present Day Flow for Biophysical Nodes]:*
    - *[2.2.1 Information on Catchment Development and Water Use]*
    - *[2.2.2 Datasets for Selected Decision Support Systems]*
    - *[2.3.3 Present Day Time Series Files]*
  - *[2.3 Ecological Water Requirements]:*
    - *[2.3.1 Rule & Tab Data]*
    - *[2.3.2 EWR Structures]*
    - *[2.3.3 F14 Data Files]*
  - *[2.4. Operational Scenarios]:*
    - *[2.4.1 Lovu Catchment]:*
      - *[2.4.1.1 Dataset for WRSM2000]*
      - *[2.4.1.2 WRSM2000 - Executable]*
      - *[2.4.1.3 Scenario Results]*
    - *[2.4.2 Mvoti Catchment]:*
      - *[2.4.2.1 Datasets for WRYM]*
      - *[2.4.2.2 WRYM - Executable]*
      - *[2.4.2.3 Hydrology]*
      - *[2.4.2.4 Scenario Results]*
    - *[2.4.3 Mkomazi Catchment]:*
      - *[2.4.3.1 Datasets for WRYM]*
      - *[2.4.3.2 WRYM - Executable]*
      - *[2.4.3.3 Hydrology]*
      - *[2.4.3.4 Scenario Results]*
    - *[2.4.4 uMngeni Catchment]:*
      - *[2.4.4.1 Datasets for WRPM]*
      - *[2.4.4.2 WRPM - Executable]*
      - *[2.4.4.3 Hydrology]*
      - *[2.4.4.4 Scenario Results]*

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12 APPENDIX A: MAPS

Schematic of water resources supply area and location of eThekwini Municipality WWTW are provided in the following Figures.

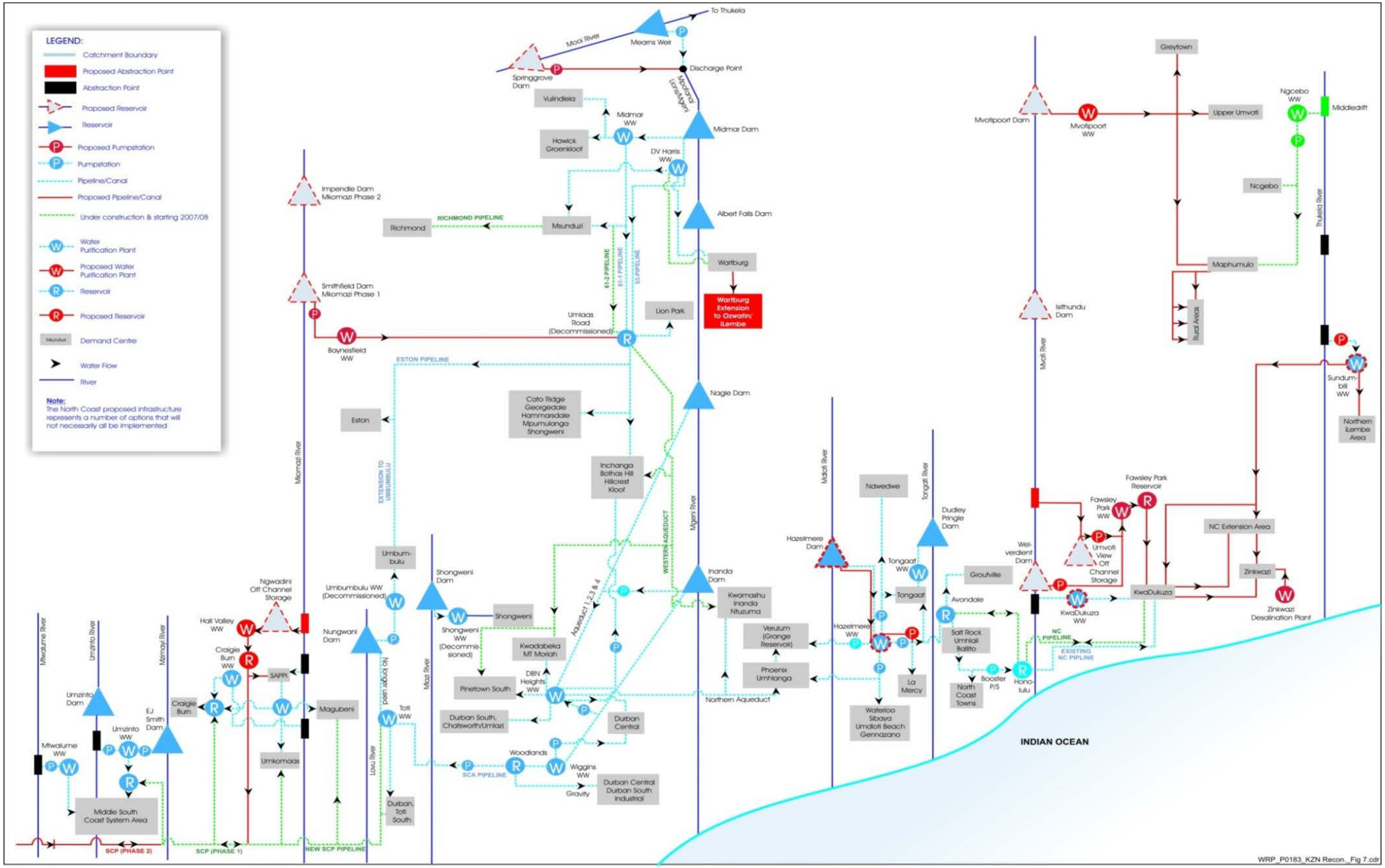

Figure 12.1 Reconciliation Strategy Study for KZN Coastal Metropolitan Areas: Simplified schematic of water resources and supply area

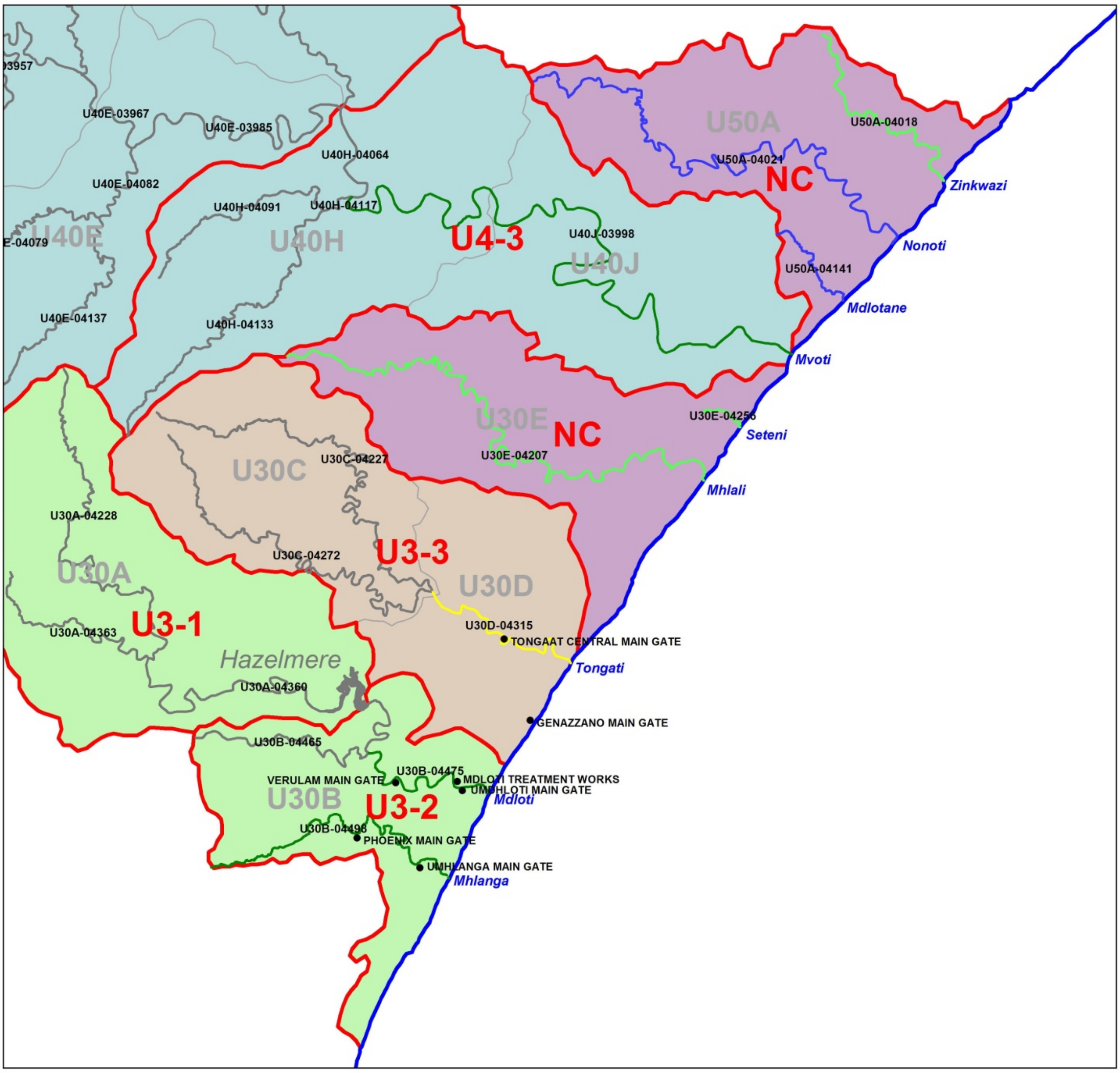

Figure 12.2 eThekwini Municipality WWTW discharging located in the Tongati, Mdloti and Mhlanga River Catchments

