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Water Affairs and Forestry
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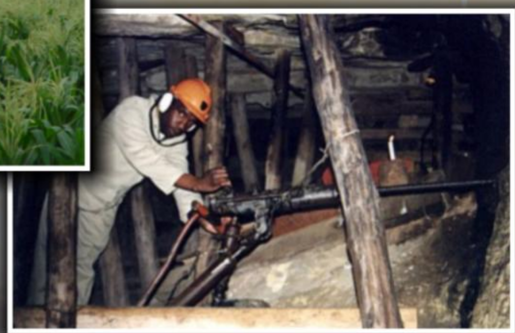
Directorate: National Water Resource Planning

Vaal River System: Large Bulk Water Supply Reconciliation Strategy

WATER RESOURCE ANALYSIS



MARCH 2009

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DEPARTMENT OF WATER AFFAIRS AND FORESTRY

DIRECTORATE: NATIONAL WATER RESOURCE PLANNING

VAAL RIVER SYSTEM: LARGE BULK WATER SUPPLY RECONCILIATION STRATEGY

Water Resource Analysis

March 2009

VAAL RIVER SYSTEM: LARGE BULK WATER SUPPLY RECONCILIATION STRATEGY

LIST OF REPORTS

Report No:	Title
P RSA C000/00/4406/01	Urban Water Requirements and Return Flows
P RSA C000/00/4406/02	Potential Savings through WC/WDM in the Upper and Middle Vaal Water Management Areas
P RSA C000/00/4406/03	Re-use Options
P RSA C000/00/4406/04	Irrigation Water Use and Return Flows
P RSA C000/00/4406/05	Water Resource Analysis
P RSA C000/00/4406/06	Groundwater Assessment: Dolomite Aquifers
P RSA C000/00/4406/07	First Stage Reconciliation Strategy
P RSA C000/00/4406/08	Second Stage Reconciliation Strategy
P RSA C000/00/4406/09	Executive Summary

Above list of reports effective as at March 2009.

VAAL RIVER SYSTEM: LARGE BULK WATER SUPPLY RECONCILIATION STRATEGY

WATER RESOURCE ANALYSIS

(March 2009)

REFERENCE

This report is to be referred to in bibliographies as:

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Prepared by:

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Title:	***Water Resource Analysis (March 2009)***
Authors:	*HS Swart and Task Team*
Project Name:	***Vaal River System: Large Bulk Water Supply Reconciliation Strategy***
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Vaal River System: Large Bulk Water Supply Reconciliation Strategy

Water Resource Analysis (March 2009)

EXECUTIVE SUMMARY

Introduction

The Department of Water Affairs and Forestry (DWAF) has, as part of the development of the Internal Strategic Perspectives (ISPs)[1] for the Vaal River Water Management areas (WMAs) identified and prioritised several studies that are necessary to further support Integrated Water Resource Management in the Vaal River System. Consequently the *Directorate: National Water Resource Planning (D:NWRP) has commissioned the reconciliation study of the large bulk water supply system of the Vaal River.*

The Large Bulk Water Supply Reconciliation Strategies for the Vaal River System Study has the objective to develop strategies for meeting the growing water requirements of the industrial and urban sectors that are served by the Integrated Vaal River System. The development of these strategies requires reliable information of the water requirements and the water resources for the current situation as well as likely future scenarios for a planning horizon of twenty to thirty years.

The key objectives of the study are to:

- *Update the current and future urban and agricultural water requirements.*
- *Assess the water resources and existing infrastructure.*
- *Take into account the Reserve requirements for alternative classifications.*
- *Formulate reconciliation interventions, both structural and administrative/regulatory.*
- *Conduct stakeholder consultation in the development of the strategies.*

Since the study was conducted over a period of 3 years, initial water resource analyses were undertaken for the development of a First Stage Reconciliation Strategy. The information,

[1] The Internal Strategic Perspective (ISP) was the first version of its kind compiled in 2004.

*assumptions and findings of the First Stage water resource analyses are presented in **Part A** of this report. The recommendations resulting from the First Stage assessment, as well as updated water requirements and further refinements to the Water Resources Planning Model (WRPM), were finally incorporated in the development of the Second Stage Reconciliation Strategy. The latter is documented in **Part B** of this report.*

Study area

*The core of the study area consists of the Upper, Middle and Lower Vaal River Water Management areas (WMAs), however, due to the numerous inter-basin transfers that link this core area with other WMAs, reconciliation planning has to be undertaken in the context of the Integrated Vaal River System which also includes portions of the Komati, Usutu, Thukela and Senqu River (Located in Lesotho) catchments. In addition, significant water transfers occur to water users in the Olifants and Crocodile (West) River catchments of which most are totally dependant on the water resources of the Integrated Vaal River System. **Figure B-1** in **Appendix B** shows a geographical map of the Integrated Vaal River System which is the area of concern for the study.*

Purpose of this report

*This report describes the water resource analyses undertaken for the Integrated Vaal River System (IVRS) with the Water Resource Planning Model (WRPM) as part of the First and Second Stage Reconciliation Strategy which are presented in **Part A** and **Part B** respectively. For both sets of analyses the revised water requirement and return flow projections resulting from this study are summarised in terms of the WRPM configuration. Further refinements made to the WRPM configuration adopted for the planning scenario analyses are also described in the report. Owing to the timing of the analyses, it should be noted that certain refinements (as described in **Part B** of this report) were only available for the development of the Second Stage Reconciliation Strategy. Finally the planning scenario and scheduling analysis results required for the assessment of reconciliation options are presented and discussed for both the First (**Part A**) and Second Stage (**Part B**) Reconciliation Strategies .*

Water resource analysis methodology

The following approach was adopted for the water resource analysis tasks of both strategies:

- *The Water Resource Planning Model (WRPM) configurations of the Integrated Vaal River System (IVRS), as well as the water requirement and return flow database resulting from the 2006-2007 and 2007-2008 Annual Operating Analyses (AOA), were adopted as basis for the water resource assessment of the First and Second Stage Reconciliation Strategy respectively.*

- *The water requirement and return flow database was then updated to include the revised irrigation water requirements obtained as part of this study (**DWAF, 2006d**).*

- *Two alternative water requirement and return flow scenarios were developed for the urban water use sector of the Gauteng Province (**DWAF, 2006a**) and were incorporated in the water requirement and return flow database of the WRPM.*

- *The Water Resource Planning Model (WRPM) configuration was updated to enable realistic modelling of the revised water requirements of both the irrigation and the urban water use sector of the Gauteng Province. Additional refinements were available for inclusion in the WRPM configuration adopted for the Second Stage Reconciliation Strategy.*

- *WRPM scenarios were identified and analysed to assess the need for intervention. These scenarios included assessment of alternative Water Conservation and Demand Management initiatives as well as the implementation of preliminary Ecological Flow Requirements.*

- *The recommendations resulting from the First Stage Reconciliation Strategy were considered in the development of the Second Stage Reconciliation Strategy.*

Review of hydrology for selected sub-catchments

*The purpose of the hydrology review was to identify key catchments, in consultation with the Client, for which it was necessary to update the hydrology. Although no hydrological updates were done as part of this study, cognisance was taken of work that was carried out by other studies. During the year 2005 the hydrology of the Renoster River catchment was refined at quaternary catchment level to facilitate modelling of the assurance of supply to the proposed Voorspoed Mine (**DWAF, 2005**). The hydrology of the Schoonspruit Sub-system was also recently updated as part of the Schoonspruit Sub-system Analysis Study (**DWAF, 2006**). Owing to time constraints the re-assessment of the Bloemhof Dam incremental hydrology in context of the updated Schoonspruit hydrology and refined Renoster hydrology was not undertaken prior to the First Stage assessments. The updated Schoonspruit and refined Renoster hydrology could, therefore, not be used in combination with the rest of the existing Vaal River System for the development of the First*

Stage Reconciliation Strategy. This information was, however, included in the WRPM configuration adopted for the Second Stage assessment. Furthermore, the hydrological data and information of the Harts River Sub-system was recently evaluated as part of the inception phase of the study entitled "Feasibility Study For Utilisation of Taung Dam Water". The recommendation from the evaluation was that the existing Harts River hydrology resulting from the VRSAU Study be adopted for further analyses.

Short-term curves for the Senqu and Bloemhof Sub-systems

*A revised Ecological Reserve (ER) that is different to that described in the Lesotho Highlands Water Project (LHWP) Treaty has been adopted for Katse and Mohale dams. In addition to this, the Mohale-Katse transfer tunnel operating rule finally adopted by the Lesotho Highlands Development Authority (LHDA) and documented in July 2004, had to be incorporated in the configurations of the water resource models (WRYM and WRPM). Since these changes impact on the yield capability of the Senqu Sub-system, it was necessary to revise the short-term yield reliability curves of the sub-system (refer to **Chapter A.4** of **Part A** for details). The updated information was not available for the First Stage Reconciliation Strategy but was included in the analyses of the Second Stage Reconciliation Strategy.*

An alternative set of short-term yield reliability curves was also derived for the Bloemhof Sub-system based on changes made to the WRYM configuration of the Upper Thukela River catchment. These changes incorporate, inter alias, releases that have to be made for the Ecological Reserve in the Thukela catchment once future phases of the TWP are implemented.

Water requirements and return flows

***Chapters A.5** and **B-5** describe the water requirements and return flow scenarios that were developed as part of the Fist and Second Stages of this study respectively and pertinent results are summarised below.*

***Table i** provides a summary of the current (year 2005) irrigation water use included in the WRPM configuration for the Integrated Vaal River System excluding the Thukela and Orange River Sub-systems. The results adopted for the First Stage analyses show that the estimated gross water use in the year 2005 for the three Vaal Water Management Areas (WMAs) is 1195 million m^3/annum (note that this demand includes Vaalharts canal losses in the order of 127 million m^3/annum). Preliminary results from the Upper Vaal WMA Validation Study indicated that as much as 239 million m^3/annum of the year 2005 irrigation water use could be unlawful (calculated from **Table A**.5.1 and Error! Reference source not found. presented in **Part A**). Results from the* *irrigation return flow model were not yet available at the time when the First Stage Reconciliation Strategy analyses were undertaken. Consequently, for all irrigation activities that were not being modelled with irrigation modules during the First Stage Strategy development, the general assumption was made that irrigation return flows are equal to 10% of the gross irrigation water use. The net irrigation water use is defined as the difference between the gross irrigation water use and the relevant irrigation return flows.*

For the Second Stage analysis the results of the irrigation return flow model were used and all irrigation activities within the Val River system were modelled by means of irrigation modules (refer to ***Section B.5.2*** *for details). Based on these refinements the estimated gross irrigation water use included in the WRPM configuration for the three WMAs was found to be in the order of 1200 million m^3/annum. From* ***Table i*** *it can be seen that, although the refinements did not result in a significant difference in the gross water use, the Second Stage net irrigation water use based on the updated return flow information was about 5% less than that of the First Stage.*

Table i: Summary of irrigation water use for the Vaal River System

Description	***Recommended current (year 2005) water use (million m^3/a)***			
	First Stage Analysis		***Second Stage Analysis***	
	Gross	***Net***	***Gross***	***Net***
Upper Vaal WMA	*392.2*	*354.3*	*399.3*	*316.1*
Middle Vaal WMA	*238.9*	*215.8*	*240.5*	*204.8*
Lower Vaal WMA (including consumptive canal losses) (1)	*563.8*	*501.3*	*559.7*	*492.8*
Sub-total for three Vaal WMA:	***1194.9***	***1071.4***	***1199.5***	***1013.7***
Supporting Sub-systems (2)	*32.5*	*32.5*	*32.5*	*32.5*
Total for the IVRS:	***1227.4***	***1103.9***	***1232.0***	***1046.2***

Note : (1) Includes Vaalharts canal losses equal to 127 million m^3/annum.

(2) Excluding the Thukela and Orange River Sub-systems

In terms of future irrigation water use, ***Irrigation Scenario 1*** *(see* ***Section A.5.2.8*** *of* ***Part A****) was adopted for all the First and Second Stage planning scenarios analysed with the WRPM. This scenario assumes that irrigation water use in the Middle and Lower Vaal WMA will remain constant over the planning period. However, for the Upper Vaal WMA the following assumptions were adopted:*

- *The growing trend observed over the period 1998 to 2005 was assumed to continue for two years (i.e. until 2008). This implies interventions will take two years to become effective.*
- *Eradication of unlawful irrigation water use will take effect from 2008 onwards, assuming that the water use will decrease over a period of four years.*
- *It is assumed that interventions will finally decrease the irrigation water use to the lawful volume plus 15% and that this" target" will be achieved in the year 2011 (refer to **Figure A.5.1** of **Part A**).*

*Water requirement scenarios for the three large industries Eskom, Sasol and Mittal Steel were provided by the respective organisation for the development of the strategy. The water requirement projections adopted for the First and Second Stage Strategies are described in **Section A.5.3** of **Part A** and **Section A.5.3** of **Part B** respectively.*

*Urban water requirement scenarios were developed for the **Rand Water supply area** by applying the Water Requirement and Return Flow Model (**DWAF, 2004e**) for the planning period up to 2030. One of the driver variables in the model is population scenarios which were obtained from a parallel study that was carried out by the Directorate: Water Resource Planning Systems of the DWAF. Two future population scenarios were developed, the first scenario was made available in January 2006 and, after a review and comparison with information that was produced by Statistics South Africa (**Stats SA, 2006**), the second scenario was developed in August 2006 (see **Section A.5.4.2** of **Part A** for details). A further population scenario, based on the National Water Resource Strategy Population, was applied to develop an alternative water requirement and return flow scenario.*

*The Water Requirement and Return Flow Model was configured for 47 Sewage Drainage Areas (SDAs) and calibrated for the year 2001 (year for which census data was available). The calibration involved changing model parameters to match both the water use and return flows observed for each SDA for the year 2001. The 47 SDAs were divided into those draining into the Crocodile River System (Northern SDAs) and those discharging into the Vaal River System (Southern SDAs), see of **Part A** for a map showing the location of the SDAs.*

*Water requirement and return flow scenarios were compiled based on the NWRS population scenarios (**Scenario A**) and the August 2006 DWAF population scenario (**Scenario B**) for the Rand Water supply area, as summarised in **Table ii**.*

Table ii: Water Requirements and return flow scenarios for the Rand Water supply area

Scenario	Component	Planning Year					
		2005	2010	2015	2020	2025	2030
Scenario A (NWRS)(1)	*Water Requirements*	*1,300*	*1,352*	*1,431*	*1,496*	*1,582*	*1,681*
	Return Flows	*652*	*694*	*735*	*769*	*807*	*852*
Scenario B (August 2007) (2)	*Water Requirements*	*1,300*	*1,403*	*1,512*	*1,596*	*1,679*	*1,766*
	Return Flows	*556*	*653*	*724*	*785*	*841*	*882*

Notes:
(1) Based on the National Water Resource Strategy population scenario.
(2) Based on the DWAF August 2007 population scenario.
(3) All volumetric values are given in million m^3/annum

*Water requirement scenarios for **Sedibeng Water** and **MidVaal Water Company** were obtained from the respective organisations and for all the **other urban areas** the water requirement projections were determined using the growth rates from the National Water Resource Strategy (NWRS). Where actual water use data were available, the starting point (volume for the first year in the projection) was adjusted to match the actual value on which the future growths were applied.*

***Tables iii** and **iv** summarises the water requirements for **Scenarios A** and **B** respectively, presenting the overall IVRS gross and net water requirements for the planning years 2006 to 2030 that were used for the First Stage Strategy development scenarios. It is important to note that, except for the **Rand Water supply area**, the water requirement projections of the remaining water users are identical for both demand scenarios.*

Table iii: Summary of water requirements and return flows (Scenario A)

Water users	Planning years					
	2006	2010	2015	2020	2025	2030
Water Requirements						
Rand Water	*1297*	*1338*	*1417*	*1481*	*1568*	*1666*
Mittal Steel	*17*	*17*	*17*	*17*	*17*	*17*
ESKOM (Incl DWAF 3RD Party Users)	*330*	*381*	*407*	*416*	*417*	*416*
SASOL (Sasolburg)	*24*	*27*	*30*	*33*	*37*	*41*
SASOL (Secunda)	*92*	*104*	*108*	*112*	*117*	*123*
Midvaal Water Company	*35*	*35*	*35*	*35*	*35*	*35*
Sedibeng Water (Balkfontein only)	*41*	*41*	*41*	*41*	*42*	*43*

Water users	*Planning years*					
	2006	***2010***	***2015***	***2020***	***2025***	***2030***
Other towns and industries	*161*	*163*	*167*	*167*	*167*	*168*
Vaalharts/Lower Vaal irrigation	*542*	*542*	*542*	*542*	*542*	*542*
Other irrigation	*722*	*599*	*500*	*500*	*500*	*500*
Wetland / River Losses	*325*	*326*	*327*	*329*	*330*	*331*
Return Flows						
Southern Gauteng (Rand Water)	*331*	*343*	*359*	*372*	*386*	*400*
Midvaal Water Company	*1*	*1*	*1*	*1*	*1*	*1*
Sedibeng Water	*2*	*2*	*2*	*2*	*2*	*2*
Other towns and industries	*61*	*65*	*69*	*72*	*76*	*80*
Irrigation	*60*	*48*	*38*	*38*	*38*	*38*
Mine dewatering	*114*	*105*	*121*	*123*	*121*	*121*
Increased urban runoff	*101*	*103*	*107*	*113*	*121*	*129*
OVERALL GROSS SYSTEM DEMAND:	*3587*	*3572*	*3590*	*3672*	*37711*	*3881*
OVERALL NET SYSTEM DEMAND:	*2917*	*2905*	*2893*	*2950*	*3025*	*3108*

Notes: (1) All volumetric values are given in million m^3/annum.