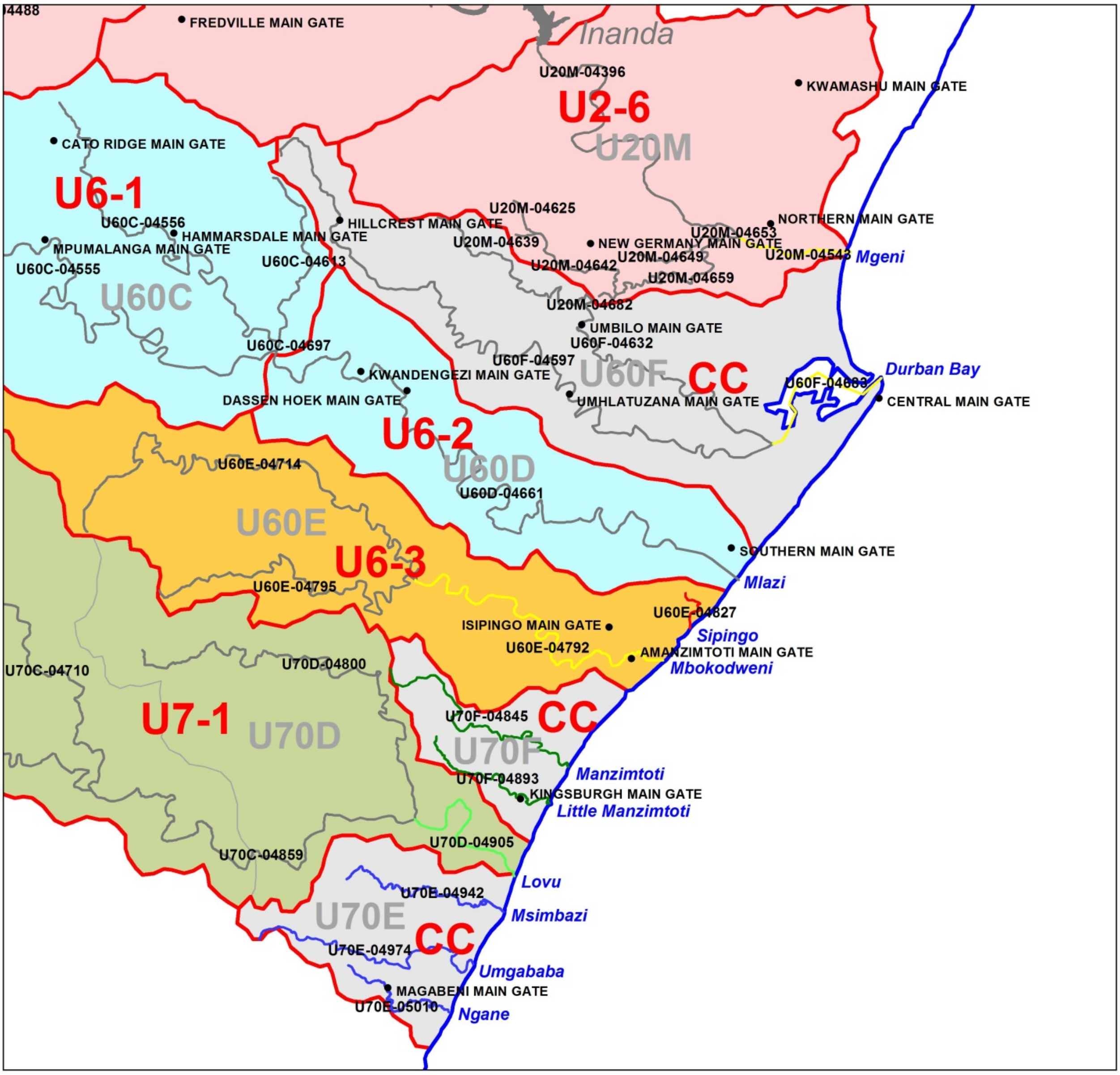

Figure 12.3 eThekwini Municipality WWTW located in the uMngeni to the Ngane River Catchments

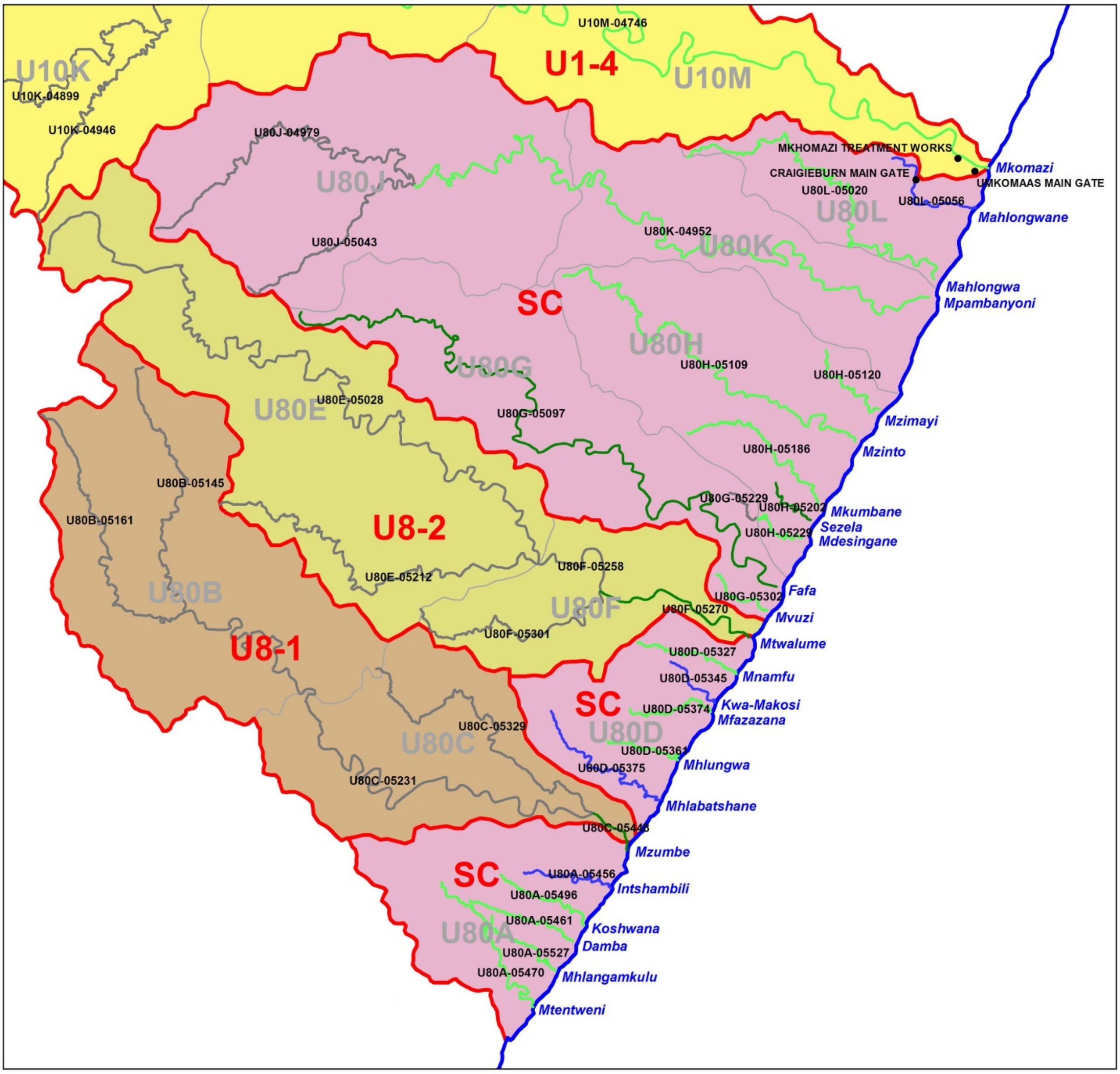

Figure 12.4 eThekwini Municipality WWTW located in the Mkomazi and Mahlongwane River Catchments

13 APPENDIX B: EWR STRUCTURES

The corresponding EWR structures incorporated in the WRYM and WRPM configurations for the modelling of the specified EWR scenario are provided in the following sections. Natural Flow (NF) and the EWR is provided in m^3/s).

13.1 MVOTI RIVER SYSTEM: EWR STRUCTURES

Table 13.1 Mv_I_EWR1: Recommended Total Flows C EC

October		November		December		January		February		March		April		May		June		July		August		September	
NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.049	0.031	0.050	0.032	0.082	0.037	0.164	0.046	0.287	0.062	0.291	0.072	0.224	0.080	0.157	0.070	0.120	0.065	0.075	0.049	0.052	0.036	0.050	0.029
0.075	0.032	0.120	0.037	0.194	0.043	0.243	0.053	0.356	0.068	0.370	0.080	0.343	0.082	0.231	0.077	0.158	0.065	0.101	0.049	0.075	0.036	0.069	0.030
0.086	0.032	0.147	0.052	0.235	0.068	0.336	0.087	0.451	0.101	0.463	0.111	0.413	0.106	0.261	0.083	0.174	0.067	0.112	0.049	0.086	0.036	0.081	0.032
0.116	0.036	0.181	0.067	0.261	0.087	0.388	0.117	0.529	0.136	0.571	0.141	0.471	0.130	0.299	0.100	0.189	0.073	0.127	0.049	0.101	0.038	0.104	0.034
0.134	0.038	0.235	0.076	0.299	0.101	0.448	0.135	0.631	0.154	0.657	0.169	0.505	0.154	0.347	0.103	0.212	0.079	0.134	0.051	0.108	0.040	0.112	0.037
0.161	0.044	0.255	0.088	0.347	0.113	0.526	0.150	0.737	0.182	0.713	0.197	0.583	0.169	0.377	0.114	0.224	0.088	0.153	0.058	0.127	0.048	0.123	0.041
0.179	0.053	0.278	0.182	0.396	0.242	0.601	0.344	0.938	0.379	0.982	0.359	0.660	0.304	0.403	0.134	0.270	0.104	0.172	0.073	0.134	0.056	0.139	0.049
0.202	0.062	0.316	0.207	0.515	0.282	0.736	0.409	1.586	0.458	1.307	0.422	0.737	0.359	0.448	0.159	0.301	0.123	0.205	0.090	0.157	0.066	0.162	0.059
0.213	0.076	0.394	0.230	0.676	0.335	1.169	0.469	2.049	0.516	1.826	0.473	0.930	0.398	0.508	0.181	0.336	0.144	0.243	0.107	0.187	0.085	0.177	0.073
0.302	0.102	0.471	0.270	1.755	0.411	3.230	0.592	2.958	0.607	2.673	0.516	1.269	0.443	0.571	0.209	0.397	0.167	0.287	0.130	0.246	0.111	0.247	0.097
9999.9	0.102	9999.9	0.270	9999.9	0.411	9999.9	0.592	9999.9	0.607	9999.9	0.516	9999.9	0.443	9999.9	0.209	9999.9	0.167	9999.9	0.130	9999.9	0.111	9999.9	0.097

Table 13.2 Mv_I_EWR1: Recommended Low Flows C EC

October		November		December		January		February		March		April		May		June		July		August		September	
NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.049	0.031	0.050	0.032	0.082	0.037	0.164	0.046	0.287	0.062	0.291	0.072	0.224	0.080	0.157	0.070	0.120	0.065	0.075	0.049	0.052	0.036	0.050	0.029
0.075	0.032	0.120	0.036	0.194	0.042	0.243	0.052	0.356	0.067	0.370	0.079	0.343	0.081	0.231	0.077	0.158	0.065	0.101	0.049	0.075	0.036	0.069	0.030
0.086	0.032	0.147	0.037	0.235	0.048	0.336	0.057	0.451	0.073	0.463	0.089	0.413	0.089	0.261	0.083	0.174	0.067	0.112	0.049	0.086	0.036	0.081	0.032
0.116	0.036	0.181	0.041	0.261	0.051	0.388	0.066	0.529	0.087	0.571	0.103	0.471	0.099	0.299	0.100	0.189	0.073	0.127	0.049	0.101	0.038	0.104	0.034
0.134	0.038	0.235	0.044	0.299	0.056	0.448	0.071	0.631	0.093	0.657	0.121	0.505	0.115	0.347	0.103	0.212	0.079	0.134	0.051	0.108	0.040	0.112	0.037
0.161	0.044	0.255	0.053	0.347	0.065	0.526	0.082	0.737	0.117	0.713	0.146	0.583	0.128	0.377	0.114	0.224	0.088	0.153	0.058	0.127	0.048	0.123	0.041
0.179	0.053	0.278	0.063	0.396	0.078	0.601	0.108	0.938	0.155	0.982	0.181	0.660	0.162	0.403	0.134	0.270	0.104	0.172	0.073	0.134	0.056	0.139	0.049
0.202	0.062	0.316	0.073	0.515	0.096	0.736	0.142	1.586	0.204	1.307	0.221	0.737	0.198	0.448	0.159	0.301	0.123	0.205	0.090	0.157	0.066	0.162	0.059
0.213	0.076	0.394	0.086	0.676	0.136	1.169	0.184	2.049	0.246	1.826	0.258	0.930	0.226	0.508	0.181	0.336	0.144	0.243	0.107	0.187	0.085	0.177	0.073
0.302	0.102	0.471	0.119	1.755	0.203	3.230	0.294	2.958	0.324	2.673	0.291	1.269	0.263	0.571	0.209	0.397	0.167	0.287	0.130	0.246	0.111	0.247	0.097
9999.9	0.102	9999.9	0.119	9999.9	0.203	9999.9	0.294	9999.9	0.324	9999.9	0.291	9999.9	0.263	9999.9	0.209	9999.9	0.167	9999.9	0.130	9999.9	0.111	9999.9	0.097

Table 13.3 Mv_I_EWR1: Low Flow+ C EC

October		November		December		January		February		March		April		May		June		July		August		September	
NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.049	0.031	0.050	0.032	0.082	0.037	0.164	0.046	0.287	0.062	0.291	0.072	0.224	0.080	0.157	0.070	0.120	0.065	0.075	0.049	0.052	0.036	0.050	0.029
0.075	0.032	0.120	0.036	0.194	0.042	0.243	0.053	0.356	0.068	0.370	0.080	0.343	0.081	0.231	0.077	0.158	0.065	0.101	0.049	0.075	0.036	0.069	0.030
0.086	0.032	0.147	0.037	0.235	0.048	0.336	0.087	0.451	0.101	0.463	0.111	0.413	0.089	0.261	0.083	0.174	0.067	0.112	0.049	0.086	0.036	0.081	0.032
0.116	0.036	0.181	0.041	0.261	0.051	0.388	0.117	0.529	0.136	0.571	0.141	0.471	0.099	0.299	0.100	0.189	0.073	0.127	0.049	0.101	0.038	0.104	0.034
0.134	0.038	0.235	0.044	0.299	0.056	0.448	0.135	0.631	0.154	0.657	0.169	0.505	0.115	0.347	0.103	0.212	0.079	0.134	0.051	0.108	0.040	0.112	0.037
0.161	0.044	0.255	0.053	0.347	0.065	0.526	0.150	0.737	0.182	0.713	0.197	0.583	0.128	0.377	0.114	0.224	0.088	0.153	0.058	0.127	0.048	0.123	0.041
0.179	0.053	0.278	0.063	0.396	0.078	0.601	0.344	0.938	0.379	0.982	0.359	0.660	0.162	0.403	0.134	0.270	0.104	0.172	0.073	0.134	0.056	0.139	0.049
0.202	0.062	0.316	0.073	0.515	0.096	0.736	0.409	1.586	0.458	1.307	0.422	0.737	0.198	0.448	0.159	0.301	0.123	0.205	0.090	0.157	0.066	0.162	0.059
0.213	0.076	0.394	0.086	0.676	0.136	1.169	0.469	2.049	0.516	1.826	0.473	0.930	0.226	0.508	0.181	0.336	0.144	0.243	0.107	0.187	0.085	0.177	0.073
0.302	0.102	0.471	0.119	1.755	0.203	3.230	0.592	2.958	0.607	2.673	0.516	1.269	0.263	0.571	0.209	0.397	0.167	0.287	0.130	0.246	0.111	0.247	0.097
9999.9	0.102	9999.9	0.119	9999.9	0.203	9999.9	0.592	9999.9	0.607	9999.9	0.516	9999.9	0.263	9999.9	0.209	9999.9	0.167	9999.9	0.130	9999.9	0.111	9999.9	0.097