Table iv: Summary of water requirements and return flows (Scenario B)

Water users	*Planning years*					
	2006	***2010***	***2015***	***2020***	***2025***	***2030***
Water Requirements						
Rand Water	*1308*	*1390*	*1498*	*1582*	*1665*	*1753*
Mittal Steel	*17*	*17*	*17*	*17*	*17*	*17*
ESKOM (Incl DWAF 3RD Party Users)	*330*	*381*	*407*	*416*	*417*	*416*
SASOL (Sasolburg)	*24*	*27*	*30*	*33*	*37*	*41*
SASOL (Secunda)	*92*	*104*	*108*	*112*	*117*	*123*
Midvaal Water Company	*35*	*35*	*35*	*35*	*35*	*35*
Sedibeng Water (Balkfontein only)	*41*	*41*	*41*	*41*	*42*	*43*
Other towns and industries	*161*	*163*	*167*	*167*	*167*	*168*
Vaalharts/Lower Vaal irrigation	*542*	*542*	*542*	*542*	*542*	*542*
Other irrigation	*722*	*599*	*500*	*500*	*500*	*500*
Wetland / River Losses	*325*	*326*	*327*	*329*	*330*	*331*
Return Flows						
Southern Gauteng (Rand Water)	*335*	*362*	*392*	*418*	*438*	*459*
Midvaal Water Company	*1*	*1*	*1*	*1*	*1*	*1*

Water users	Planning years					
	2006	2010	2015	2020	2025	2030
Sedibeng Water	2	2	2	2	2	2
Other towns and industries	61	65	69	72	76	80
Irrigation	60	48	38	38	38	38
Mine dewatering	114	105	121	123	121	121
Increased urban runoff	101	103	107	113	121	129
OVERALL GROSS SYSTEM DEMAND:	3597	3624	3672	3773	3868	3967
OVERALL NET SYSTEM DEMAND:	2923	2939	2942	3005	3071	3136

Notes: (1) All volumetric values are given in million m^3/annum.

*Two water demand scenarios, **Scenario D_2** (base scenario) and **Scenario B_2** (alternative scenario) were considered for the Second Stage of this study. **Table v** summarises the water requirements for **Scenario D_2**, presenting the overall IVRS gross and net water requirements for the planning years 2007 to 2030. This scenario incorporates the **Scenario D** water requirement projection for the **Rand Water supply area** which is based on a reduction in wastage over a period of 5 years. Furthermore, the revised projections obtained from Eskom, Sasol, Sedibeng Water and Midvaal Water Company in 2007were also included in the demand **Scenario D_2** projections.*

Table v: Summary of water requirements and return flows (Scenario D_2)

Water users	Planning years					
	2007	2010	2015	2020	2025	2030
Water Requirements						
Rand Water	1255	1210	1307	1382	1452	1540
Mittal Steel	17	17	17	17	17	17
ESKOM (Including DWAF 3rd Party Users)	354	408	417	415	414	411
SASOL (Sasolburg)- Raw water	25	27	30	33	37	41
SASOL (Secunda)	91	95	107	115	123	130
Midvaal Water Company	37	37	37	37	37	37
Sedibeng Water (Balkfontein only)	44	45	46	47	48	49
Other towns and industries	183	185	188	189	189	190
Vaalharts/Lower Vaal irrigation	542	542	542	542	542	542
Other irrigation	751	593	494	494	494	494
Wetland / River Losses	325	326	327	329	330	331

Return Flows						
Southern Gauteng (Rand Water)	*314*	*294*	*317*	*337*	*351*	*366*
Midvaal Water Company	*1*	*1*	*1*	*1*	*1*	*1*
Sedibeng Water	*2*	*2*	*2*	*2*	*2*	*2*
Other towns and industries	*63*	*65*	*69*	*73*	*77*	*81*
Irrigation	*68*	*52*	*43*	*43*	*43*	*43*
Mine dewatering	*116*	*109*	*126*	*128*	*126*	*126*
Increased urban runoff	*101*	*103*	*107*	*113*	*121*	*129*
OVERALL GROSS SYSTEM DEMAND:	*3624*	*3483*	*3513*	*3599*	*3682*	*3782*
OVERALL NET SYSTEM DEMAND:	*2959*	*2856*	*2849*	*2902*	*2962*	*3034*

Notes: (1) All volumetric values are given in million m^3/annum.

Table vi *summarises the water requirements for* ***Scenario B₂****, presenting the overall IVRS gross and net water requirements for the planning years 2007 to 2030 that were used for the Second Stage Strategy development scenarios. This scenario incorporates the* ***Scenario B*** *water requirement projection for the* ***Rand Water supply area****. Adjustments were, however, made over the period 2006 to 2010 based on the actual water use for 2006 that was used as starting point. The projections included for Eskom, Sasol, Sedibeng Water and Midvaal Water Company were identical to that of* ***Scenario D_2***

Table vi: Summary of water requirements and return flows (Scenario B_2)

Water users	***Planning years***					
	2007	***2010***	***2015***	***2020***	***2025***	***2030***
Water Requirements						
Rand Water	*1339*	*1390*	*1498*	*1582*	*1665*	*1753*
Mittal Steel	*17*	*17*	*17*	*17*	*17*	*17*
ESKOM (Including DWAF 3rd Party Users)	*354*	*408*	*417*	*415*	*414*	*411*
SASOL (Sasolburg)- Raw water	*25*	*27*	*30*	*33*	*37*	*41*
SASOL (Secunda)	*91*	*95*	*107*	*115*	*123*	*130*
Midvaal Water Company	*37*	*37*	*37*	*37*	*37*	*37*
Sedibeng Water (Balkfontein only)	*44*	*45*	*46*	*47*	*48*	*49*
Other towns and industries	*183*	*185*	*188*	*189*	*189*	*190*
Vaalharts/Lower Vaal irrigation	*542*	*542*	*542*	*542*	*542*	*542*
Other irrigation	*751*	*593*	*494*	*494*	*494*	*494*
Wetland / River Losses	*325*	*326*	*327*	*329*	*330*	*331*

Water users	Planning years					
	2007	2010	2015	2020	2025	2030
Return Flows						
Southern Gauteng (Rand Water)	342	362	392	418	438	459
Midvaal Water Company	1	1	1	1	1	1
Sedibeng Water	2	2	2	2	2	2
Other towns and industries	63	65	69	73	77	81
Irrigation	68	52	43	43	43	43
Mine dewatering	116	109	126	128	126	126
Increased urban runoff	101	103	107	113	121	129
OVERALL GROSS SYSTEM DEMAND:	3708	3664	3704	3799	3895	3995
OVERALL NET SYSTEM DEMAND:	3015	2968	2966	3021	3088	3154

Notes: (1) All volumetric values are given in million m^3/annum.

Potential savings from water conservation and water demand management

*Three saving scenarios were compiled from the assessment of the potential for water conservation and water demand managements (WC/WDM) in the urban sector. The savings were applied to the water requirements of **Scenario B** (see **Section A.5.5** of **Part A**) and were labelled **Scenarios C**, **D** and **E** respectively. The description of the WC/WDM scenarios is as follows:*

- ***Scenario C**: 5 Year water loss programme (wastage reduction) and efficiency improvement measures.*
- ***Scenario D**: Reduction in wastage over 5 years.*
- ***Scenario E**: Reduction in wastage over 10 years.*

*A summary of the estimated savings in the water requirements of the three above-mentioned scenarios are presented in **Table vii.***

Table vii: Savings for the indicated planning years and Scenarios C, D and E

Scenarios	Planning Years				
	2010	2015	2020	2025	2030
C	177	272	329	379	378
D	180	191	200	213	213
E	110	176	193	206	208

Notes: (1) All volumetric values are given in million m^3/annum.

Infrastructure intervention options

The Vaal Augmentation Planning Study (VAPS), completed in 1996, concluded that either a further phase of the Lesotho Highlands Water Project (LHWP) or further water resource developments in the Thukela River System could be considered as alternatives for augmenting the water resources of the Vaal River System.

The Thukela Water Project Feasibility Study (TWPFS) concluded that two proposed dams, one on the Bushman's River (Mielietuin Dam) and the other on the main stem of the Thukela River (Jana Dam), with transfer infrastructure, would be the most feasible scheme configuration to provide a nominal transferable yield of 15m^3/s (473 million m^3/annum).

A further study, the "Thukela Water Project Decision Support Phase" (TWPDSP) study, was carried out to, among other things, undertake a Comprehensive Reserve Determination Study for the Thukela River System and compile an implementation programme for the TWP. The results from this study indicated that the first water could be delivered twelve years after the decision is taken to proceed with the development. The Historic Firm Yield (HFY) of the TWP, incorporating the Ecological Water Requirements (EWR), for the largest dam sizes was determined to be 454 million m^3/annum. The HFY of 136 million m^3/annum was adopted for Mielietuin Dam and its associated transfer link whereas the HFY of Jana Dam and its associated transfer link was taken as 318 million m^3/annum.

A joint feasibility study by the South African and Lesotho governments were commissioned in 2005 with the purpose of identifying the most feasible further phases of the scheme. Results from the first phase of the study were made available to the Reconciliation Study Team which indicated the proposed Polihali Dam with transfer infrastructure as the preferred option. The implementation period required for the scheme was estimated to be ten years after the decision is taken to proceed with the scheme. (If the decision is taken immediately, however, a further three years' preparation phase has to be added to the ten years. This is to complete the current feasibility study and to investigate funding options.) The Historical Firm Yield of the Polihali Dam option was determined to be 458 million m^3/annum.

*The second phase of the LHFP Feasibility Study commenced in October 2006 and the recommended Polihali Dam option with conveyance infrastructure (refer to **Section B.8.9**) was* *incorporated in the WRPM configuration used for the Second Stage of this study. The incremental yield of the preferred Polihali option was found to be 541 million m^3/annum (17.1 m^3/s) with an associated reduction in yield of the Orange River System (ORS) of about 257 million m^3/annum*

Updating of WRPM configuration for First Stage Strategy development

*The WRPM configuration resulting from the 2006-2007 Annual Operating Analysis of the IVRS was adopted as basis for the First Stage of this study. This configuration included the updated short-term yield reliability curves determined for the Usutu Sub-system during 2006. The revised curves were based on the increased capacity of the transfer link between Morgenstond and Jericho dams. The inter-reservoir operating rules for the Usutu dams were also re-assessed at the same time and the adopted rules were included in the 2006-2007 AOA (refer to **Section A.9.3** of **Part A** for details).*

*Revised catchment development information obtained as part of this study prompted several changes to be made to the WRPM configuration to ensure realistic modelling of the water resources system and its associated water requirements. The demand centre configuration for Rand Water was refined as described in **Section A.8.2** of **Part A** and the associated additional salt load assessment is discussed in **Section A.8.3**. The resulting schematic diagrams of the IVRS are provided in **Appendix A** (**Figures A-1** to **A-12**).*

Updating of WRPM configuration for Second Stage Strategy development

*The WRPM configuration resulting from the 2007-2008 Annual Operating Analysis of the IVRS was adopted as basis for this study. This configuration included the revised Senqu Sub-system configuration based on the final adopted Mohale-Katse transfer tunnel operating rules and updated short-term yield reliability curves (**Section A.4.1**). The updated hydrology (**Section B.3.2**) and system configuration of the Schoonspruit Sub-system (**Section B.4.1**), as well as the refined Renoster (**Section B.4.2**) and Mooi (**Section B.4.3**) sub-systems were also included in the WRPM configuration. Subsequent refinements to the Bloemhof incremental catchment (**Section B.3.4**) were also incorporated in the WRPM database. Furthermore, the need for the explicit modelling of the Waterval catchment (**Section B.4.4**) prompted the refinement of the Vaal incremental sub-catchment. The resulting schematic diagrams of the IVRS used for the Second Stage analysis are provided in **Appendix J** (**Figures J-1** to **J-12**).*

Planning scenarios for First Stage Strategy development

*Seven planning scenarios (summarised in **Table vii** below) were formulated and evaluated as part of the First Stage Reconciliation Strategy development, covering a range of possible future conditions and interventions. The basic assumptions common to all the scenarios analysed are listed in **Section A.9.3** and only the assumptions that are unique to each scenario are listed in **Table viii.***

Table viii: Summary of planning scenarios analysed as part of First Stage Strategy

Planning Scenario	*WRPM Run Reference*	*Urban Demand Projection*	*Future Irrigation Scenario*	*WC/DM Initiatives Implemented*
A	*VT06R03*	*Scenario A*	*Scenario 1*	*None*
B	*VT06R04*	*Scenario B*	*Scenario 1*	*None*
C	*VT06R05*	*Scenario B*	*Scenario 1*	*Al identified measures (Error! Reference source not found.of **Part A**)*
D	*VT06R08*	*Scenario B*	*Scenario 1*	*Waste management initiatives over 5 years (Error! Reference source not found. of **Part A**)*
E	*-*	*Scenario B*	*Scenario 1*	*Waste management initiatives over 10 years (Error! Reference source not found. of **Part A**)*
F	*-*	*Scenario B*	*Scenario 2*	*None*
G	*VT06R02*	*Scenario B*	*- (1)*	*None*

*Note: (1) The irrigation water requirements adopted for **Scenario G** are based on that of the 2006-2007 AOA and were, therefore, not updated with the irrigation water use presented in **Section A.5.2** of **Part A**.*