Table 13.4 Mv_I_EWR2: Recommended Total Flows B/C EC

October		November		December		January		February		March		April		May		June		July		August		September	
NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.777	0.144	0.965	0.276	1.408	0.367	2.535	0.481	3.134	0.703	3.073	0.828	2.230	0.625	1.691	0.443	1.208	0.314	0.821	0.151	0.676	0.126	0.683	0.138
1.307	0.320	2.203	0.407	2.587	0.505	3.218	0.661	5.121	0.849	5.137	1.028	3.904	0.910	2.673	0.867	1.821	0.588	1.187	0.364	0.952	0.285	0.938	0.266
1.688	0.578	2.967	0.971	4.014	1.166	4.406	1.386	6.277	1.601	6.358	1.791	5.135	1.569	3.162	1.092	2.041	0.695	1.340	0.432	1.105	0.362	1.204	0.330
2.158	0.821	3.858	1.444	5.108	1.666	5.910	2.100	7.764	2.295	8.613	2.489	6.335	2.095	3.644	1.297	2.392	0.833	1.557	0.541	1.344	0.451	1.597	0.417
2.356	1.070	4.437	1.851	5.507	2.125	7.183	2.714	9.366	2.917	9.550	3.071	7.168	2.583	4.286	1.556	2.554	1.020	1.699	0.686	1.471	0.578	1.744	0.552
2.897	1.343	5.112	2.162	6.489	2.493	9.584	3.168	11.681	3.513	11.089	3.560	8.198	2.917	4.596	1.817	3.113	1.361	1.863	0.758	1.725	0.721	1.971	0.732
3.510	1.739	5.860	2.754	7.706	3.158	11.141	4.005	14.258	4.445	13.725	4.274	9.460	3.514	5.518	2.101	3.318	1.672	2.031	0.939	1.919	0.859	2.411	0.968
4.088	2.106	8.171	3.270	10.633	3.932	13.086	4.845	21.046	5.044	16.924	4.810	10.895	4.027	6.179	2.598	3.719	1.958	2.953	1.361	2.184	1.013	2.681	1.260
4.716	2.367	9.599	3.827	14.068	4.545	21.961	5.526	31.133	5.596	24.754	5.181	13.708	4.405	6.605	2.901	4.437	2.340	3.386	1.984	3.006	1.478	2.990	1.518
8.737	2.813	18.789	4.454	21.868	5.132	36.589	5.900	38.520	6.292	41.950	5.436	17.581	4.712	8.557	3.051	6.520	2.559	4.454	2.121	3.879	1.894	4.896	1.696
9999.9	2.813	9999.9	4.454	9999.9	5.132	9999.9	5.900	9999.9	6.292	9999.9	5.436	9999.9	4.712	9999.9	3.051	9999.9	2.559	9999.9	2.121	9999.9	1.894	9999.9	1.696

Table 13.5 Mv_I_EWR2: Recommended Low Flows B/C EC

October		November		December		January		February		March		April		May		June		July		August		September	
NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.777	0.144	0.965	0.276	1.408	0.367	2.535	0.481	3.134	0.703	3.073	0.828	2.230	0.625	1.691	0.443	1.208	0.314	0.821	0.151	0.676	0.126	0.683	0.138
1.307	0.313	2.203	0.390	2.587	0.487	3.218	0.639	5.121	0.828	5.137	1.011	3.904	0.899	2.673	0.867	1.821	0.588	1.187	0.364	0.952	0.285	0.938	0.266
1.688	0.376	2.967	0.498	4.014	0.656	4.406	0.745	6.277	1.007	6.358	1.304	5.135	1.247	3.162	1.092	2.041	0.695	1.340	0.432	1.105	0.362	1.204	0.330
2.158	0.474	3.858	0.633	5.108	0.790	5.910	0.999	7.764	1.277	8.613	1.654	6.335	1.541	3.644	1.297	2.392	0.833	1.557	0.541	1.344	0.451	1.597	0.417
2.356	0.637	4.437	0.839	5.507	1.032	7.183	1.340	9.366	1.646	9.550	2.029	7.168	1.892	4.286	1.556	2.554	1.020	1.699	0.686	1.471	0.578	1.744	0.552
2.897	0.880	5.112	1.079	6.489	1.324	9.584	1.698	11.681	2.153	11.089	2.444	8.198	2.177	4.596	1.817	3.113	1.361	1.863	0.758	1.725	0.721	1.971	0.732
3.510	1.134	5.860	1.338	7.706	1.629	11.141	2.083	14.258	2.668	13.725	2.816	9.460	2.546	5.518	2.101	3.318	1.672	2.031	0.939	1.919	0.859	2.411	0.968
4.088	1.422	8.171	1.672	10.633	2.207	13.086	2.676	21.046	3.038	16.924	3.163	10.895	2.935	6.179	2.598	3.719	1.958	2.953	1.361	2.184	1.013	2.681	1.260
4.716	1.623	9.599	2.084	14.068	2.664	21.961	3.160	31.133	3.409	24.754	3.386	13.708	3.215	6.605	2.901	4.437	2.340	3.386	1.984	3.006	1.478	2.990	1.518
8.737	2.014	18.789	2.585	21.868	3.115	36.589	3.363	38.520	3.946	41.950	3.511	17.581	3.436	8.557	3.051	6.520	2.559	4.454	2.121	3.879	1.894	4.896	1.696
9999.9	2.014	9999.9	2.585	9999.9	3.115	9999.9	3.363	9999.9	3.946	9999.9	3.511	9999.9	3.436	9999.9	3.051	9999.9	2.559	9999.9	2.121	9999.9	1.894	9999.9	1.696

Table 13.6 Mv_I_EWR2: Low Flows+ B/C EC

October		November		December		January		February		March		April		May		June		July		August		September	
NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.777	0.144	0.965	0.276	1.408	0.367	2.535	0.481	3.134	0.703	3.073	0.828	2.230	0.625	1.691	0.443	1.208	0.314	0.821	0.151	0.676	0.126	0.683	0.138
1.307	0.313	2.203	0.390	2.587	0.487	3.218	0.661	5.121	0.849	5.137	1.028	3.904	0.899	2.673	0.867	1.821	0.588	1.187	0.364	0.952	0.285	0.938	0.266
1.688	0.376	2.967	0.498	4.014	0.656	4.406	1.386	6.277	1.601	6.358	1.791	5.135	1.247	3.162	1.092	2.041	0.695	1.340	0.432	1.105	0.362	1.204	0.330
2.158	0.474	3.858	0.633	5.108	0.790	5.910	2.100	7.764	2.295	8.613	2.489	6.335	1.541	3.644	1.297	2.392	0.833	1.557	0.541	1.344	0.451	1.597	0.417
2.356	0.637	4.437	0.839	5.507	1.032	7.183	2.714	9.366	2.917	9.550	3.071	7.168	1.892	4.286	1.556	2.554	1.020	1.699	0.686	1.471	0.578	1.744	0.552
2.897	0.880	5.112	1.079	6.489	1.324	9.584	3.168	11.681	3.513	11.089	3.560	8.198	2.177	4.596	1.817	3.113	1.361	1.863	0.758	1.725	0.721	1.971	0.732
3.510	1.134	5.860	1.338	7.706	1.629	11.141	4.005	14.258	4.445	13.725	4.274	9.460	2.546	5.518	2.101	3.318	1.672	2.031	0.939	1.919	0.859	2.411	0.968
4.088	1.422	8.171	1.672	10.633	2.207	13.086	4.845	21.046	5.044	16.924	4.810	10.895	2.935	6.179	2.598	3.719	1.958	2.953	1.361	2.184	1.013	2.681	1.260
4.716	1.623	9.599	2.084	14.068	2.664	21.961	5.526	31.133	5.596	24.754	5.181	13.708	3.215	6.605	2.901	4.437	2.340	3.386	1.984	3.006	1.478	2.990	1.518
8.737	2.014	18.789	2.585	21.868	3.115	36.589	5.900	38.520	6.292	41.950	5.436	17.581	3.436	8.557	3.051	6.520	2.559	4.454	2.121	3.879	1.894	4.896	1.696
9999.9	2.014	9999.9	2.585	9999.9	3.115	9999.9	5.900	9999.9	6.292	9999.9	5.436	9999.9	3.436	9999.9	3.051	9999.9	2.559	9999.9	2.121	9999.9	1.894	9999.9	1.696