Scheduling analysis results for First Stage Strategy development

*Projection analyses were carried out with the Water Resource Planning Model (WRPM) for the scenarios and based on the assessment of the risk of curtailments (refer to the scenario results presented in **Section A.9.4**) the supply capability of the system was determined to be 2921 million m^3/annum (i.e. the net system water requirement of **Scenario B** for the year 2013). **Figure A.9.6*** *included in **Part A** shows the net water requirements of **Scenario A** to **E** in relation to the system supply capability from which the following observations can be made:*

- *The unlawful water use in the irrigation sector results in the system being in a deficit situation from 2007 to 2009 for all the scenarios. This illustrates the importance of curbing the unlawful irrigation water use in order to maintain a positive water balance in the system and prevent excessive curtailments during drought periods.*

- *Based on the projected balance situation for **Scenario B**, it is shown that the system will require intervention by the year 2013.*

- *If the potential savings through WC/WDM of **Scenario C** is achieved, no further intervention is required for the planning period until after the year 2030.*

- *The balance situation for **Scenarios D** and **E** shows that by eliminating wastage through WC/WDM further intervention is only required in the year 2023.*

- *Risk analysis showed that the supply capability of the Vaal River System would decrease by 138 million m^3/annum, and according to the balance situation provided in Error! Reference source not found., only **Scenario C** will achieve a positive water supply balance between 2011 and 2020.*

Conclusions and recommendations for First Stage Strategy development

*The main conclusions are merely a summary of the findings of the scheduling analysis results presented above (refer to **Chapter A.10** of **Part A**).*

*Based on the results and conclusions presented in **Part A** of this report, it is recommended that the following aspects be considered in the development of the Second Stage Reconciliation Strategy:*

- *Re-evaluate system balance once the validation studies and the comprehensive reserve determination study produce information.*

- *The irrigation return flows determined with the Water Requirement and Return Flow database model (**DWAF, 2004e**) should be incorporated in the WRPM configuration.*

- *To ensure that the water quality downstream of the irrigation areas is modelled correctly, it is recommended that the irrigation water use be modelled with the irrigation block modules. This process would involve the recalibration of the exiting irrigation modules to obtain the required* *volumetric abstractions and return flows whilst at the same time maintaining the salt balance which resulted from the VRSAU Study calibrations.*

- *The revised Senqu short-term yield reliability curves (refer to **Section A.4.1.4**) as well as the operating rule finally adopted for the Mohale-Katse transfer tunnel (refer to **Section A.4.1.3**) should be included in the WRPM configuration.*

- *The short-term yield capability of the Bloemhof Dam Sub-system is currently being overestimated. This is due to the fact that the Vaal Dam Sub-system was included in the definition of the Bloemhof Sub-system when the short-term yield reliability curves were derived as part of the VRSAU Study. Consequently, when the short-term yield capability of the Bloemhof Dam Sub-system is determined the allocation algorithm of the WRPM assumes that water stored in Bloemhof Dam is available for supply to upstream users. To overcome this problem, it is therefore recommended that the Vaal Dam and Bloemhof Dam sub-systems should be modeled as two separate sub-systems and that short-term yield reliability curves should be derived for each of these sub-systems.*

Planning scenarios for Second Stage Strategy development

*Although twenty planning scenarios were formulated (refer to **Table B.9.3**) only seven planning scenarios (summarised in **Table viii** below) were analysed with the WRPM as part of the Second Stage Reconciliation Strategy development, covering a range of possible future conditions and interventions. The basic assumptions common to all the scenarios analysed are listed in **Section B.9.3** and only the assumptions that are unique to each scenario are listed in **Table ix.***

Table ix: Summary of planning scenarios analysed as part of Second Stage Strategy

Planning Scenario No.	*WRPM Run Reference*	*Water Use Scenario*	*Intervention Option Included*	*Water Quality Scenario*	*Purpose*
1a	*V07R1ABP*	*D_2*	*LHFP (Polihali Dam)*	• *No TDS treatment* • *Rand Water supplied from Vaal Dam* • *Dilution to 600 mg/l in Vaal Barrage*	*Assessment of:* • *Current management practices* • *Augmentation from Polihali Dam option* • *Supply of excess water in Bloemhof Dam to ORS*
1b	*VT07R1B*	*D_2*	*None*	• *No TDS treatment* • *Rand Water*	*Assessment of: alternative dilution rule*

Planning Scenario No.	WRPM Run Reference	Water Use Scenario	Intervention Option Included	Water Quality Scenario	Purpose
				supplied from Vaal Dam • Dilution to 450 mg/l in Vaal Barrage	
1c	VT07R1C	D_2	Reuse of mine and industrial discharges	• Treatment of mine and industrial discharges • Rand Water supplied from Vaal Dam • Dilution to 450 mg/l in Vaal Barrage	Evaluate impact of direct reuse of water and the removal of salinity.
1c1	VT07R1C1	D_2	Partial reuse of mine discharges	• Treatment of selected mine discharges • Rand Water supplied from Vaal Dam • Dilution to 450 mg/l in Vaal Barrage	Evaluate direct partial reuse of water and the removal of salinity.
2a	VT07R2A	B_2	None	• No TDS treatment • Rand Water supplied from Vaal Dam • Dilution to 600 mg/l in Vaal Barrage	Assessment of alternative water requirement and return flow scenario (Alternative to Scenario 1a).
3	VT07R03	D_2	None	• No TDS treatment • Rand Water supplied from Vaal Barrage • Blend RW supply to 300 mg/l with water from Vaal Dam • Dilution to 600 mg/l in Vaal Barrage	Assessment of alternative source of supply for Rand Water (Alternative to Scenario 1a).
8a	VT07R08	D_2	None	• No water quality management • Rand Water supplied from Vaal Barrage	Alternative base scenario excluding the EWR.

Scheduling analysis results for Second Stage Strategy development

*Projection analyses were carried out with the Water Resource Planning Model (WRPM) for the scenarios listed in **Table ix** above and based on the assessment of the risk of curtailments (refer to the scenario results presented in **Section B.9.4**) the supply capability of the system was* *determined to be 2877 million m^3/annum (i.e. the net system demand in 2018 for **Scenario 1a**). **Figure B.9.4** shows the net water requirements of **Scenario B_2** to **K_2** in relation to the system supply capability.*

The following observations can be made from Error! Reference source not found.:

- *The unlawful water use in the irrigation sector results in the system being in a deficit situation from 2007 to 2009 for all the scenarios. This illustrates the importance of curbing the unlawful irrigation water use in order to maintain a positive water balance in the system and prevent excessive curtailments during drought periods.*
- *Based on the projected balance situation for **Scenarios B_2, K_2, H_2** and **I_2** it is shown that the system is in deficit over the entire planning period.*
- *If the potential savings through WC/WDM of **Scenarios D_2** and **E_2** (reduction in wastage over 5 and 10 years respectively) is achieved, further intervention is required in 2019.*
- *The balance situation for **Scenario J_2**, shows that by trading the irrigation water rights in the Vaal River catchment upstream of Vaal Dam, further intervention is only required in the year 2015.*

Conclusions and recommendations for Second Stage Strategy development

The main conclusions are similar to the findings of the scheduling analyses and can be summarised as follows:.

- *Assuming that curtailment of unlawful irrigation water use (as described for **Irrigation Scenario 1**) materialises, it was found that a deficit situation occurred over the medium term (from 2007 to 2009) for all the scenarios analysed.*
- *The **Scenario 1a** results indicated that intervention is required in the year 2019. This means that, with WC/WDM the decision to proceed with an infrastructural intervention measure has to be taken immediately as the recommended LHFP option (Polihali Dam and conveyance infrastructure) can only be commissioned in May 2019.*
- *The scheduling analysis results for **Scenarios B_2, K_2, H_2** and **I_2** showed that the system is in deficit over the entire planning period. Therefore, saving water through the reduction of wastage by means of water conservation and demand management measures in the urban*

sector is essential as the earliest augmentation scheme (LHFP) can only be implemented in ten year's time.

- *Although none of the scenarios that were analysed included the preliminary EWR, from the First Stage results it is perceived that the implementation of the ER will cause the date at which intervention is required for **Scenario D_2** to move forward by a number of years.*

- *The Comprehensive Reserve Determination Study (commissioned by the DWAF Directorate Resource Directed Measures (RDM) in August 2006) will produce Ecological Water Requirement Scenarios and the implication thereof on the reconciliation options will have to be determined and evaluated.*

*Based on the results and conclusions presented in **Part B** of this report, it is recommended that the following aspects be considered:*

- *The curtailment of unlawful irrigation water use in the Upper Vaal WMA is essential and the necessary measures to enforce these curtailments should be implemented as a matter of urgency.*

- *Since the implementation of waste water management measures as assumed for demand **Scenario D_2** will ensure that the assurance of supply in the IVRS is not jeopardized prior to the commissioning of the preferred LHFP option (Polihali Dam), it is recommended that these WC/WDM initiatives be imposed immediately and that the resulting water saving achievements be monitored on a continuous basis.*

- *Re-evaluate the system balance once the validation studies and the comprehensive reserve determination study produce information.*

- *In confirmation of the First Stage recommendation, the need to model the Vaal Dam and Bloemhof Dam sub-systems as two separate sub-systems has again been identified.*

Vaal River System: Large Bulk Water Supply Reconciliation Strategy

Water Resource Analysis: Part A

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ABBREVIATIONS

Acronym	Meaning
BP	Business Plan
CMA	Catchment Management Agency
CMS	Catchment Management Strategy
DCM	Demand Centre Module
Dir: HI	Directorate: Hydrological Information
Dir: NWRP	Directorate: National Water Resource Planning
CMS	Catchment Management Strategy
Dir: OA	Directorate: Option Analysis
Dir: PSC	Directorate: Policy and Strategic Co-ordination
Dir: WRPS	Directorate: Water Resource Planning Systems
Dir: RDM	Directorate: Resource Directed Measures
Dir: WCDM	Directorate: Water Conservation and Demand Management
Dir: WDD	Directorate: Water Discharge and Disposal
Dir: WUE	Directorate: Water Use Efficiency
DWAF	Department of Water Affairs and Forestry
FSC	Full Supply Capacity
GDP	Gross Domestic Product
GGP	Gross Geographical Product
HFY	Historic Firm Yield
IDP	Integrated Development Plan
ISP	Internal Strategic Perspective
IVRS	Integrated Vaal River System
LHWP	Lesotho Highlands Water Product
LORMS	Lower Orange River Management Study
MAP	Mean Annual Precipitation
MAR	Mean Annual Runoff
NAY	Nominal Annual Yield
NWA	National Water Act
NWRS	National Water Resource Strategy
ORRS	Orange River Replanning Study
VRSAU	Vaal River System Analysis Update
WARMS	Water Authorisation Registration Management System
WDM	Water Demand Management
WC	Water Conservation
WMA	Water Management Area
WSDP	Water Services Development Plan
WRPM	Water Resource Planning Model
WRSAS	Water Resource Situation Assessment Study
WRYM	Water Resource Yield Model
WUA	Water User Association

Vaal River System: Large Bulk Water Supply Reconciliation Strategy

Water Resource Analysis: Part A

A.1 INTRODUCTION

A.1.1 BACKGROUND

The Department of Water Affairs and Forestry (DWAF) has, as part of the development of the Internal Strategic Perspectives (ISPs)[1] for the Vaal River Water Management areas (WMAs) identified and prioritised several studies that are necessary to further support Integrated Water Resource Management in the Vaal River System. Although previous water balance assessments indicated that augmentation of the Vaal River System is only required by the year 2025 (**DWAF, 2004a to d**), several factors were identified that could influence this date and require further investigations.

Firstly, it was acknowledged that the water requirement projection scenarios used in the ISP study did not explicitly include the effect of water conservation and water demand management initiatives (**DWAF, 2004d**) and as a result the Directorate Water Use Efficiency commissioned the Water Conservation and Water Demand Management study with particular focus on the Upper and Middle Vaal River WMAs.

Secondly, it was recognised that the time it takes to implement a large water resource augmentation scheme could be as long as fifteen years and coupled with the fact that the future water requirement scenarios exhibit low growth rates makes the timing of any future intervention critical.

Thirdly, a comprehensive Reserve Determination has not been undertaken for the Vaal River System and will have to be incorporated into the development of reconciliation strategies.

In view of the above considerations as well as other uncertainties identified in the assumptions used in the ISP study (see **DWAF, 2004d** for details), the Directorate: National Water Resource

[1] The Internal Strategic Perspective (ISP) was the first version of its kind compiled in 2004.

Planning (D:NWRP) has commissioned the reconciliation study of the large bulk water supply system of the Vaal River.

The ISPs for the Vaal River WMAs further identified the need for integrated water quality management of the Vaal River and its major tributaries. Although there are several individual Catchment Management Strategies already completed, these strategies and their objectives need to be integrated and co-ordinated in a system context. To this end, the D:NWRP has commissioned a study to develop an Integrated Water Quality Management Plan for the Vaal River System which is running concurrently with the Reconciliation and Water Conservation and Water Demand Management studies.

During the inception phases of these studies it was identified by the respective management teams that the integration of strategies and co-ordination of study activities would be essential to development coherent water resource management measures for the Vaal River System. The management of the studies was therefore coordinated by combining the project management of the Water Conservation and Reconciliation studies and have cross representation of study managers on the Water Quality Study.

In each of the tree abovementioned studies the importance of stakeholder involvement in the development of the strategies was emphasised and an integrated stakeholder engagement process was designed. This resulted in combining the stakeholder meetings for all three the studies, combining the Steering Committee Meetings of the Water Conservation and Reconciliation studies and having shared representation on the Water Quality Study.

A.1.2 PURPOSE OF THE STUDY

The Large Bulk Water Supply Reconciliation Strategies for the Vaal River System Study has the objective to develop strategies for meeting the growing water requirements of the industrial and urban sectors that are served by the Integrated Vaal River System. The development of these strategies requires reliable information of the water requirements and the water resources for the current situation as well as likely future scenarios for a planning horizon of twenty to thirty years.

The key objectives of the study are to:

- Update the current and future urban and agricultural water requirements.
- Assess the water resources and existing infrastructure.
- Take into account the Reserve requirements for alternative classifications.
- Formulate reconciliation interventions, both structural and administrative/regulatory.
- Conduct stakeholder consultation in the development of the strategies.

In order to achieve these objectives the study was undertaken through a series of tasks which culminated into a set of study reports that are listed on the back of the cover page of the report. The information from the task reports were combined to formulate the reconciliation strategy, the main deliverable from the study, which is presented in the report “First Stage Reconciliation Strategy” (**DWAF, 2006g**).

A.1.3 STUDY AREA

The core of the study area consists of the Upper, Middle and Lower Vaal River Water Management areas, however, due to the numerous inter-basin transfers that link this core area with other WMAs, reconciliation planning has to be undertaken in the context of the Integrated Vaal River System which also includes portions of the Komati, Usutu, Thukela and Senqu River (Located in Lesotho) catchments. In addition, significant water transfers occur to water users in the Olifants and Crocodile (West) River catchments of which most are totally dependant on the water resources of the Integrated Vaal River System. **Figure B-1** in **Appendix B** shows a geographical map of the Integrated Vaal River System which is the area of concern for the study.