13.2 uMNGENI RIVER SYSTEM: EWR STRUCTURES

Table 13.7 Mg_I_EWR2: Recommended Total Flows C EC

October		November		December		January		February		March		April		May		June		July		August		September	
NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1.049	0.327	1.227	0.589	1.329	0.470	1.520	0.513	1.356	0.281	2.098	0.654	1.902	0.393	1.288	0.457	0.910	0.350	0.739	0.379	0.739	0.404	0.610	0.395
1.467	0.517	2.315	0.617	2.543	0.659	3.315	0.561	4.523	0.457	4.633	0.960	3.333	0.846	2.177	0.584	1.547	0.540	1.120	0.506	0.904	0.413	0.976	0.461
1.826	0.688	2.894	0.784	3.118	0.836	4.615	0.985	6.731	0.930	6.732	1.489	4.969	1.078	2.849	0.691	1.910	0.710	1.333	0.646	1.385	0.585	1.265	0.565
2.218	0.786	3.561	0.836	4.529	0.934	6.564	1.269	7.596	1.340	8.961	1.871	5.370	1.414	3.043	0.852	2.195	0.826	1.624	0.750	1.497	0.672	1.613	0.680
2.528	0.818	4.406	0.877	5.839	1.040	7.990	1.700	9.878	1.697	9.730	2.237	6.358	1.719	3.651	1.024	2.577	0.882	1.852	0.854	1.792	0.834	1.975	0.810
2.961	0.836	5.127	0.914	7.799	1.189	9.771	2.068	11.468	1.984	10.947	2.534	7.465	1.850	4.148	1.157	2.971	0.924	2.322	0.876	2.158	0.862	2.211	0.826
3.338	0.872	5.926	0.947	8.994	1.409	11.895	3.077	14.217	3.182	12.493	3.551	7.921	2.540	4.518	1.307	3.148	0.999	2.561	0.909	2.408	0.872	2.330	0.840
4.017	0.890	6.732	1.030	10.099	2.120	13.430	3.734	18.076	3.532	15.218	3.752	9.479	2.635	5.313	1.526	3.418	1.033	2.819	0.939	2.849	0.896	3.067	0.871
5.003	0.973	7.913	1.303	15.804	3.479	17.581	3.944	25.217	3.736	17.944	3.852	11.779	2.688	5.675	1.592	3.823	1.130	3.297	0.978	3.203	0.948	3.700	0.902
9.610	2.000	13.233	2.132	20.266	3.654	27.322	4.121	34.161	3.873	25.814	3.928	15.289	2.770	6.422	1.650	4.988	1.264	4.749	1.060	3.640	1.068	4.394	1.008
9999.9	2.000	9999.9	2.132	9999.9	3.654	9999.9	4.121	9999.9	3.873	9999.9	3.928	9999.9	2.770	9999.9	1.650	9999.9	1.264	9999.9	1.060	9999.9	1.068	9999.9	1.008

Table 13.8 Mg_I_EWR2: Recommended Low Flows C EC

October		November		December		January		February		March		April		May		June		July		August		September	
NF	**EWR**	**NF**	**EWR**	**NF**	**EWR**	**NF**	**EWR**	**NF**	**EWR**	**NF**	**EWR**	**NF**	**EWR**	**NF**	**EWR**	**NF**	**EWR**	**NF**	**EWR**	**NF**	**EWR**	**NF**	**EWR**
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1.049	0.327	1.227	0.589	1.329	0.470	1.520	0.513	1.356	0.281	2.098	0.654	1.902	0.393	1.288	0.457	0.910	0.350	0.739	0.379	0.739	0.404	0.610	0.395
1.467	0.515	2.315	0.613	2.543	0.655	3.315	0.556	4.523	0.453	4.633	0.955	3.333	0.844	2.177	0.584	1.547	0.540	1.120	0.506	0.904	0.413	0.976	0.461
1.826	0.627	2.894	0.690	3.118	0.717	4.615	0.701	6.731	0.600	6.732	1.210	4.969	1.069	2.849	0.691	1.910	0.710	1.333	0.646	1.385	0.585	1.265	0.565
2.218	0.714	3.561	0.806	4.529	0.855	6.564	0.854	7.596	0.774	8.961	1.391	5.370	1.262	3.043	0.852	2.195	0.826	1.624	0.750	1.497	0.672	1.613	0.680
2.528	0.818	4.406	0.877	5.839	1.033	7.990	1.062	9.878	0.990	9.730	1.638	6.358	1.385	3.651	1.024	2.577	0.882	1.852	0.854	1.792	0.834	1.975	0.810
2.961	0.836	5.127	0.914	7.799	1.187	9.771	1.250	11.468	1.191	10.947	1.861	7.465	1.476	4.148	1.157	2.971	0.924	2.322	0.876	2.158	0.862	2.211	0.826
3.338	0.872	5.926	0.947	8.994	1.347	11.895	1.403	14.217	1.363	12.493	2.007	7.921	1.682	4.518	1.307	3.148	0.999	2.561	0.909	2.408	0.872	2.330	0.840
4.017	0.890	6.732	1.030	10.099	1.495	13.430	1.554	18.076	1.512	15.218	2.039	9.479	1.682	5.313	1.526	3.418	1.033	2.819	0.939	2.849	0.896	3.067	0.871
5.003	0.973	7.913	1.303	15.804	1.592	17.581	1.643	25.217	1.604	17.944	2.043	11.779	1.683	5.675	1.592	3.823	1.130	3.297	0.978	3.203	0.948	3.700	0.902
9.610	1.286	13.233	1.382	20.266	1.691	27.322	1.728	34.161	1.656	25.814	2.047	15.289	1.725	6.422	1.650	4.988	1.264	4.749	1.060	3.640	1.068	4.394	1.008
9999.9	1.286	9999.9	1.382	9999.9	1.691	9999.9	1.728	9999.9	1.656	9999.9	2.047	9999.9	1.725	9999.9	1.650	9999.9	1.264	9999.9	1.060	9999.9	1.068	9999.9	1.008

Table 13.9 Mg_I_EWR2: Low Flows+ C EC

October		November		December		January		February		March		April		May		June		July		August		September	
NF	**EWR**	**NF**	**EWR**	**NF**	**EWR**	**NF**	**EWR**	**NF**	**EWR**	**NF**	**EWR**	**NF**	**EWR**	**NF**	**EWR**	**NF**	**EWR**	**NF**	**EWR**	**NF**	**EWR**	**NF**	**EWR**
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1.049	0.327	1.227	0.589	1.329	0.470	1.520	0.513	1.356	0.281	2.098	0.654	1.902	0.393	1.288	0.457	0.910	0.350	0.739	0.379	0.739	0.404	0.610	0.395
1.467	0.515	2.315	0.613	2.543	0.655	3.315	0.561	4.523	0.457	4.633	0.960	3.333	0.844	2.177	0.584	1.547	0.540	1.120	0.506	0.904	0.413	0.976	0.461
1.826	0.627	2.894	0.690	3.118	0.717	4.615	0.985	6.731	0.930	6.732	1.489	4.969	1.069	2.849	0.691	1.910	0.710	1.333	0.646	1.385	0.585	1.265	0.565
2.218	0.714	3.561	0.806	4.529	0.855	6.564	1.269	7.596	1.340	8.961	1.871	5.370	1.262	3.043	0.852	2.195	0.826	1.624	0.750	1.497	0.672	1.613	0.680
2.528	0.818	4.406	0.877	5.839	1.033	7.990	1.700	9.878	1.697	9.730	2.237	6.358	1.385	3.651	1.024	2.577	0.882	1.852	0.854	1.792	0.834	1.975	0.810
2.961	0.836	5.127	0.914	7.799	1.187	9.771	2.068	11.468	1.984	10.947	2.534	7.465	1.476	4.148	1.157	2.971	0.924	2.322	0.876	2.158	0.862	2.211	0.826
3.338	0.872	5.926	0.947	8.994	1.347	11.895	3.077	14.217	3.182	12.493	3.551	7.921	1.682	4.518	1.307	3.148	0.999	2.561	0.909	2.408	0.872	2.330	0.840
4.017	0.890	6.732	1.030	10.099	1.495	13.430	3.734	18.076	3.532	15.218	3.752	9.479	1.682	5.313	1.526	3.418	1.033	2.819	0.939	2.849	0.896	3.067	0.871
5.003	0.973	7.913	1.303	15.804	1.592	17.581	3.944	25.217	3.736	17.944	3.852	11.779	1.683	5.675	1.592	3.823	1.130	3.297	0.978	3.203	0.948	3.700	0.902
9.610	1.286	13.233	1.382	20.266	1.691	27.322	4.121	34.161	3.873	25.814	3.928	15.289	1.725	6.422	1.650	4.988	1.264	4.749	1.060	3.640	1.068	4.394	1.008
9999.9	1.286	9999.9	1.382	9999.9	1.691	9999.9	4.121	9999.9	3.873	9999.9	3.928	9999.9	1.725	9999.9	1.650	9999.9	1.264	9999.9	1.060	9999.9	1.068	9999.9	1.008