The water resource components of the Integrated Vaal River System are highly inter-dependant due to the cascading orientation of the three Vaal River WMAs as well as the links that exist as a result of the transfer schemes (indicated by the arrows on **Figure B-1**). The water resource system provides water to one of the most populated and important areas in the country as reflected by the magnitude of the developments located in the Upper and Middle Vaal, the Olifants and the upper portion of the Crocodile West Marico Water Management areas. These developments include many of the country’s power stations, gold mines, platinum mines, petro-chemical plants as well as various other strategic industries. The water requirements in the area are therefore very important to sustain the economy of the country and the well being of its people.

It should be noted that the study area of the Integrated Water Quality Management Study (IWQMS) covers a slightly larger area than the three Vaal River WMAs and also include the Riet and Modder River Catchments, which is part of the Upper Orange WMA. The inclusion of these catchments was necessary to cover all water quality aspects of the entire Vaal River’s catchment down to it’s confluence with the Orange River.

A.1.4 PURPOSE AND LAYOUT OF THIS REPORT

This report describes the water resource analyses undertaken for the Integrated Vaal River System (IVRS) as part of the First Stage Reconciliation Strategy. The water resource analyses comprised of the following sub-tasks:

- Review hydrology of selected sub-catchments;
- Derive revised short-term yield reliability curves for the Senqu Sub-system based on the latest ecological flow releases and the officially adopted operating rule for the Mohale-Katse transfer tunnel;
- Assessment of the Thukela Water Project (TWP);
- Assessment of the Lesotho Highlands Further Phases (LHFP);
- Update the WRPM configuration by incorporating the water requirement and return flow projections of all the water user groups revised as part of this study;
- Undertake projection analyses with the Water Resource Planning Model (WRPM) to determine the need for intervention based on various assumptions; and
- Reporting.

The introduction to the study, given in **Chapter A.1**, is followed by a description of the methodology adopted for the water resource analysis in **Chapter A.2**. **Chapter A.3** reports on the hydrology reviews of selected catchments. The derivation of the revised short-term yield reliability curves for the Senqu Sub-system and the updating of the Bloemhof Sub-system is documented in **Chapter A.4**. **Chapter A.5** describes the water requirement and return flow scenarios on which the water conservation and water demand management scenarios, presented in **Chapter A.6**, were based. Infrastructure intervention options are discussed in **Chapter A.7** and the update of the Water Resource Planning Model (WRPM) configuration is described in **Chapter A.8**. Future intervention requirements which include descriptions of the WRPM scenarios analysed as part of the First Stage Reconciliation Strategy as well as the scenario results are provided in **Chapter A.9**. Conclusions and recommendations are provided in **Chapters A.10** and **A.11** respectively and finally, the references used in the report are presented in **Chapter A.12**.

A.2 WATER RESOURCE ANALYSIS METHODOLOGY

A.2.1 APPROACH TO WATER RESOURCE ANALYSIS

Details on the study procedure in terms of the technical work, as well as the methodology adopted for the development of reconciliation strategies, are described in the report “First Stage Reconciliation Strategy”, compiled as part of this study (**DWAF, 2006g**).

The focus of the assessments for the First Stage Strategy included, inter alias, the following:

- Development of water requirement and return flow scenarios for the urban water use sector of the Gauteng Province (**DWAF, 2006a**);
- Determination of the potential for Water Conservation and Demand Management by concentrating on the main urban areas (**DWAF, 2006b**).
- Estimation of irrigation water requirements (**DWAF, 2006d**);
- Identification and assessment of potential large scale water reuse options that could have water quality and water supply benefits (**DWAF, 2006c**).

The following approach was subsequently adopted for the water resource analysis task:

- The Water Resource Planning Model (WRPM) configuration of the Integrated Vaal River System (IVRS), as well as the water requirement and return flow database resulting from the 2006-2007 Annual Operating Analysis (AOA), was adopted as basis for the water resource assessment.
- The water requirement and return flow database was then updated to include the revised irrigation water requirements obtained as part of this study (**DWAF, 2006d**).
- Two alternative water requirement and return flow scenarios were developed for the urban water use sector of the Gauteng Province (**DWAF, 2006a**) and were incorporated in the water requirement and return flow database of the WRPM.

- The Water Resource Planning Model (WRPM) configuration was updated to enable realistic modelling of the revised water requirements of both the irrigation and the urban water use sector of the Gauteng Province.

- WRPM scenarios were identified and analysed to assess the need for intervention (refer to **Section A.2.3** below) based on the following:

  - Two alternative water requirement and return flow projection scenarios for the urban sector in the Gauteng Province;

  - Alternative Water Conservation and Demand Management initiatives focussing on the nine largest urban water users in the Gauteng Province;

  - Existing water quality management options relating to blending, dilution and water reuse; and

  - Implementation of preliminary Ecological Water Requirements (refer to **Section A.2.2** below).

A.2.2 RECONCILIATION FOR A PRELIMINARY RESERVE SCENARIO

In the Vaal River System Overarching ISP it was recommended that a comprehensive reserve determination of the Vaal River System and the supporting source catchments has to be undertaken. Although high confidence reserve determinations have been carried out in a few catchments the need for a Comprehensive Reserve Determination Study that covers the entire integrated system has been identified by DWAF. The Directorate: Resource Directed Measures (Dir: RDM) has, therefore commissioned studies during the end of 2006 for undertaking Comprehensive Reserve Determination Studies.

In order to provide an interim perspective on the water balance concerning the Reserve, as part of this study, an analysis was carried out where all available Ecological Water Requirement (EWR) information was sourced from Dir: RDM and incorporated into the WRPM. Two scenarios were simulated, one with and the other without the EWRs, and in each case the date when system failure occurred were determined for a selected water requirement projection scenario that covers the planning period up to 2030. The results are discussed in **Section A.9.6.**

A.2.3 DETERMINATION OF THE REQUIRED INTERVENTION DATES

Operational and planning decisions concerning the Integrated Vaal River System are informed by risk analysis techniques involving simulation of the water resource system using computer models. The analysis is undertaken by means of a suite of water resource simulation models which contains an extensive hydrological database that covers all the catchments and river systems comprising the Integrated Vaal River System. The suite of models consists of various supporting utilities all having the function of generating data and information require by the WRPM.

The WRPM is the main decision support system which through scenario analysis determines, among other things, the future date when intervention is required based on the probability (risk) of curtailments for a given set of variables and assumptions. The model contains an allocation procedure (algorithm) to simulate curtailment rules which reduce (curtail) the water requirements when the storage state of the system is depleted to such levels that the short-term yield (supply capability) is less than the water requirements.

The date when intervention is required, is determined by analysing a large number of possible hydrological inflows (runoff) and by implementing curtailments in each of the inflow sequence when droughts occur, an estimate of the probability of curtailments is obtained. These simulations are carried out for a planning period of about twenty years during which the water requirements increase over time resulting in more frequent curtailments being required from year to year. The most important result from the simulations is the annual projected risk of curtailments and the year in which the reliability criteria are violated, defines the date when intervention is necessary.

In this study the above described methodology were applied to the scenarios described in **Section A.9.2** and the scheduling results are presented in **Section A.9.5**.

A.3 REVIEW HYDROLOGY OF SELECTED SUB-CATCHMENTS

A.3.1 GENERAL

The hydrological database of the Komati, Usutu, Buffalo, Assegaai, Vaal and Senqu Sub-systems incorporated in the WRPM configuration originates from the Vaal River System Analysis Update (VRSAU) Study (**DWAF, 2000**). The VRSAU hydrological database covers the period October 1920 to September 1995 and one of the study's recommendations was that the hydrology of the Vaal River System be updated again in 15 to 20 year's time or after a severe drought period.

The update of the hydrology of the IVRS was not part of the TOR for this study. However, in view of the current updating of land use data, it was proposed that the hydrology of selected catchments be reviewed. The purpose of the hydrology review was to identify key catchments, in consultation with the Client, for which it was necessary to update the hydrology. The review of the Schoonspruit and Harts River catchment hydrology is discussed in the following sections.

A.3.2 SCHOONSPRUIT SUB-SYSTEM

The hydrology of the Schoonspruit Sub-system resulting from the VRSAU Study has been revised as part of the Schoonspruit Sub-system Analysis Study (**DWAF, 2006**). The observed flow from the Schoonspruit Eye was not available when the hydrology for the VRSAU study was created. The hydrology for the Schoonspruit catchment was therefore re-calibrated and the recently developed groundwater surface water interaction model by K Sami was used to model the flow from the Schoonspruit Eye. An improved calibration was obtained and the updated hydrology is considered to be a definite improvement on the VRSAU hydrology and can be used with more confidence.

From the VRSAU hydrology reports it was clear that the hydrologists struggled with a large number of negative flow values in the overall balance to Bloemhof Dam. Due to the relative high base flow from the Schoonspruit (as result of the flow from the Schoonspruit Eye) a fair amount of the negatives were absorbed in the Schoonspruit flows. When it was attempted to incorporate the updated Schoonspruit hydrology into the overall system up to Bloemhof Dam negative flows again resulted in the Schoonspruit hydrology. Consequently, for the purposes of the Schoonspruit Sub-system Analysis Study (**DWAF, 2006**), it was decided to model the Schoonspruit sub-system on its own.

The re-assessment of the Bloemhof Dam incremental hydrology in context of the updated Schoonspruit hydrology was identified as a possible activity to be undertaken as part of this study. Owing to time constraints, the re-assessment of the Bloemhof Dam incremental hydrology was not undertaken as part of the First Stage Reconciliation Strategy development and the updated Schoonspruit hydrology could not be used in combination with the rest of the existing Vaal River System due to the negative values. It is, therefore, recommended to redo the hydrology at least for the Vaal River catchment between Vaal Dam and Bloemhof Dam, taking into account the effects of updated hydrology created for sub-catchments included in this area (refer to **Section B.3** of **Part B** for information on subsequent work done in this regard).

A.3.3 HARTS RIVER SUB-SYSTEM

The hydrological data and information of the Harts River Sub-system was recently evaluated as part of the inception phase of the study entitled "Feasibility Study For Utilisation of Taung Dam Water".

The evaluation of the suitability of the hydrological database originating from the VRSAU Study was carried out by assessing the following items:

- Assess the availability of flow data and if there is new information available that may be used to improve the confidence in the hydrological database.
- Assess if significant land use changes occurred since the VRSAU study which may validate a re-calibration of the rainfall-runoff model.
- Assess if the record period after 1994 was significantly different in character to the available data.
- Evaluate if abstractions from the dolomites in the upper part of the Harts River Catchment may have a significant impact on the surface water resources.

The evaluation of the suitability of the current hydrological database by assessing the above-mentioned items clearly showed that none of these items warrant a revision or extension of the hydrology. It was, therefore, recommended that the existing VRSAU hydrology be adopted for the analysis to be carried out as part of the Feasibility Study For Utilisation of Taung Dam Water.

A.4 UPDATES FOR THE SENQU AND BLOEMHOF SUB-SYSTEMS

A.4.1 REVISED SHORT-TERM CURVES FOR THE SENQU SUB-SYSTEM

A.4.1.1 Background

The Senqu sub-system comprises the catchment of the Orange River (Senqu in Lesotho) within the borders of Lesotho as shown in **Figure B-2** of **Appendix B**. The main tributaries of the Senqu River are the Malibamatsu, Tsoelike and Senqunyane Rivers. The Lesotho Highlands Water Project (LHWP) was initiated to transfer water from within Lesotho to South Africa. The existing transfer scheme (indicated by the relevant arrows on **Figure B-1**) was developed in different phases as described below:

Phase 1A (Katse Dam): The first phase consisted of Katse Dam on the Senqu River, with approximately 80 km of tunnels delivering water to the Axle River, a tributary of the Liebenbergsvlei River which in turn flows into the Vaal River. The tunnel from Katse to the Axle River is broken 45 km from Katse, at which point a hydro-electric power station has been constructed. The tailrace of the power station discharges into a small dam, Muela Dam, in which the intake for the delivery tunnel to the Axle River is situated. Katse Dam was constructed with a gross Full Supply Capacity (FSC) of 1950.0 million m^3. The lowest intake level of the Katse transfer tunnel is at 1989.0 m with an associated storage of 431.4 million m^3 resulting in a net FSC of 1518.6 million m^3. Impoundment at Katse Dam started in December 1996 and delivery to the Vaal catchment commenced in April 1998. The maximum transfer capacity of the Katse-Vaal transfer tunnel is 35.7 m^3/s.

Phase 1B (Katse Dam, Matsoku Weir and Mohale Dam): Phase 1B consisted of a dam at Mohale on the Senqunyane River and the Matsoku Weir on the Matsoku River, which transfer water via gravity tunnels to Katse Dam from where it is transferred through the Phase 1A tunnels to South Africa. Delivery from Matsoku Weir into Katse Dam (at a maximum transfer rate of 35.0 m^3/s) commenced in January 2001. Mohale Dam has a gross FSC of 946.9 million m^3 and a dead storage volume of 89.8 million m^3 (i.e. 9.5% of its gross FSC). The Mohale-Katse transfer tunnel has a maximum transfer capacity of 27.5 m^3/s and is capable of transferring water in both directions depending on the relative storage levels of the two dams. Impoundment at Mohale Dam started on 1 November 2002 and although the construction of the Mohale-Katse tunnel was completed by February 2004, transfers were only expected to commence in January 2006.

The LHWP Phase 1A and 1B components described above were included in the WRPM configuration of the IVRS (refer to **Figure A-3** of **Appendix A**). The short-term yield reliability curves determined for the Senqu sub-system as part of the VRSAU Study were based on the following assumptions in terms of ecological flow releases and inter-reservoir transfer rules:

- **Katse Dam compensation releases**: A constant monthly release of 0.5 m^3/s (i.e. 15.8 million m^3/a).
- **Mohale Dam compensation releases**: A constant monthly release of 0.3 m^3/s (i.e. 9.5 million m^3/a).
- **Matsoku-Katse transfer tunnel**: Transfers are modelled based on the VRSAU study's diversion function as presented in **Table A.4.1**Error! Reference source not found..

Table A.4.1: Matsoku Weir diversion relationship

Description	Flow (m^3/s)							
Inflow	0.00	1.90	3.80	7.61	11.41	15.21	19.01	20.91
Diverted flow	0.00	1.43	3.03	6.90	10.35	13.80	17.17	18.93

- **Mohale-Katse transfer tunnel**: The rate of flow between Mohale Dam and Katse Dam depends on the relative levels of storage in Mohale Dam and Katse Dam. The relationship between the difference in head and the rate of transfer derived as part of the VRSAU Study is given in **Table A.4.2** and was incorporated in the WRPM configuration. As indicated in **Table A.4.2** the VRSAU Study used the head versus. flow relationship based on a roughness (K) of 6 mm.

Table A.4.2 Mohale Dam to Katse Dam transfer

Head difference (m)	0.00	2.40	4.80	7.20	9.60	12.00	14.40	36.77	59.13	81.50
Transfer K = 6 mm (m^3/s)	0.00	7.71	10.91	13.36	15.43	17.25	18.90	30.20	38.29	44.96

The compensation releases mentioned above formed part of the Lesotho Highlands Water Project (LHWP) Treaty and the transfer tunnel relationships were based on physical characteristics of the infrastructure components. The Ecological Reserve (ER) water requirements have, however, subsequently been revised. Furthermore, the rules finally adopted by the Lesotho Highlands Development Authority (LHDA) for operating the Mohale-Katse transfer tunnel were recently submitted to the DWAF for inclusion into the water resource simulation models (WRYM and WRPM). Since these changes have a direct impact on the yield capability of the Senqu sub-system, it was necessary to revise the short-term yield reliability curves currently incorporated in the WRPM configuration.

A.4.1.2 Revised Ecological Reserve information

A revised Ecological Reserve (ER) that is different to that described in the Lesotho Highlands Water Project (LHWP) Treaty has been adopted for Katse and Mohale dams. The adopted releases are in accordance with an assessment that was made in 2003 (**LHDA, 2003**). The DWAF, the Lesotho Highlands Development Authority (LHDA) and the World Bank accepted the new rule and the principles of the new rule that were documented in February 2003 (LHDA, 2003).

Since the LHDA's approach is different to that generally adopted for system modelling (WRYM and WRPM) in South Africa in that annual reference flows are used for the modelling of monthly IFRs, an additional IFR release structure was incorporated in the WRYM and WRPM. The new feature was designed to accommodate the alternative IFR modelling approach which was followed in the Lesotho Highlands Development Project (LHDP). As mentioned above, the LHDP methodology requires for monthly IFRs to be modelled based on annual reference inflow values. Information provided in the LHDA report (LHDA, 2003) was used for defining the IFR release structures that were adopted for Katse and Mohale dams.

The new IFR release structures had already been incorporated in the WRPM configuration of the IVRS as part of the 2005-2006 Annual Operating Analysis. The impact of the revised Ecological Flow Releases on the yield capability of the Senqu sub-system was, however, accounted for by using a "dummy" abstraction of 74.3 million m^3/a that was imposed on the sub-system as part of the allocation algorithm calculations. The "dummy" abstraction of 74.3 million m^3/a was calculated as the difference between the original Treaty compensation releases and the average long-term releases based on the revised Ecological Flow Releases.

A.4.1.3 Mohale-Katse transfer tunnel operating rule

The document entitled "Mohale Tunnel Operation Procedure" (Draft 1 of July 2004) was obtained from the LHDA as part of the 2006/2007 AOA of the Integrated Vaal River System. This document describes the approach adopted for the assessment of the rules for operating the tunnel. It also provides precise instructions that must be taken by the LHWP Phase 1 system operator under different storage conditions of the Mohale and Katse dams. A rule level method, whereby a prescribed difference (in meters) between water levels in Mohale and Katse dam is used as an operating criterium, was selected as it is easy to implement.

A rule level of 12 meters was finally chosen on the basis that it increases the chances of Mohale Dam spilling together with Katse Dam. The criteria for operating Mohale tunnel is, therefore, to keep the difference in water level between Katse and Mohale to below 12 meters unless Katse is near spilling in which case Mohale Dam is allowed to rise in isolation from Katse Dam. Reverse flows from Katse to Mohale are made whenever conditions allow. These decisions are made at the beginning of each month unless Katse Dam is under spill conditions. The criteria used for selecting the optimal rule level of 12 meters were based on maximising the Nominal Annual Yield (NAY). The operation of the tunnel is such that either it is fully open or it is fully closed. The quantity of water transferred is determined by the actual head difference between Mohale and Katse dams and the roughness of the tunnel.

The WRYM and WRPM were not capable of modelling the above-mentioned operating rule. The required functionality, therefore, had to be built into these simulation models.

A.4.1.4 Revised short-term curves

The updated WRYM was used for the derivation of the revised short-term yield reliability curves. The assessment was based on the system configuration of the Senqu Sub-system as shown in **Figure C-1** and the final hydrology of the Senqu as adopted for the VRSAU Study. It should be noted that, as shown in **Figure C-1**, allowance was also made for a constant compensation release of 0.65 m^3/s (i.e. 20.5 million m^3/a) from Matsoku Weir.

501 stochastically generated flow sequences, each five years in length, were used in the short-term yield analysis. The multiple period option was selected whereby multiple period curves (1 year, 2 years, 3 years, 4 years and 5 years) were derived. The objective with multiple period curves is to obtain the most conservative yield-reliability result in all cases by selecting the period length with the smallest yield. A maximum period of 5 years was used as it represents the typical

length of the critical period during drought events for most of the river systems. The analysis was repeated for the following different starting storage volumes: 100%, 80%, 60%, 40%, 20% and 10% of the net full supply capacities of the dams. The corresponding starting storage levels were determined from the storage-elevation relationships of the dams.

For each starting storage volume the yield results were produced for all the period lengths up to and including five years. The firm yield curves for each period length were compared and the most conservative result was selected. This is most evident in low starting storage conditions where the yield curves for period lengths less than five years produce the most conservative results.

The results of the short-term analysis for the Senqu Sub-system are presented in **Table A.4.3** and the short-term curves are provided in **Figures C-2** to **C-7** of **Appendix C**. **Figure C-8** shows the family of short-term firm yield lines for the Senqu sub-system. The coefficients of the short-term yield reliability curves are presented in **Appendix C** for each of the starting storages. The coefficient data files which are produced from the short-term stochastic yield curves are used as input to the WRPM.

Table A.4.3: Results of the short-term stochastic analysis for the Katse/Mohale Sub-system

System Start Volume as % of Live Storage	Firm Yield for Indicated Recurrence Interval (million m^3/annum)							
	1:20 year		1:50 year		1:100 year		1:200 year	
	VRSAU	Revision 2006	VRSAU	Revision 2006	VRSAU	Revision 2006	VRSAU	Revision 2006
100%	1 160	1 106	1 075	1 017	1 010	979	980	954
80%	1 075	1 015	960	930	910	886	890	856
60%	965	906	860	827	820	781	780	754
40%	860	790	750	717	700	673	665	645
20%	710	640	615	569	560	531	520	500
10%	560	465	480	411	440	392	390	368

From **Table A.4.3** it can be seen that the revised 2006 firm yields are all lower than that of VRSAU with differences ranging between 2.6% (80% starting storage and 1:100 year RI) and 17% (10% starting storage and 1:20 year RI). This was expected as the compensation releases based on the revised Ecological Releases are on average about 74.3 million m^3/a higher than the original Treaty releases for Katse and Mohale dams alone.

It should be noted that the revised short-term curves presented above were not available for inclusion in the WRPM configuration that was adopted for the First Stage Reconciliation Strategy scenario analyses. Therefore, for all the WRPM scenarios presented in **Part A** of this report, the impact of the revised Ecological Flow Releases (refer to **Section A.4.1.2**) was accounted for by using a "dummy" abstraction that was imposed on the sub-system as part of the allocation algorithm calculations. No compensation releases were modelled downstream of Matsoku Weir. Furthermore, flow through the Mohale-Katse transfer tunnel was determined by the relationship presented in **Table A.4.2** as the operating rule described in **Section A.4.1.3** was not yet included as an additional feature when the WRPM scenario analyses were undertaken for the First Stage Strategy development.

A.4.2 UPDATING OF THE BLOEMHOF SUB-SYSTEM

A.4.2.1 Objectives

The objective of this task was to update the Water Resource Yield Model (WRYM) configuration of the Bloemhof Sub-system resulting from the Vaal River System Analysis Update (VRSAU) Study with the following information obtained from the Thukela Water Project Decision Support Phase (TWPDSP) Study that was undertaken in 2003:

- IFR 1 requirements upstream of Spioenkop Dam;
- Projected 2025 water demands upstream of Spioenkop Dam; and
- Minor infrastructure and climatic updates (as discussed in Section).

It should be noted that no changes were made to the hydrology of the Bloemhof Sub-system, but relevant incremental runoff files were proportioned according to the TWPDSP Study where necessary, as was the dummy dam sizes.

The main aim of the analysis was to quantify the impact on the yield of the Bloemhof Dam Sub-system due to the implementation of the projected water demands and ecological water requirements within the Thukela System.

A.4.2.2 Methodology

The Bloemhof Sub-System originating from the VRSAU Study and the refined Thukela System resulting from the TWPDSP Study were analysed using the Water Resources Information Management System (WRIMS Version 1.16.1). The WRIMS results were compared against those documented in the final VRSAU and TWPDSP Study reports. The Bloemhof Sub-System was then adjusted using the Visio Network Visualiser of the WRIMS. The part of the Bloemhof Sub-System that was altered using the Visio Network Visualiser is presented in **Figure C-16** of **Appendix C**.

A.4.2.3 Modelling of EWR upstream of Spioenkop Dam

The VRSAU configuration of the Upper Thukela catchment which is incorporated in the Bloemhof Sub-System did not allow for the modelling of the Ecological Reserve. IFR Site 1, located in the Upper Thukela River, upstream of Spioenkop Dam at the outlet of quaternary catchment V11J was identified as part of the TWPDSP Study. The Ecological Water Requirements at IFR Site 1 in the TWPDSP Study was incorporated into the Upper Thukela section of the Bloemhof Sub-system to assess the potential impact on the yield at Bloemhof Dam. To this end, the system configuration changes described below were applied to the Bloemhof Sub-System.

Runoff contributions upstream and downstream of IFR Site 1 had to be proportioned according to the revised sub-catchment areas based on the location of the IFR site. The TWPDSP Study proportion for the runoff split was used to scale the relevant runoff contributions of the Bloemhof Sub-System.

Runoff contributions from the TM69 and TM59 incremental catchments represented the dummy dam and mainstream contributions respectively in the Bloemhof Sub-System which had to be split to represent IFR Site 1's location. The combined runoff contributions from these two incremental catchments amounted to 119.38 million m^3/annum which was split according to the TWPDSP Study's proportioning for upstream and downstream contributions. A summary of the results is provided in **Table A.4.4**.

The existing Bloemhof Sub-System TM69 and TM 59 time series were also scaled proportionally to the contribution to dummy dams and the mainstream as in the TWPDSP Study. A summary of the scaling is provided in **Table A.4.5**.

Table A.4.4: Proportioning of runoff contributions relative to location of IFR Site 1

Runoff contribution	TWPDSP Study		Bloemhof Sub-system
	Runoff (million m^3/a)	% of Total	Runoff (million m^3/a)
Upstream of IFR Site 1	37.46	31.72	37.87
Downstream of IFR Site 1	80.62	68.28	81.51
Total	**118.08**	**100**	**119.38**

Table A.4.5: Proportioning of runoff contributions for dummy dams and mainstream nodes

			Dummy Dams	Main Stream	Total
TWPDSP Study	Runoff Contribution (%)	Upstream IFR1	15	85	100
		Downstream IFR1	23	77	100
Bloemhof Sub-System	Required runoff (million m^3/a)	Upstream IFR1	5.68	32.19	37.87
		Downstream IFR1	18.75	62.76	81.51
	Catchment Reference Number (Total Runoff - million m^3/a)		TM69 (31.04)	TM59 (88.34)	(119.38)
	Scaling of Bloemhof Sub-System Runoff (%)	Upstream IFR1	18.30	36.44	-
		Downstream IFR1	60.41	62.76	

The new area-capacity relationships calculated for the dummy dams upstream and downstream of the IFR Site 1 in the TWPDSP Study was also used. These area-capacity relationships were calculated by assessing the distribution of the farm dams upstream and downstream of the IFR Site 1. A summary of the data is provided in **Table A.4.6** below.

Table A.4.6: Area-capacity relationship for dummy dams up- and downstream of IFR Site 1

Elevation (m.a.s.l)	Capacity (million m^3)	Surface Area (km^2)
Upstream of IFR Site 1 (Node 49)		
1062.6	0.00	0.00
1069.4	4.70	1.27
1071.8	9.40	2.54

Elevation (m.a.s.l)	Capacity (million m^3)	Surface Area (km^2)
Downstream of IFR Site 1 (Node 105)		
1062.6	0.00	0.00
1069.4	11.49	3.10
1071.8	22.98	6.21

The upstream and downstream irrigation requirements relative to the IFR Site 1 was also obtained from the TWPDSP Study and is provided with the rest of the updated water requirements in **Table A**.4.7**.**

A.4.2.4 2025 Projected water requirements

Projected water requirements were obtained from Water Resources and Hydrology Module – Water Requirements Report (February 2002) of the Thukela Water Project Decision Support Phase. A summary of the 2025 irrigation development demands and urban/rural demands are provided in **Table A.4.7** and **Table A.4.8** respectively.

Table A.4.7: Irrigation requirements (1925 – 1994) for 2025 development

Channel Number	Description	Specified Demand File Name	Annual Average Requirement (million m^3)
205	Main catchment irrigation upstream Woodstock Dam	THW_40.IRD	4.98
203	Woodstock Dummy Irrigation	TM02_40.IRD	2.22
210	Irrigation upstream of Driel Barrage	THDRI_40.IRD	2.35
215	Mainstream irrigation upstream of IFR Site 1	THS_A_40.IRD	37.76
267	Irrigation downstream IFR Site 1	THS_B_40.IRD	Channel Number
262	Irrigation from Spioenkop Dummy	TM6_A_40.IRD	7.58
268	Irrigation from Spioenkop Dummy 2	TM6_B_40.IRD	3.56

Table A.4.8: Urban/rural demands for 2025 development

Channel Number	Description	Annual Average Requirement (million m^3)
207	Woodstock Dam abstraction for rural, Jagersrust and Drakensville	1.79
216	Abstraction for Bergville, Emmaus, Carnation Ind and National Parks Board	1.84

A.4.2.5 Minor infrastructure and climatic updates

Updated area-capacity relationships were obtained from the DWAF for both Woodstock Dam and Driel Barrage, which were incorporated into the configuration of the Bloemhof Sub-System. The revised area-capacity relationships of Driel Barrage and Woodstock Dam are provided in **Table A.**4.9.

Table A.4.9: Area-capacity relationships for Driel Barrage and Woodstock Dam

Elevation (m.a.s.l)	Capacity (million m^3)	Surface Area (km^2)	Elevation (m.a.s.l)	Capacity (million m^3)	Surface Area (km^2)
Driel Barrage			**Woodstock Dam**		
1150.0	200.000	26.160	1177.00	416.877	31.552
1140.0	37.860	6.268	1175.56	373.260	29.129
1139.0	31.904	5.645	1173.00	303.443	25.536
1137.0	21.725	4.534	1171.00	255.081	22.892
1135.0	13.654	3.538	1166.00	156.177	16.750
1134.0	10.359	3.051	1161.00	88.319	10.765
1132.0	5.428	1.879	1156.00	45.900	6.560
1131.0	3.811	1.356	1153.00	28.972	4.802
1129.0	1.731	0.724	1150.00	17.125	3.249
1127.0	0.660	0.347	1145.00	5.433	1.663
1126.0	0.363	0.247	1141.00	1.085	0.524
1125.0	0.168	0.143	1135.50	0.000	0.000
1124.0	0.048	0.095			

The evaporation data for the Driel Barrage was also updated in the TWPDSP Study and incorporated into the WRYM configuration of the Bloemhof Sub-System, as provided in **Table A.**4.10.

Table A.4.10: Updated evaporation data for Driel Barrage

Month	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
(mm)	112	104	110	108	95	94	84	81	65	72	99	110

A.4.2.6 Alternative short-term curves for Bloemhof Sub-system

The above-mentioned changes implemented in the Upper Thukela catchment configuration of the Bloemhof Sub-system influence the inter-basin transfers that can be made via the Thukela-Vaal transfer scheme (i.e. from Woodstock Dam and Driel Barrage to Sterkfontein Dam). Consequently, these changes also impact on the yield of the Bloemhof Sub-system.

The Historic Firm Yield (HFY) of the original Bloemhof Sub-system (i.e. originating from the VRSAU Study) amounted to 1703 million m^3/annum. Based on the updated WRYM configuration of the Bloemhof Sub-system, it was found that the HFY reduced to 1651 million m^3/annum. The adjustments and refinements discussed in **Sections A.4.2.3** to **A.4.2.5,** therefore, caused the HFY of the Bloemhof Sub-system to decrease by 52 million m^3/annum (i.e. a reduction of almost 3.1%).