Table 13.10 Mg_I_EWR5: Recommended Total Flows C/D EC

October		November		December		January		February		March		April		May		June		July		August		September	
NF	**EWR**	**NF**	**EWR**	**NF**	**EWR**	**NF**	**EWR**	**NF**	**EWR**	**NF**	**EWR**	**NF**	**EWR**	**NF**	**EWR**	**NF**	**EWR**	**NF**	**EWR**	**NF**	**EWR**	**NF**	**EWR**
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2.610	0.973	3.684	1.137	3.390	1.289	5.877	1.566	4.105	1.704	6.246	2.029	4.236	1.703	2.789	1.328	2.319	1.136	1.915	1.038	2.221	0.999	1.894	0.857
3.539	1.119	5.235	1.342	6.392	1.467	7.803	1.601	12.656	1.873	12.033	2.500	8.684	2.141	4.835	1.766	4.039	1.483	3.155	1.272	2.531	1.075	2.724	1.015
4.126	1.663	6.779	2.376	8.934	2.765	10.947	3.019	14.475	3.210	14.684	3.951	11.620	3.275	7.157	2.018	4.892	1.796	3.614	1.547	3.256	1.408	3.372	1.319
4.794	2.180	8.106	2.785	11.395	3.091	14.397	3.557	20.628	4.374	19.325	4.507	12.704	3.763	7.833	2.428	5.590	2.214	4.051	1.909	3.625	1.548	3.931	1.730
5.365	2.313	9.402	3.079	12.795	3.312	19.646	3.875	23.242	5.299	24.526	5.755	15.201	4.184	9.222	3.014	6.698	2.789	4.786	2.518	4.316	2.253	4.425	2.221
6.209	2.768	11.127	3.250	15.950	3.474	24.223	4.482	31.965	6.243	28.166	8.085	18.376	4.433	10.685	3.454	7.608	3.009	5.563	2.602	4.917	2.444	5.042	2.573
7.295	2.892	12.909	3.388	19.228	3.721	30.772	6.353	39.729	7.321	30.809	10.006	20.756	5.097	12.089	3.728	8.137	3.102	6.138	2.696	5.395	2.572	5.648	2.704
8.733	3.177	15.594	3.669	27.591	4.879	36.171	9.060	48.488	11.055	43.754	13.356	26.331	7.200	13.269	4.287	8.711	3.448	6.519	2.962	6.194	2.814	6.686	2.860
10.185	3.361	20.112	3.844	40.356	9.963	44.064	13.395	60.771	15.506	51.228	15.066	34.691	12.512	15.203	4.796	9.958	3.791	7.852	3.294	7.359	3.172	7.554	3.336
17.637	4.490	29.498	8.247	49.149	13.705	66.842	15.526	94.002	18.118	65.912	15.901	40.783	13.597	19.079	5.518	11.381	4.039	12.317	3.840	8.961	3.589	9.101	3.652
9999.9	4.490	9999.9	8.247	9999.9	13.705	9999.9	15.526	9999.9	18.118	9999.9	15.901	9999.9	13.597	9999.9	5.518	9999.9	4.039	9999.9	3.840	9999.9	3.589	9999.9	3.652

Table 13.11 Mg_I_EWR5: Recommended Low Flows C/D EC

October		November		December		January		February		March		April		May		June		July		August		September	
NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2.610	0.973	3.684	1.137	3.390	1.289	5.877	1.566	4.105	1.704	6.246	2.029	4.236	1.703	2.789	1.328	2.319	1.136	1.915	1.038	2.221	0.999	1.894	0.857
3.539	1.116	5.235	1.332	6.392	1.453	7.803	1.585	12.656	1.857	12.033	2.486	8.684	2.134	4.835	1.766	4.039	1.483	3.155	1.272	2.531	1.075	2.724	1.015
4.126	1.439	6.779	1.629	8.934	1.792	10.947	1.918	14.475	2.025	14.684	2.973	11.620	2.765	7.157	2.018	4.892	1.796	3.614	1.547	3.256	1.408	3.372	1.319
4.794	1.797	8.106	2.000	11.395	2.231	14.397	2.394	20.628	2.342	19.325	3.582	12.704	3.182	7.833	2.428	5.590	2.214	4.051	1.909	3.625	1.548	3.931	1.730
5.365	1.834	9.402	2.532	12.795	2.835	19.646	3.018	23.242	2.761	24.526	3.936	15.201	3.182	9.222	3.014	6.698	2.789	4.786	2.518	4.316	2.253	4.425	2.221
6.209	2.768	11.127	3.250	15.950	3.474	24.223	3.913	31.965	3.532	28.166	5.799	18.376	3.836	10.685	3.454	7.608	3.009	5.563	2.602	4.917	2.444	5.042	2.573
7.295	2.892	12.909	3.388	19.228	3.721	30.772	5.053	39.729	4.603	30.809	7.704	20.756	5.097	12.089	3.728	8.137	3.102	6.138	2.696	5.395	2.572	5.648	2.704
8.733	3.177	15.594	3.669	27.591	4.879	36.171	8.166	48.488	8.338	43.754	11.054	26.331	7.200	13.269	4.287	8.711	3.448	6.519	2.962	6.194	2.814	6.686	2.860
10.185	3.361	20.112	3.844	40.356	9.126	44.064	11.156	60.771	12.789	51.228	12.765	34.691	11.343	15.203	4.796	9.958	3.791	7.852	3.294	7.359	3.172	7.554	3.336
17.637	4.490	29.498	6.987	49.149	11.476	66.842	12.957	94.002	15.402	65.912	13.599	40.783	12.428	19.079	5.518	11.381	4.039	12.317	3.840	8.961	3.589	9.101	3.652
9999.9	4.490	9999.9	6.987	9999.9	11.476	9999.9	12.957	9999.9	15.402	9999.9	13.599	9999.9	12.428	9999.9	5.518	9999.9	4.039	9999.9	3.840	9999.9	3.589	9999.9	3.652

Table 13.12 Mg _I_EWR5: Low Flows+ C/D EC

October		November		December		January		February		March		April		May		June		July		August		September	
NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2.610	0.973	3.684	1.137	3.390	1.289	5.877	1.566	4.105	1.704	6.246	2.029	4.236	1.703	2.789	1.328	2.319	1.136	1.915	1.038	2.221	0.999	1.894	0.857
3.539	1.116	5.235	1.332	6.392	1.453	7.803	1.601	12.656	1.873	12.033	2.500	8.684	2.134	4.835	1.766	4.039	1.483	3.155	1.272	2.531	1.075	2.724	1.015
4.126	1.439	6.779	1.629	8.934	1.792	10.947	3.019	14.475	3.210	14.684	3.951	11.620	2.765	7.157	2.018	4.892	1.796	3.614	1.547	3.256	1.408	3.372	1.319
4.794	1.797	8.106	2.000	11.395	2.231	14.397	3.557	20.628	4.374	19.325	4.507	12.704	3.182	7.833	2.428	5.590	2.214	4.051	1.909	3.625	1.548	3.931	1.730
5.365	1.834	9.402	2.532	12.795	2.835	19.646	3.875	23.242	5.299	24.526	5.755	15.201	3.182	9.222	3.014	6.698	2.789	4.786	2.518	4.316	2.253	4.425	2.221
6.209	2.768	11.127	3.250	15.950	3.474	24.223	4.482	31.965	6.243	28.166	8.085	18.376	3.836	10.685	3.454	7.608	3.009	5.563	2.602	4.917	2.444	5.042	2.573
7.295	2.892	12.909	3.388	19.228	3.721	30.772	6.353	39.729	7.321	30.809	10.006	20.756	5.097	12.089	3.728	8.137	3.102	6.138	2.696	5.395	2.572	5.648	2.704
8.733	3.177	15.594	3.669	27.591	4.879	36.171	9.060	48.488	11.055	43.754	13.356	26.331	7.200	13.269	4.287	8.711	3.448	6.519	2.962	6.194	2.814	6.686	2.860
10.185	3.361	20.112	3.844	40.356	9.126	44.064	13.395	60.771	15.506	51.228	15.066	34.691	11.343	15.203	4.796	9.958	3.791	7.852	3.294	7.359	3.172	7.554	3.336
17.637	4.490	29.498	6.987	49.149	11.476	66.842	15.526	94.002	18.118	65.912	15.901	40.783	12.428	19.079	5.518	11.381	4.039	12.317	3.840	8.961	3.589	9.101	3.652
9999.9	4.490	9999.9	6.987	9999.9	11.476	9999.9	15.526	9999.9	18.118	9999.9	15.901	9999.9	12.428	9999.9	5.518	9999.9	4.039	9999.9	3.840	9999.9	3.589	9999.9	3.652