The updated WRYM configuration of the Bloemhof Sub-system was used for the derivation of an alternative set of short-term yield reliability curves. Curves were derived for starting storages equal to 10%, 20%, 40%, 60%, 80% and 100% of the net full supply storage of the system. The preliminary curves are presented in **Figures C-10** to **C-15** of **Appendix C**. These short-term yield reliability curves should be used in combination with future phases of the Thukela Water Project.

A.5 WATER REQUIREMENTS AND RETURN FLOWS

A.5.1 INTRODUCTION

This chapter describes the water requirements and return flow scenarios that were developed as part of this study. The approach adopted for the presentation of the water requirement and return flow information is to reference the detail reports where applicable and to provide a summary of the data finally accepted for inclusion in the WRPM scenario configurations. The information is presented according to the following headings:

- Irrigation water requirements **(Section A.5.2).**
- Bulk industrial water requirements **(Section A.5.3).**
- Urban water requirements and return flows **(Section A.5.4).**
- Summary of the water requirement and return flow scenarios **(Section A.5.5).**

A.5.2 IRRIGATION WATER REQUIREMENTS

A.5.2.1 Methodology adopted for irrigation modelling within the WRPM

The purpose of this section is to provide some background in terms of the approach adopted for the modelling of irrigation water requirements in the WRPM prior to this study.

A major update of the WRPM configuration of the IVRS was undertaken in 1999 to incorporate the results of the VRSAU Study. As part of this process, all the irrigation water requirements were set to be modelled by means of the so-called irrigation modules. These irrigation modules require as input data information on inter alias irrigation areas, crop factors, rainfall efficiency, irrigation efficiency and return flow factors as well as water quality related information. The irrigation module, therefore, has the functionality of modelling not only the volumetric irrigation water requirements and return flows, but also the water quality in terms of Total Dissolved Solids (TDS) that is associated with these irrigation activities.

Subsequent to the VRSAU Study, investigations into the agricultural irrigation water use in the whole of the Vaal River catchment was conducted by Loxton Venn and Associates. Their findings were documented in the report entitled “Report for the Vaal River Irrigation Study” dated

September 1999 (**DWAF 1999**). Since the data resulting from the *"Loxton Venn"* Study was considered as the most accurate information available at the time, it was incorporated into the WRPM demand database.

Owing to the fact that the *"Loxton Venn"* Study and the WRPM use different calculation methods, it was necessary to redefine the existing WRPM irrigation parameters and to verify that the water quality calibrations are still acceptable. This task was, however, not included as part of subsequent operating analyses and for the purposes of these operating analyses it was agreed to adopt an intermediate approach whereby the irrigation abstractions were modelled as fixed annual net irrigation requirements as defined in the *"Loxton Venn"* Study. This method ensured that the desirable volumetric modelling of the irrigation requirements is achieved regardless of the fact that the simulated salinity results downstream of the irrigation areas would not be representative.

It should, however, be noted that only the irrigation in the Vaal River catchment upstream of Bloemhof Dam was affected by the *"Loxton Venn"* Study update and that the irrigation water requirements of the remainder of the supporting sub-systems still originate from the VRSAU. Consequently, irrigation water requirements within the Lower Vaal catchment are still modelled by means of the irrigation modules.

A.5.2.2 Overview

Irrigations water requirements comprise about thirty percent of the total system water use of which the Vaalharts Irrigation Scheme, the largest in the country, uses 50% of this sector's water. The ISP of the Vaal WMAs indicated that, due to the strategic decision that any new water use will have to pay the full cost of water, irrigation water use is likely to remain constant. The Water Resource Managers in the regions, however, expressed their concern that they expect substantial irrigation developments to have taken place since 1998 of which most is perceived to be illegal. This lead to the commissioning of a water use validation study in the Upper Vaal WMA from which preliminary information was received and assessed in this study.

Water requirements of the Irrigation Sector have been the subject of various studies in the past of which the information from the *"Loxton Venn"* Study (**DWAF, 1999**) was used in all recent water resource planning investigations. The subsequent water use registration, validation and verification processes commissioned by DWAF have generated further sources of information in the form of the Water Authorisation Registration Management System (WARMS) and the database generated from the validation studies. At the time the irrigation water requirement task was carried out the validation study of the Upper Vaal Water Management Area was partly completed and it was possible to extract partial validated information (about 70% of the properties were validated) for analysis in this study. The validation studies of the other two Vaal WMAs were, however, only commissioned and no validated information was available at the time. Therefore, the approach that was followed to estimate the irrigation water use in the Middle and Lower Vaal WMAs was to prepare comparison reports of data sources from previous studies as well as the WARMS database. These comparison reports were then discussed with the water resource managers of the respective regional offices to make a decision on the most appropriate data to use for the study.

The accurate modelling of irrigation return flows is becoming more and more important. To this end, the irrigation return flow model developed as part of the Crocodile (West) Return Flow Analysis Study was set up for the major irrigation schemes in the Vaal River System. The aim of the model was to obtain a better indication and understanding of the irrigation return flows in the Vaal River basin and to also assess the likely impact of WC/WDM measures on the water requirements and return flows. Information from the irrigation return flow model can also be used to update the irrigation modules contained in the WRPM (refer to **Section A.5.2.1**).

Results from the irrigation return flow model were not yet available at the time when the First Stage Reconciliation Strategy scenario analyses were undertaken with the WRPM. The general assumption was, therefore, made that irrigation return flows are in the order of 10% of the irrigation water use. It was also assumed that there would be no return flows from diffuse irrigation water use in the incremental sub-catchments. The results of the irrigation return flow model are presented in the detailed irrigation report of this study (**DWAF, 2006d**) and will be incorporated in the WRPM configuration of the scenarios analysed as part of the Second Stage Reconciliation Strategy.

Since detailed information on the irrigation water use and return flows can be found in the report “Irrigation Sector Demands and Economic Importance” compiled as part of this study (**DWAF, 2006d**), this report merely provides information on irrigation water use that was finally adopted for the study. The following sections summarise the irrigation data within the context of the three WMAs. Furthermore, the irrigation water requirements are presented with specific references to the WRPM configuration of the IVRS the schematic diagrams of which are included in **Figures A-1** to **A-12** of **Appendix A**.

A.5.2.3 Upper Vaal Water Management Area

The Upper Vaal WMA was divided in two main catchments, upstream and downstream of Vaal Dam, and thirteen sub-catchments for the purposes of presenting the results. The sub-catchments are presented in **Figure B-3** of **Appendix B**.

The WRPM configuration of the Upper Vaal WMA is shown on the following schematic diagrams provided in **Appendix A**:

- **Figure A-1**: Vaal River catchment upstream of Vaal Dam;
- **Figure A-4**: Vaal River catchment downstream of Vaal Dam and upstream of Vaal Barrage;
- **Figure A-5**: Mooi River catchment.

The approach adopted for the modelling of the irrigation within this WMA was to assign the irrigation water requirements regarded as the "Possible Existing Lawful Use" to existing irrigation elements included in the WRPM configuration. The unlawful irrigation water use (calculated as the difference between the "Water use in 2005" and the "Possible Existing Lawful Use") was then included in the WRPM configuration by adding additional abstraction channels. The reason for distinguishing between these two components of the total irrigation water use is to allow for alternative management options to be modelled in terms of the unlawful irrigation water use. As mentioned in **Section A.5.2.2**, results from the irrigation return flow model were not yet available at the time when the First Stage Reconciliation Strategy scenario analyses were undertaken with the WRPM. The general assumption was, therefore, made that irrigation return flows are in the order of 10% of the irrigation water use. Similar to the approach described in **Section A.5.2.1**, all irrigation abstractions were subsequently modelled as fixed annual net irrigation water requirements. It was also assumed that there would be no return flows from diffuse irrigation water use in the sub-catchments.

Table A.5.1 summarises the irrigation water requirements finally adopted for the Upper Vaal WMA upstream of Vaal Dam. These water requirements were included in the WRPM configuration and references to the specific WRPM components are also included in **Table A.5.1** to facilitate comparison with the schematic diagrams provided in **Appendix A**.

Table A.5.1 : Irrigation water requirements in the Upper Vaal WMA upstream of Vaal Dam

Sub-catchment [(1)]	Description	WRPM Irrigation Module Number/ File Name	WRPM Channel Number	Status of water use	Irrigation Water Use (million m^3/a)	
					Gross	Net
Grootdraai	Mainstream Irrigation upstream of Grootdraai Dam	RR12	765	Lawful	12.26	11.03
	Mainstream Irrigation upstream of Grootdraai Dam	-	1000	Unlawful	17.28	15.55
Sub-total: Grootdraai		**-**	**-**	**Water Use 2005**	**29.54**	**26.58**
Delangesdrift	Diffuse irrigation in sub-catchment	DELA9.IRR	-	Lawful	2.79	2.79
	Diffuse irrigation in sub-catchment	-	581	Unlawful	7.12	7.12
Sub-total: Delangesdrift		**-**	**-**	**Water Use 2005**	**9.91**	**9.91**
Frankfort	Irrigation from small dams	RR9	705	Lawful	17.49	15.74
	Irrigation from small dams	-	1004	Unlawful	27.21	24.49
	Irrigation from Saulspoort Dam and small dams upstream	RR10	761	Lawful	0.98	0.88
	Irrigation from Saulspoort Dam and small dams upstream	-	1005	Unlawful	0.68	0.61
	Mainstream Irrigation	RR11	763	Lawful	26.26	23.63
	Mainstream Irrigation	-	1006	Unlawful	72.64	65.38
Sub-total: Frankfort		**-**	**-**	**Water Use 2005**	**145.26**	**130.73**
Vaal Dam	Irrigation from small dams	RR13	770	Lawful	6.34	5.71
	Irrigation from small dams	-	1007	Unlawful	22.34	20.11
	Mainstream Irrigation	RR14	772	Lawful	19.01	17.11
	Mainstream Irrigation	-	1008	Unlawful	35.27	31.74
Sub-total: Vaal Dam		**-**	**-**	**Water Use 2005**	**82.96**	**74.67**
Total for catchment upstream of Vaal Dam		**-**	**-**	Lawful	**85.13**	**76.89**
		-	**-**	Unlawful	**182.54**	**165.00**
		-	**-**	**Water Use 2005**	**267.67**	**241.89**

*Notes: (1) The sub-catchments are presented in **Figure B-3** of **Appendix B**.*

The results in **Table A.5.1** show that the preliminary estimates of the Lawful water use in the catchment upstream of Vaal Dam are significantly less compared to the estimates of the water use in the year 2005.

Table A.5.2 provides the final irrigation water use for the area downstream of Vaal Dam as incorporated in the WRPM configuration.

Table A.5.2 : Irrigation water requirements in the Upper Vaal WMA, downstream of Vaal Dam

Sub-catchment (1)	Description	WRPM Irrigation Module Number/ File Name	WRPM Channel Number	Status of water use	Irrigation Water Use (million m^3/a)	
					Gross	Net
Suikerbosrand	Mainstream Irrigation (17%)	RR1	58	Lawful	0.64	0.58
	Mainstream Irrigation (17%)	-	1009	Unlawful	1.83	1.65
	Mainstream Irrigation (83%)	RR335	838	Lawful	3.11	2.80
	Mainstream Irrigation (83%)	-	1011	Unlawful	8.96	8.06
Sub-total: Suikerbosrand		**-**	**-**	**Water Use 2005**	**14.54**	**13.09**
Klip	Mainstream Irrigation	RR336	842	Lawful	7.90	7.11
	Mainstream Irrigation	-	1012	Unlawful	19.22	17.30
Sub-total: Klip		**-**	**-**	**Water Use 2005**	**27.12**	**24.41**
Riet	Mainstream Irrigation	RR337	852	Lawful	10.32	9.29
	Mainstream Irrigation	-	1013	Unlawful	18.37	16.53
Sub-total: Riet		**-**	**-**	**Water Use 2005**	**28.69**	**25.82**
Mooi	Klerkskraal: Diffuse irrigation	KLERK9.IRR	-	Lawful	0.00	0.00
	Klerkskraal: Diffuse irrigation	-	1004	Unlawful	0.02	0.02
	Boskop: Diffuse irrigation	BOSK9.IRR	-	Lawful	0.00	0.00
	Boskop: Diffuse irrigation (2)	-	1018	Unlawful	2.21	2.21
	Boskop: Irrigation from small dams	RR19	739	Lawful	0.00	0.00
	Boskop: Irrigation from small dams (2)	-	1015	Unlawful	1.47	1.32
	Mooi GWS: Klerkskraal Dam	KLERK.DEM	102	Lawful	6.36	5.72
	Mooi GWS: Boskop Dam	BOSKOP.DEM	105	Lawful	28.92	26.03
	Klipdrift: Diffuse irrigation	KLIPD9.IRR	-	Lawful	0.44	0.44

Sub-catchment (1)	Description	WRPM Irrigation Module Number/ File Name	WRPM Channel Number	Status of water use	Irrigation Water Use (million m^3/a)	
					Gross	**Net**
	Klipdrift: Diffuse irrigation	-	1019	Unlawful	0.77	0.77
	Klipdrift: Irrigation from dam	-	107	Lawful	7.12	6.41
Sub-total: Mooi		**-**	**-**	**Water Use 2005**	**47.31**	**42.92**
Kromdraai	Irrigation from small dams	RR338	160	Lawful	2.94	2.65
	Irrigation from small dams	-	1016	Unlawful	3.91	3.52
Sub-total: Kromdraai		**-**	**-**	**Water Use 2005**	**6.85**	**6.17**
Total for catchment downstream of Vaal Dam		**-**	**-**	Lawful	**67.75**	**61.03**
		-	**-**	Unlawful	**56.76**	**51.38**
		-	**-**	**Water Use 2005**	**124.51**	**112.41**

Notes: (1) *The sub-catchments are presented in **Figure B-3** of **Appendix B**.*

(2) *Total irrigation in Boskop Dam incremental catchment was split as follows: 60% as diffuse and 40% as irrigation from small dams*

A.5.2.4 Middle Vaal Water Management Area

Due to the absence of Validation Study information for the Middle and Lower Vaal WMA, a different approach was adopted in these areas to determine the irrigation water use. The approach involved preparing water use comparisons from the data of the VRSAU and Loxton Venn studies as well as the WARMS database. These comparisons were presented to the DWAF Regional Office Water Resource Managers to obtain their consent at deriving the “Suggested” water use figures.

Error! Reference source not found. summarises the final irrigation water requirements as incorporated in the WRPM configuration. The schematic diagram of the Middle Vaal catchment is shown in **Figure A-5** of **Appendix A**. It should be noted that the irrigation water use information that was proposed for some of the sub-catchments reflected the net water requirements. For these catchments it was, therefore, necessary to assess the gross irrigation requirements. This was done by assuming that irrigation return flows are in the order of 10% and reversing the calculation.