13.3 MKOMAZI RIVER SYSTEM: EWR STRUCTURES

Table 13.13 MK_I_EWR2: Recommended Total Flows B EC

October		November		December		January		February		March		April		May		June		July		August		September	
NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2.274	1.621	3.110	2.306	4.730	2.864	7.680	4.340	10.869	5.149	12.627	8.014	7.188	5.901	3.950	2.935	2.307	1.698	1.561	1.107	1.370	1.053	1.246	1.110
3.457	2.009	7.666	2.936	8.714	3.643	22.793	5.219	26.311	6.091	27.539	8.933	11.674	6.534	5.709	4.270	3.468	2.665	2.225	1.646	2.039	1.518	2.191	1.551
4.704	3.507	10.741	5.936	16.267	7.683	29.465	9.251	39.393	10.206	35.615	11.492	15.995	7.803	7.034	4.673	4.167	2.965	2.994	2.239	2.468	1.599	3.206	1.941
5.320	4.297	12.253	8.560	26.262	11.327	36.559	13.236	42.261	14.324	37.907	14.503	18.661	9.990	8.681	5.834	5.031	3.644	3.528	2.670	3.058	2.014	3.831	2.374
6.127	4.990	15.980	10.528	32.699	13.654	42.447	16.184	55.220	17.464	43.242	17.039	23.777	11.846	9.928	7.039	5.868	4.375	4.249	3.286	3.767	2.568	4.279	2.869
7.882	6.299	20.818	11.812	38.482	15.560	54.581	18.374	62.246	19.930	46.412	19.062	26.370	14.123	10.659	8.215	6.335	4.998	4.745	3.823	4.398	3.056	4.610	3.306
10.454	7.185	23.098	13.049	43.776	17.562	60.036	21.258	71.223	22.471	52.998	21.051	29.630	16.012	11.436	9.270	6.910	5.618	5.096	4.214	4.966	3.771	5.590	3.662
13.504	7.928	26.617	14.372	52.740	19.950	69.093	23.640	81.580	25.064	58.490	22.608	31.651	17.382	13.247	9.726	7.600	5.747	5.847	4.500	5.623	4.087	7.230	3.887
16.077	8.580	31.898	16.061	67.876	22.276	87.586	26.564	109.153	27.724	73.891	24.655	41.852	18.191	15.808	9.776	9.549	6.193	7.224	4.956	6.552	4.175	9.383	4.012
23.611	9.494	57.041	18.087	92.316	24.571	112.451	29.200	134.292	30.537	105.063	26.950	62.917	19.589	20.583	9.983	12.840	6.294	14.333	5.827	10.921	4.274	14.830	4.075
9999.9	9.494	9999.9	18.087	9999.9	24.571	9999.9	29.200	9999.9	30.537	9999.9	26.950	9999.9	19.589	9999.9	9.983	9999.9	6.294	9999.9	5.827	9999.9	4.274	9999.9	4.075

Table 13.14 MK_I_EWR2: Recommended Low Flows B EC

October		November		December		January		February		March		April		May		June		July		August		September	
NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2.274	1.621	3.110	2.306	4.730	2.864	7.680	4.340	10.869	5.149	12.627	8.014	7.188	5.901	3.950	2.935	2.307	1.698	1.561	1.107	1.370	1.053	1.246	1.110
3.457	1.974	7.666	2.851	8.714	3.543	22.793	5.115	26.311	5.991	27.539	8.862	11.674	6.501	5.709	4.270	3.468	2.665	2.225	1.646	2.039	1.518	2.191	1.551
4.704	2.370	10.741	3.162	16.267	4.423	29.465	5.869	39.393	6.948	35.615	9.152	15.995	6.731	7.034	4.673	4.167	2.965	2.994	2.239	2.468	1.599	3.206	1.941
5.320	2.757	12.253	3.798	26.262	5.731	36.559	7.432	42.261	8.732	37.907	10.488	18.661	8.150	8.681	5.834	5.031	3.644	3.528	2.670	3.058	2.014	3.831	2.374
6.127	3.267	15.980	4.584	32.699	6.668	42.447	8.938	55.220	10.483	43.242	12.026	23.777	9.549	9.928	7.039	5.868	4.375	4.249	3.286	3.767	2.568	4.279	2.869
7.882	3.694	20.818	5.453	38.482	8.087	54.581	10.623	62.246	12.461	46.412	13.700	26.370	11.666	10.659	8.215	6.335	4.998	4.745	3.823	4.398	3.056	4.610	3.306
10.454	4.437	23.098	6.339	43.776	9.676	60.036	13.078	71.223	14.590	52.998	15.392	29.630	13.419	11.436	9.270	6.910	5.618	5.096	4.214	4.966	3.771	5.590	3.662
13.504	4.811	26.617	6.761	52.740	11.005	69.093	14.363	81.580	16.125	58.490	16.190	31.651	14.442	13.247	9.726	7.600	5.747	5.847	4.500	5.623	4.087	7.230	3.887
16.077	4.879	31.898	7.026	67.876	11.658	87.586	15.550	109.153	17.113	73.891	17.035	41.852	14.700	15.808	9.776	9.549	6.193	7.224	4.956	6.552	4.175	9.383	4.012
23.611	5.009	57.041	7.135	92.316	11.700	112.451	15.849	134.292	17.674	105.063	17.714	62.917	15.357	20.583	9.983	12.840	6.294	14.333	5.827	10.921	4.274	14.830	4.075
9999.9	5.009	9999.9	7.135	9999.9	11.700	9999.9	15.849	9999.9	17.674	9999.9	17.714	9999.9	15.357	9999.9	9.983	9999.9	6.294	9999.9	5.827	9999.9	4.274	9999.9	4.075

Table 13.15 MK_I_EWR2: Low Flows+ B EC

October		November		December		January		February		March		April		May		June		July		August		September	
NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2.274	1.621	3.110	2.306	4.730	2.864	7.680	4.340	10.869	5.149	12.627	8.014	7.188	5.901	3.950	2.935	2.307	1.698	1.561	1.107	1.370	1.053	1.246	1.110
3.457	1.974	7.666	2.851	8.714	3.543	22.793	5.219	26.311	6.091	27.539	8.933	11.674	6.501	5.709	4.270	3.468	2.665	2.225	1.646	2.039	1.518	2.191	1.551
4.704	2.370	10.741	3.162	16.267	4.423	29.465	9.251	39.393	10.206	35.615	11.492	15.995	6.731	7.034	4.673	4.167	2.965	2.994	2.239	2.468	1.599	3.206	1.941
5.320	2.757	12.253	3.798	26.262	5.731	36.559	13.236	42.261	14.324	37.907	14.503	18.661	8.150	8.681	5.834	5.031	3.644	3.528	2.670	3.058	2.014	3.831	2.374
6.127	3.267	15.980	4.584	32.699	6.668	42.447	16.184	55.220	17.464	43.242	17.039	23.777	9.549	9.928	7.039	5.868	4.375	4.249	3.286	3.767	2.568	4.279	2.869
7.882	3.694	20.818	5.453	38.482	8.087	54.581	18.374	62.246	19.930	46.412	19.062	26.370	11.666	10.659	8.215	6.335	4.998	4.745	3.823	4.398	3.056	4.610	3.306
10.454	4.437	23.098	6.339	43.776	9.676	60.036	21.258	71.223	22.471	52.998	21.051	29.630	13.419	11.436	9.270	6.910	5.618	5.096	4.214	4.966	3.771	5.590	3.662
13.504	4.811	26.617	6.761	52.740	11.005	69.093	23.640	81.580	25.064	58.490	22.608	31.651	14.442	13.247	9.726	7.600	5.747	5.847	4.500	5.623	4.087	7.230	3.887
16.077	4.879	31.898	7.026	67.876	11.658	87.586	26.564	109.153	27.724	73.891	24.655	41.852	14.700	15.808	9.776	9.549	6.193	7.224	4.956	6.552	4.175	9.383	4.012
23.611	5.009	57.041	7.135	92.316	11.700	112.451	29.200	134.292	30.537	105.063	26.950	62.917	15.357	20.583	9.983	12.840	6.294	14.333	5.827	10.921	4.274	14.830	4.075
9999.9	5.009	9999.9	7.135	9999.9	11.700	9999.9	29.200	9999.9	30.537	9999.9	26.950	9999.9	15.357	9999.9	9.983	9999.9	6.294	9999.9	5.827	9999.9	4.274	9999.9	4.075