Table A.5.3: Irrigation water requirements in the Middle Vaal WMA

Sub-catchment (1)	Description	WRPM Irrigation Module Number/ File Name	WRPM Channel Number	Irrigation Water Use (million m^3/a)	
				Gross	Net
Schoonspruit	Rietspruit catchment: Diffuse irrigation	RIETS9.IRR	-	0.07	0.07
	Rietspruit & Elandskuil dams: Irrigation	RR22	119	18.68	16.81
	Johan Neser: Irrigation from small dams	RR23	188	2.46	2.21
	Johan Neser: Mainstream irrigation	RR24	189	2.31	2.08
	Irrigation from Johan Neser	RR25	121	10.25	9.22
Sub-total: Schoonspruit		**-**	**-**	**33.77**	**30.39**
Renoster (2)	Rietfontein catchment: Diffuse Irrigation	RIETF9.IRR	-	4.28	4.28
	Koppies: Irrigation from small dams	RR15	173	2.67	2.40
	Koppies: Mainstream irrigation	RR16	776	0.73	0.66
	Rietfontein: Irrigation from small dams	RR17	184	3.97	3.57
	Rietfontein: Mainstream irrigation	RR18	781	6.44	5.80
Sub-total: Renoster		**-**	**-**	**18.09**	**16.71**
Vals	Irrigation from small dams	RR332	123	6.47	5.82
	Mainstream irrigation	RR334	826	23.28	20.95
Sub-total: Vals		-	-	**29.75**	**26.77**
Allemanskraal (Sand-Vet)	Diffuse irrigation	ALLEM9.IRR	-	1.15	1.15
	Irrigation from small dams	RR30	746	6.38	5.74
	Irrigation from Allemanskraal Dam	RR26	131	36.99	33.29
Sub-total: Allemanskraal		-	-	**44.52**	**40.18**
Erfenis (2) (Sand-Vet)	Diffuse irrigation	ERF9.IRR	-	1.28	1.28
	Irrigation from small dams	RR331	585	3.61	3.25
	Irrigation from Erfenis Dam	RR27	133	43.64	39.28
Sub-total: Erfenis		**-**	**-**	**48.53**	**43.81**
Sand/Vet Incremental Catchment (2)	Diffuse irrigation	SAND9.IRR	-	1.28	1.28
	Irrigation from small dams	RR28	743	0.51	0.46
	Mainstream irrigation	RR29	807	10.38	9.34

Sub-catchment (1)	**Description**	**WRPM Irrigation Module Number/ File Name**	**WRPM Channel Number**	**Irrigation Water Use (million m^3/a)**	
				Gross	**Net**
Sub-total: Sand/Vet Incremental Catchment		**-**	**-**	**12.17**	**11.08**
Bloemhof Incremental Catchment (2)	Irrigation from small dams upstream of Mooi River confluence	RR340	876	4.18	3.76
	Vaal River mainstream irrigation upstream of Schoonspruit confluence	RR339	872	13.98	12.58
	Irrigation from small dams upstream of Schoonspruit River confluence	RR341	741	3.86	3.47
	Vaal River mainstream irrigation downstream of Schoonspruit confluence	RR2	129	30.03	27.03
Sub-total: Bloemhof Incremental Catchment		**-**	**-**	**52.05**	**46.84**
Total for Middle Vaal WMA:		**-**	**-**	**238.88**	**215.78**

Notes: (1) *The sub-catchments are presented in **Figure B-3** of **Appendix B**.*

(2) *Net water use information was available for these catchments. Therefore, gross water use was derived by assuming that net water use equals 90% of gross water use (i.e. return flows are in the order of 10%).*

A.5.2.5 Lower Vaal Water Management Area

The schematic diagram of the Lower Vaal catchment (including the Riet-Modder Sub-system) is shown in **Figure A-6** of **Appendix A**. As mentioned in **Section A.5.2.1**, irrigation activities in the Lower Vaal catchment are being modelled by means of irrigation modules. Where changes to the irrigation water use information currently incorporated in the WRPM were required to match the suggested water use, refinements had to be made in terms of the irrigation module input data.

The water use in the Lower Vaal WMA is predominantly for irrigation water supplied to the Vaalharts Irrigation Scheme as shown in **Table A.5.4** below. The suggested water use for 2005 is slightly lower compared to the VRSAU and Loxton Venn studies and is due to unused allocations which are currently not developed in the Taung portion of the Vaalharts Irrigation Scheme. The VRSAU and Loxton-Venn studies provided similar water requirements for the Lower Vaal WMA. The irrigation water requirements resulting from the VRSAU Study were, however, incorporated in the WRPM configuration prior to this study.

Table A.5.4 : Irrigation water requirements in the Lower Vaal WMA

Sub-catchment (1)	Description	WRPM Irrigation Module Number/ File Name	Gross Water Use		Irrigation Return Flows	
			WRPM Channel No.	(million m^3/a)	WRPM Channel No.	(million m^3/a)
Upper Harts (Harts River Upstream of Wentzel Dam)	Wentzel Dummy Dam Irrigation	RR357	612	1.21	614	0.15
	Mainstream irrigation: Upstream of Wentzel Dam	RR360	617	3.62	618	0.46
	Wentzel Dam Irrigation (Terminated)	RR362	621	0.00	625	0.00
Sub-total: Upper Harts			**-**	**4.83**	**-**	**0.61**
Harts Remainder (Middle and Lower Harts)	Spitskop small dams irrigation	RR376	640	1.50	642	0.15
	Mainstream Irrigation: Taung to C3H007	HARTU7.ABS	650	2.80	-	-
	Mainstream Irrigation: C3h007 to Spitskop	HARTD7.ABS	657	0.39	-	-
	Spitskop Dam irrigation	407	728	12.81	734	1.55
Sub-total: Harts Remainder			-	**17.50**	**-**	**1.70**
Bloemhof Dam to Douglas Weir	Mainstream Irrigation: Bloemhof Dam to Vaalharts Weir	RR397	682	27.42	684	2.30
	Mainstream irrigation: Vaalharts to De Hoop	RR405	731	25.06	733	2.34
	Mainstream irrigation: De Hoop to confluence of Vaal and Harts	RR289	984	24.20	985	2.27
	Mainstream irrigation: Confluence of Vaal and Harts to Schmidtsdrift	RR290	998	7.67	999	0.72
	Mainstream irrigation: Schmidtsdrift to confluence of Vaal and Riet rivers	RR291	1001	2.40	1002	0.22
Sub-total: Bloemhof Dam to Douglas Weir			**-**	**86.75**	**-**	**7.85**
Vaalharts Scheme	Part of Taung irrigation	RR370	629	6.34	632	1.61
	North canal and part of Taung	RR379	646	270.04	644	50.37
	West and Barkley-West canals	RR383	654	51.38	652	0.41
Sub-total: Vaalharts Scheme			**-**	**327.76**	**-**	**52.39**
Total for Lower Vaal WMA:			**-**	**436.84**	**-**	**62.55**

*Notes: (1) The sub-catchments are presented in **Figure B-3** of **Appendix B.***

The irrigation water requirements of the sub-catchments Upper Harts and Harts Remainder that were originally included in the WRPM configuration as part of the VRSAU Study were also considered as the most reliable data to be used for this study. Adjustments had to be made to the irrigation water requirements of the mainstream irrigators situated between Bloemhof Dam and Douglas Weir, as well as the Vaalharts Irrigation Scheme. Since it was necessary to adjust the input data of the irrigation modules iteratively in order to achieve the recommended 2005 water use, it was not possible to obtain the exact values. Consequently, there is a slight difference (0.37 million m^3/a) between the total revised water use of 436.84 million m^3/a for the Lower Vaal WMA incorporated in the WRPM and the 437.21 million m^3/a quoted in the detailed irrigation report of this study (**DWAF, 2006d**).

Owing to the importance of the Vaalharts Irrigation Scheme, the original VRSAU Study results are compared with the recommended 2005 water use in **Table A.5.5**. Losses through the canal system are quite high and are also shown in **Table A.5.5**.

Table A.5.5 : Comparison for Vaalharts Irrigation Scheme

Description	VRSAU Study (million m^3/a)	This Study (million m^3/a)
Total irrigation water use	350.47	327.76
Total losses excluding tailwater losses	45.03	127.00
Total abstraction from Vaalharts Weir:	**395.50**	**454.76**

From **Table A.5.5** it can be seen that the recommended 2005 water use for the Vaalharts Irrigation Scheme is about 6% less than that of the previous assessments. A detailed evaluation of the monthly water schedule data obtained for the Vaalharts Irrigation Scheme showed that the losses (including canal and tail water losses) are significantly more than what was estimated in previous studies. From **Table A.5.5** it is clear that the losses determined as part of this study are approximately 180 % higher than the losses resulting from the previous assessments. This implies an overall increase of about 59.3 million m^3/a in the water use for the Vaalharts Irrigation Scheme based on the results of this study. The losses are modelled through WRPM channel number 651.

On the other hand, the recommended 2005 water use for Vaal River mainstream irrigation is 17.8 million m^3/a less than the previous assessment, resulting in an overall increase in water use for the Lower Vaal WMA of 41.5 million m^3/a.

A.5.2.6 Irrigation water use in supporting sub-systems

The most recent assessments of the irrigation water use of the supporting sub-systems of the IVRS were undertaken as part of the VRSAU Study. The VRSAU water use was incorporated in the WRPM configuration and is modelled as time series abstraction files. The irrigation water use of the supporting sub-systems adopted for this study is summarised in **Table A.5.6**.

Table A.5.6: Irrigation water use within supporting sub-systems of the IVRS

Sub-system	Description	WRPM Filename	WRPM Channel Number	Water Use (million m^3/a)
Komati	Nooitgedacht small dams irrigation	NOOI94N.CIR	724	2.16
	Gemsbokhoek diffuse irrigation	GEMS9.IRR	-	3.06
	Gemsbokhoek small dams irrigation	GEM94N.CIR	723	4.67
	Vygeboom diffuse irrigation	VYG9.IRR	-	2.85
	Vygeboom mainstream irrigation	VYG94N.CIR	725	9.74
Sub-total for Komati Sub-system:				**22.48**
Usutu	Morgenstond diffuse irrigation	MORG9.IRR	-	1.53
Heyshope	Irrigation from small dams	HEYD94N.CIR	714	6.82
	Mainstream irrigation	HEYM94N.CIR	716	1.71
Sub-total for Heyshope Sub-system:				**8.53**
Total diffuse irrigation water use for supporting sub-systems:				**7.44**
Total controlled irrigation water use for supporting sub-systems:				**25.10**
Total irrigation water use for supporting sub-systems:				**32.54**

A.5.2.7 Summary of irrigation water use for the Vaal River System

Table A. 5.7 provides a summary of the current (year 2005) irrigation water use included in the WRPM configuration for the Integrated Vaal River System excluding the Thukela and Orange River Sub-systems.

Table A. 5.7: Summary of irrigation water use for the Vaal River System

Description	Recommended current (year 2005) water use (million m^3/a)	
	Gross	Net
Upper Vaal WMA	392.18	354.30
Middle Vaal WMA	238.88	215.78
Lower Vaal WMA (including consumptive canal losses) (1)	563.84	501.29
Sub-total for three Vaal WMA:	**1194.90**	**1071.37**
Supporting Sub-systems (2)	32.54	32.54
Total for the IVRS:	**1227.44**	**1103.91**

Note : (1) Includes Vaalharts canal losses of 127 million m^3/annum

(2) Excluding the Thukela and Orange River Sub-systems

A.5.2.8 Scenarios of future irrigation water use

The information presented in the previous sections focused on the historical and current irrigation water use. However, what is required for planning purposes is to compile scenarios of future water use for the period up to 2030. Most of the increases in the water use since 1998 is considered to be unlawful and poses a significant challenge to the DWAF as the regulating authority. Given that the current (year 2005) water use estimates are significantly higher than the preliminary estimates of what is considered lawful, a scenario was compile where it was assumed that the current water use will be reduced over the medium term through legal interventions and water use compliance monitoring.

A scenario (**Irrigation Scenario 1**) was defined and adopted for all the WRPM scenarios analysed as part of the First Stage Reconciliation Strategy. The assumptions used in the scenario are listed below.

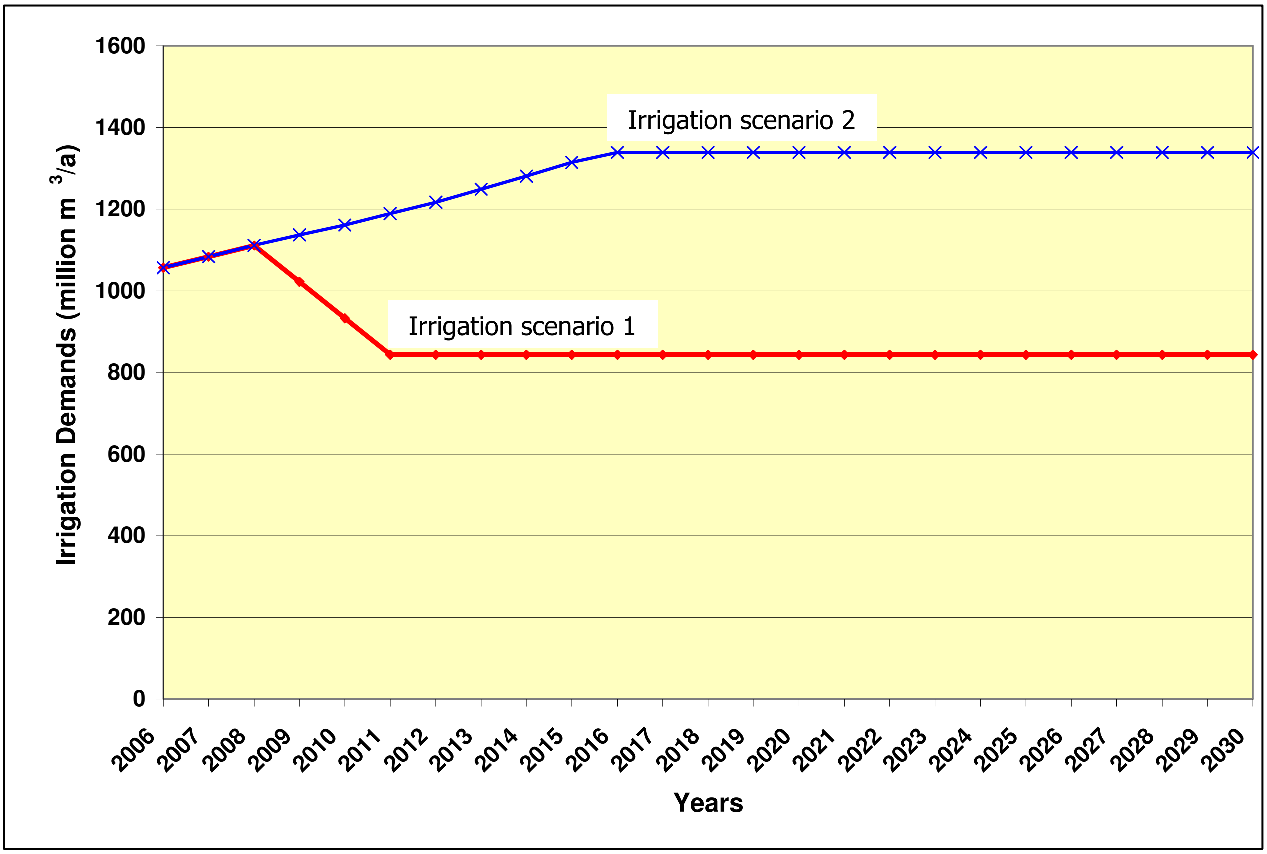
Irrigation Scenario 1: Curtailment of unlawful irrigation water use

- **Upper Vaal WMA**
  - Assume the growing trend, which was observed over the period 1998 to 2005, continues for two years until 2008. This implies the interventions will take two years to become effective.
  - Eradication of unlawful irrigation water use from 2008 onwards and assuming the water use will decrease over a period of 4 years.
  - The assumption is made that the interventions will reduce the irrigation to the lawful volume plus 15% and that this will be achieved in the year 2011. The additional 15% above the estimates of the lawful water use is a conservative assumption providing for possible under estimations from the current data.
- **Middle and Lower Vaal WMA**
  - Due to the absence of information from validation studies in these areas, it is assumed that the current suggested irrigation water use will remain constant over the planning period.