Table 13.16 MK_I_EWR2: Recommended Total Flows B EC

October		November		December		January		February		March		April		May		June		July		August		September	
NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2.852	1.792	3.839	2.514	5.507	3.178	8.438	4.662	12.873	5.554	15.367	6.961	8.457	6.092	4.887	3.120	2.986	1.832	2.091	1.019	1.777	0.895	1.590	0.899
4.182	2.282	9.919	3.299	10.503	4.031	25.474	5.676	29.089	6.724	31.728	7.884	14.252	6.686	6.635	4.736	4.387	3.009	2.696	1.659	2.472	1.420	2.909	1.647
5.735	3.762	12.238	6.801	19.280	8.836	34.334	10.412	44.883	11.945	40.823	11.608	19.028	9.099	8.830	5.385	5.224	3.386	3.607	2.471	3.174	1.840	4.039	2.213
6.440	4.909	14.001	9.758	29.488	12.827	41.510	14.537	49.857	16.459	45.979	14.810	23.410	11.179	10.891	6.412	6.296	4.063	4.462	2.980	3.715	2.341	4.788	2.651
7.594	5.610	18.839	11.653	36.989	15.409	49.141	17.332	64.979	19.209	50.004	17.518	28.642	12.894	12.381	7.235	7.276	4.498	5.294	3.390	4.544	2.666	5.177	3.037
9.091	6.181	24.387	12.914	45.296	17.137	58.401	19.526	70.850	21.463	55.473	19.719	32.060	14.868	13.306	8.443	7.998	5.110	5.821	3.862	5.470	3.122	5.976	3.323
11.578	6.727	26.825	14.073	51.228	18.625	70.833	22.101	81.797	23.738	62.425	21.769	34.915	16.757	14.344	9.173	8.488	5.391	6.369	4.109	6.071	3.586	7.153	3.503
16.066	7.316	33.152	15.149	61.432	21.219	82.392	24.894	95.178	26.301	69.556	24.140	38.522	18.528	16.891	9.833	9.626	5.599	7.228	4.252	7.254	3.821	9.097	3.604
19.706	7.700	39.012	16.367	78.323	23.253	106.683	27.111	121.645	28.118	85.331	26.445	54.549	19.256	19.224	9.926	12.160	5.976	8.976	4.794	8.460	3.992	11.397	3.656
31.515	8.331	66.655	18.030	119.482	25.190	131.821	29.594	158.981	30.608	129.365	28.594	77.813	20.086	25.631	9.926	16.505	6.161	18.309	5.411	12.787	4.071	16.208	3.685
9999.9	8.331	9999.9	18.030	9999.9	25.190	9999.9	29.594	9999.9	30.608	9999.9	28.594	9999.9	20.086	9999.9	9.926	9999.9	6.161	9999.9	5.411	9999.9	4.071	9999.9	3.685

Table 13.17 MK_I_EWR3: Recommended Low Flows B EC

October		November		December		January		February		March		April		May		June		July		August		September	
NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2.852	1.792	3.839	2.514	5.507	3.178	8.438	4.662	12.873	5.554	15.367	6.961	8.457	6.092	4.887	3.120	2.986	1.832	2.091	1.019	1.777	0.895	1.590	0.899
4.182	2.249	9.919	3.198	10.503	3.909	25.474	5.557	29.089	6.606	31.728	7.796	14.252	6.645	6.635	4.736	4.387	3.009	2.696	1.659	2.472	1.420	2.909	1.647
5.735	2.693	12.238	3.504	19.280	4.886	34.334	6.548	44.883	8.090	40.823	8.760	19.028	7.780	8.830	5.385	5.224	3.386	3.607	2.471	3.174	1.840	4.039	2.213
6.440	3.076	14.001	4.100	29.488	6.048	41.510	7.905	49.857	9.845	45.979	9.922	23.410	8.915	10.891	6.412	6.296	4.063	4.462	2.980	3.715	2.341	4.788	2.651
7.594	3.321	18.839	4.590	36.989	6.946	49.141	9.053	64.979	10.951	50.004	11.416	28.642	10.067	12.381	7.235	7.276	4.498	5.294	3.390	4.544	2.666	5.177	3.037
9.091	3.733	24.387	5.359	45.296	8.084	58.401	10.669	70.850	12.629	55.473	13.192	32.060	11.844	13.306	8.443	7.998	5.110	5.821	3.862	5.470	3.122	5.976	3.323
11.578	4.174	26.825	6.194	51.228	9.185	70.833	12.864	81.797	14.526	62.425	14.962	34.915	13.603	14.344	9.173	8.488	5.391	6.369	4.109	6.071	3.586	7.153	3.503
16.066	4.518	33.152	6.517	61.432	10.875	82.392	14.774	95.178	16.207	69.556	16.681	38.522	15.073	16.891	9.833	9.626	5.599	7.228	4.252	7.254	3.821	9.097	3.604
19.706	4.536	39.012	6.602	78.323	11.552	106.683	15.662	121.645	16.701	85.331	18.008	54.549	15.347	19.224	9.926	12.160	5.976	8.976	4.794	8.460	3.992	11.397	3.656
31.515	4.690	66.655	6.793	119.482	11.725	131.821	16.420	158.981	17.469	129.365	18.886	77.813	15.588	25.631	9.926	16.505	6.161	18.309	5.411	12.787	4.071	16.208	3.685
9999.9	4.690	9999.9	6.793	9999.9	11.725	9999.9	16.420	9999.9	17.469	9999.9	18.886	9999.9	15.588	9999.9	9.926	9999.9	6.161	9999.9	5.411	9999.9	4.071	9999.9	3.685

Table 13.18 MK_I_EWR3: Low Flows+ B EC

October		November		December		January		February		March		April		May		June		July		August		September	
NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2.852	1.792	3.839	2.514	5.507	3.178	8.438	4.662	12.873	5.554	15.367	6.961	8.457	6.092	4.887	3.120	2.986	1.832	2.091	1.019	1.777	0.895	1.590	0.899
4.182	2.249	9.919	3.198	10.503	3.909	25.474	5.676	29.089	6.724	31.728	7.884	14.252	6.645	6.635	4.736	4.387	3.009	2.696	1.659	2.472	1.420	2.909	1.647
5.735	2.693	12.238	3.504	19.280	4.886	34.334	10.412	44.883	11.945	40.823	11.608	19.028	7.780	8.830	5.385	5.224	3.386	3.607	2.471	3.174	1.840	4.039	2.213
6.440	3.076	14.001	4.100	29.488	6.048	41.510	14.537	49.857	16.459	45.979	14.810	23.410	8.915	10.891	6.412	6.296	4.063	4.462	2.980	3.715	2.341	4.788	2.651
7.594	3.321	18.839	4.590	36.989	6.946	49.141	17.332	64.979	19.209	50.004	17.518	28.642	10.067	12.381	7.235	7.276	4.498	5.294	3.390	4.544	2.666	5.177	3.037
9.091	3.733	24.387	5.359	45.296	8.084	58.401	19.526	70.850	21.463	55.473	19.719	32.060	11.844	13.306	8.443	7.998	5.110	5.821	3.862	5.470	3.122	5.976	3.323
11.578	4.174	26.825	6.194	51.228	9.185	70.833	22.101	81.797	23.738	62.425	21.769	34.915	13.603	14.344	9.173	8.488	5.391	6.369	4.109	6.071	3.586	7.153	3.503
16.066	4.518	33.152	6.517	61.432	10.875	82.392	24.894	95.178	26.301	69.556	24.140	38.522	15.073	16.891	9.833	9.626	5.599	7.228	4.252	7.254	3.821	9.097	3.604
19.706	4.536	39.012	6.602	78.323	11.552	106.683	27.111	121.645	28.118	85.331	26.445	54.549	15.347	19.224	9.926	12.160	5.976	8.976	4.794	8.460	3.992	11.397	3.656
31.515	4.690	66.655	6.793	119.482	11.725	131.821	29.594	158.981	30.608	129.365	28.594	77.813	15.588	25.631	9.926	16.505	6.161	18.309	5.411	12.787	4.071	16.208	3.685
9999.9	4.690	9999.9	6.793	9999.9	11.725	9999.9	29.594	9999.9	30.608	9999.9	28.594	9999.9	15.588	9999.9	9.926	9999.9	6.161	9999.9	5.411	9999.9	4.071	9999.9	3.685

14 APPENDIX C: REPORT COMMENTS

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