A second irrigation scenario was also defined, whereby it was assumed that no curtailment of unlawful use will take place and that the irrigation demand will continue to increase at the rate observed between 1998 and 2005 until the registered volume from the WARMS database is reached. Since **Irrigation Scenario 2** will create an unsustainable situation in the Vaal River System, it is not considered to be viable and was therefore not used for the WRPM analyses. This scenario is described in the irrigation report of this study (**DWAF, 2006d**) and was merely derived to illustrate the potential impact should interventions not be successful.

Figure A.5.1 below presents the future irrigation water requirements for the two scenarios described above. It should, however, be noted that only the irrigation water requirements of **Irrigation Scenario 1** were used in the system planning scenarios which are described in **Section A.9.2**.

Figure A.5.1 : **Irrigation water requirement scenarios for the Vaal River System**



From **Figure A.5.1** it can be seen that for **Irrigation Scenario 1** the total irrigation water use increases to a maximum of 1111 million m^3/annum in 2008 after which it decreases to 843 million m^3/annum in the year 2011. For **Irrigation Scenario 2** the total irrigation water use continues to increase until it reaches the maximum value of 1339 million m^3/annum (which is representative of the registered volume of the WARMS database) in the year 2016.

A.5.3 BULK INDUSTRIAL WATER REQUIREMENTS

A.5.3.1 Overview

There are three main industries receiving water in bulk from the Vaal River System, the electrical power utility Eskom, petrochemical (coal to liquid fuel) industry Sasol and Mittal Steel (formally known as Iscor.) These industries were requested to provide water requirements scenarios based on their future outlook of their respective operations and water management programs. These water requirement scenarios are presented in the subsequent sections.

A.5.3.2 Eskom

Eskom currently operates 12 coal fired electrical power stations which receive water from the Integrated Vaal River System. Some of these stations were decommissioned and are now reinstated to increase supply in response to the growing demand for electrical power to fuel the South African economy. There are also plans to develop three new power stations envisaged to receive water from the Vaal River System. Two of these are scheduled to receive water from Vaal Dam and current planning is that the third will be located close to the existing Kendal Power Station and receive water from the Vaal River Eastern Sub-system (a component of the Integrated Vaal River System).

Eskom revise their water requirement projections on an annual basis. Consequently, three projections, namely a Base-, High- and Drought Scenario, were provided by Eskom in April 2006. From these alternative scenarios Eskom recommended that the Base and High demand scenarios be considered for the 2006-2007 Annual Operating Analysis of the IVRS. The Base Scenario projections were, however, considered as the most probable projection scenario to be used for the purposes of this study.

Table A.5.8 provides a summary of the water requirements and lists all the power stations and their primary water source, as well as the projection of water requirements for the indicated years of the planning period. These requirements were used in all the planning scenarios (refer to **Section A.9.2** for details) and relate to planning years running from 1 May of the indicated year to 30 April of the subsequent year.

A comparison between the Base Scenario projections adopted for this study and the previous Eskom projections, as well as the historic (actual) water use is presented in **Figure D-1** of **Appendix D**.

It should be noted that there are several smaller users that are supplied with water along the Eskom water conveyance routes. These users are referred to as the so-called DWAF 3rd Party Users. The water requirements of these users are not included in the Eskom demand projections listed in **Table A.5.8** or shown in **Figure D-1** of **Appendix D**. The DWAF 3rd Party Users' projections were derived as part of the original TR134 projections and were subsequently refined based on the actual water use information collated as part of the annual operating analysis of the IVRS. The DWAF 3rd Party Users' water requirement projections are provided in **Table A.5.9.**

Table A.5.8 : Eskom power stations' water requirements (reference of projection April 2006)

Power Station	Primary Water Source	Water Requirements (million m^3/annum)					
		2006	2010	2015	2020	2025	2030
Hendrina	Komati Sub-system	31.0	32.4	33.0	32.7	32.7	32.7
Arnot		29.4	33.4	36.1	36.5	36.6	36.6
Duvha		50.8	50.4	51.6	52.2	52.2	52.2
Komati		2.6	5.6	9.9	8.3	8.4	8.4
Kriel	Usutu Sub-system	38.8	40.7	43.5	43.2	43.5	43.5
Matla		51.5	51.6	53.6	54.3	54.3	54.3
Kendal		3.2	3.3	3.4	3.4	3.4	3.4
Camden		5.5	19.2	23.2	23.2	23.2	23.2
New coal-fired 1		0.0	0.6	2.9	3.7	3.7	3.7
Majuba	Zaaihoek Sub-system	19.2	25.6	25.6	24.1	24.1	24.1
Tutuka	Grootdraai Sub-system	34.5	46.2	44.3	48.8	48.8	48.8
Grootvlei	Vaal Dam	0.8	6.1	10.4	10.1	10.1	10.1
Lethabo		45.5	46.6	49.4	50.1	50.1	50.1
New coal-fired 2		0.0	0.0	0.6	3.0	3.0	3.0
New coal-fired 3		0.0	0.0	0.0	2.6	3.0	3.0
Total		**312.9**	**361.7**	**387.5**	**396.3**	**397.2**	**397.2**

Table A.5.9 : Water requirement projections for DWAF 3rd Party users

Description of supply route	Water Requirements (million m^3/annum)					
	2006	2010	2015	2020	2025	2030
Komati pipeline	6.41	7.14	7.14	7.14	7.14	7.14
Hendrina-Duvha pipeline	4.10	4.56	4.56	4.56	4.56	4.56
Overwacht, Camden-Rietspruit, Camden-Lilliput, Rietspruit-Davel, Davel-Kriel and Khutala-Kendal pipelines	5.90	6.70	6.70	6.70	6.70	6.70
Grootdraai-Tutuka, Rietfontein-Matla and Naauwpoort-Duvha pipelines	1.00	1.00	1.00	1.00	1.00	1.00
Total for DWAF 3rd Party Users:	**17.41**	**19.40**	**19.40**	**19.40**	**19.40**	**19.40**

A.5.3.3 Sasol (Secunda and Sasolburg Complexes)

Sasol has two plants receiving water from the Integrated Vaal River System. The Sasol Secunda Complex's primary source of water is Grootdraai Dam which will be supported through the Vaal River Eastern Sub-system Augmentation Project (VRESAP) once it becomes operational in 2008. The Sasol Sasolburg Complex is supplied from Vaal Dam which is support from the Thukela-Vaal Transfer Scheme as well as the Lesotho Highlands Water Project (LHWP).

The Sasol Secunda demand projections provided in April 2004 and revised as part of Vaal River Eastern Sub-System Study (VRESSS) Bridging Study (**DWAF, 2004f**) were adopted for the AOA 2005/06. Subsequently Sasol has entered into a five year contract with Rand Water (effective from 1 July 2005) whereby a maximum water supply of 40 Ml/d (14.61 million m^3/a) could be obtained from Rand Water. Sasol provided revised projections for the first nine planning years (i.e. from 2006 to 2014) on 13 June 2006 to be used as part of the current analysis. The minimum contractual Rand Water intake requirement of 4 Ml/d (1.46 million m^3/a) was allowed for in the revised 2006 projections. Furthermore, the revised projection was extrapolated to cover the full period of analysis. This was done by adopting the April 2004 projections over the period 2015 to 2030. The Sasol Secunda projections are shown in **Figure D-2** of **Appendix D**. It should be noted that the interim reduced demands shown for the April 2004 projection were based on an intake of 40 Ml/d emergency supply from Rand Water.

Revised information on projected raw water abstractions for the Sasol Sasolburg complex was also obtained during May 2006. **Figure D-3** of **Appendix D** shows a comparison between the previous (April 2001) and updated water requirement projections. The Sasolburg complex has a permit allocation of 96 Ml/d (35.1 million m^3/a) for raw water and 6 Ml/d (2.2 million m^3/a) for potable water. It should be noted that the potable water component, which is supplied by Rand Water, is not included in the projections shown in **Figure D-3**. Water supplied to the Sasolburg complex can be obtained from two point sources, namely Letabo Weir and Vaal Barrage. Owing to the poor water quality being experienced in the Vaal Barrage, it was also confirmed by Sasol that up to 60 Ml/d (21.92 million m^3/a) will be abstracted from the Letabo Weir before they start abstracting their additional requirement from Vaal Barrage.

The water requirements for the two complexes are presented in **Table A.5.10** for the indicated years of the planning period. These requirements were used in all the planning scenarios (see **Section A.9.2** for details).

Table A.5.10 : Sasol's water requirements for the indicated complexes

Description	Water Requirements (million m³/annum)					
	2006	2010	2015	2020	2025	2030
Sasol Secunda Complex(1)	92.0	91.3	107.8	112.1	117.2	123.0
Sasol Sasolburg Complex(2)	26.4	28.9	32.3	35.5	38.9	42.7
Total	**118.5**	**120.2**	**140.1**	**147.6**	**156.1**	**165.8**

Notes: (1) Reference of projection June 2006 and March 2004.

(2) Reference of projection June 2006.

A.5.3.4 Mittal Steel

Mittal Steel (previously known as ISCOR) receives its water from Vaal Dam. The water requirement projections for Mittal Steel incorporated in the WRPM configuration was last updated in April 2001. Therefore, an attempt was made to revise the outdated water requirement projection. To this end, information on Mittal Steel that was collated as part of the Integrated Water Resource Management Studies for the Vaal River System was obtained and included in the WRPM demand database. As shown in **Figure D-4** of **Appendix D**, two water requirement projections (an Expected and High demand projection) were provided by Mittal Steel in July 2006. It should be noted that the projections shown in **Figure D-4** reflect the total water requirements and therefore include both the potable and raw water requirements that are supplied from Rand Water.

In their most probable projections (reference Expected July 2006) they are planning to decrease their water use from 17.4 million m^3/annum to 16.6 million m^3/annum in 2010 from where onwards it remains constant for the subsequent years of the planning period. The latter projection was adopted for all the scenarios that were analysed as part of this study.

A.5.4 URBAN WATER REQUIREMENTS AND RETURN FLOWS

A.5.4.1 Overview

The urban sector represents the largest portion of the Vaal River system's water use and in the Gauteng Province substantial increases in the water use occurred historically as a result of the increasing urban population and expanding economic activities. In the Gauteng Growth and Development Strategy developed by the Gauteng Provincial Government (**Gauteng Province, April 2005**) it was shown that the Tertiary Sector constitutes more than 70% of the Gross Geographic Product of the province in 2001 and has continuously increased to this level since 1996. This growth in the Tertiary Sector was at the expense of Secondary and Primary Sectors indicating that the economy of the Gauteng Province continues to expand into the service sectors where the future water requirements are predominantly driven by the population dynamics in the province.

In the Terms of Reference of the Reconciliation Study it was indicated that DWAF has commissioned a parallel demographic study (by the Directorate: Water Resource Planning Systems) to update the country wide population scenarios. The previous population scenarios used by DWAF for water resource planning purposes were developed for the National Water Resource Strategy and needed to be revised since it preceded the Census 2001 information.

The detailed results from the parallel demographic study, with the main focus on the population in the Gauteng Province, are discussed in the water requirement and return flow report of this study (**DWAF, 2006a**). A brief summary of the two population projections considered for this study is provided in the following section.

A.5.4.2 Population scenarios

A.5.4.2.1 August 2006 Population Projection Scenario for Gauteng – alternative scenario

Based on the findings and recommendations of this study, the population projection scenario from the January 2006 Population Projection Scenario Update Study was revised using the assumption of migration as reflected in the 2006 Mid-year Population Estimate of Stats SA. This was carried out by the Study Team of the Population Projection Scenario Update Study during July 2006 and an alternative scenario was developed for Gauteng Province, referenced as the ***August 2006 Population Projection Scenario***. The August 2006 Population Projection Scenario for the

Gauteng Province is presented in **Table A.5.11**, showing the projected population as well as the annual compound growth for the indicated planning years.

This population scenario was used in the planning scenarios as described in **Section A.9.2**.

Table A.5.11: August 2006 Population Projection Scenario for Gauteng Province

Description	Planning Years					
	2001	2005	2010	2015	2020	2025
Population (1)	8 254	9 012	9 989	10 878	11 678	12 274
Annual Compound Growth (%)	-	2.22%	2.08%	1.72%	1.43%	1.00%

Notes: (1) All population values are given in thousands.

A.5.4.2.2 National Water Resource Strategy Population Scenario

The National Water Resource Strategy (NWRS), published in September 2004, applied population projection scenarios to generate future water requirements for compiling a perspective on the reconciliation of the water requirements and availability for the years 2000 and 2025. The NWRS water requirement "base scenario" were developed using a population projection scenario which was a high estimate and serve as the mainstream option for the development of the strategy. In order to provide a comparison with the NWRS in this study, this high population projection scenario was used to develop an alternative water requirement scenario for the urban water users and **Table A.5.12** presents the population projection scenario for the Gauteng Province.

Table A.5.12: National Water Resource Strategy High Population Projection Scenario for Gauteng Province:

Description	Planning Years					
	2001	2005	2010	2015	2020	2025
Population (1)	8 475	9 100	9 538	10 199	10 691	11 206
Annual Compound Growth (%)	-	1.79%	1.15%	1.15%	0.95%	0.95%

Notes: (1) All population values are given in thousands.

A.5.4.3 Rand water Supply Area

A.5.4.3.1 Methodology

The water requirements and return flows for the Rand Water supply area were determined with the Water Requirement and Return Flow database model which was developed for DWAF as part of the Crocodile (West) River Return Flow Assessment Study (**DWAF, 2004e**). The model uses Sewage Drainage Areas as modelling component where a sewer pipe network system collects the wastewater for treatment at waste water treatment works before it is discharged into a river system. There were forty seven Sewage Drainage Areas (SDAs) identified in the Rand Water (Gauteng) supply area, as illustrated graphically in **Figure A.5.2,** where the thick black line shows the catchment divide between the northern and southern areas. The wastewater returned in the northern SDAs contributes to the water resources of the Crocodile (West) River and those SDAs draining to the south contributes the Vaal River System. **Table A.5.13** lists all the Sewage Drainage Areas in each of the indicated municipal areas.

Table A.5.13: List of Sewage Drainage Areas according to municipal areas

Municipality	Sewage Drainage Areas	Number of SDAs
Ekurhuleni	Waterval, Ancor, Benoni, Carl Grungling, Daveyton, Dekema, Herbert Bickley, Jan Smuts Dam, JP Marais, McComb, Rhynfield, Rondebult, Tsakane, Vlakplaats, Heidelberg, Ratanda, Hartebeestfontein, Olifantsfontein	18
Emfuleni	Sebokeng South, Vanderbijlpark, Sharpville, Vereeniging	4
Johannesburg	Bushkoppies, Olifantsvlei, Goudkoppies, JHB Northern, Driefontein, Ennerdale, Eldorado Park, Sebokeng North	8
Mogale	Percy Stewart, Flip Human	2
Randfontein	Randfontein	1
Tshwane	Baviaanspoort, Zeekoegat, Daspoort, Rooiwal, Rietgat, Temba, Babalegi, Sandspruit, Sunderlandridge, Klipgat, Tolwane, Kutswane, Apies, Remainder – North	14
TOTAL NUMBER OF SEWAGE DRAINAGE AREAS		**47**

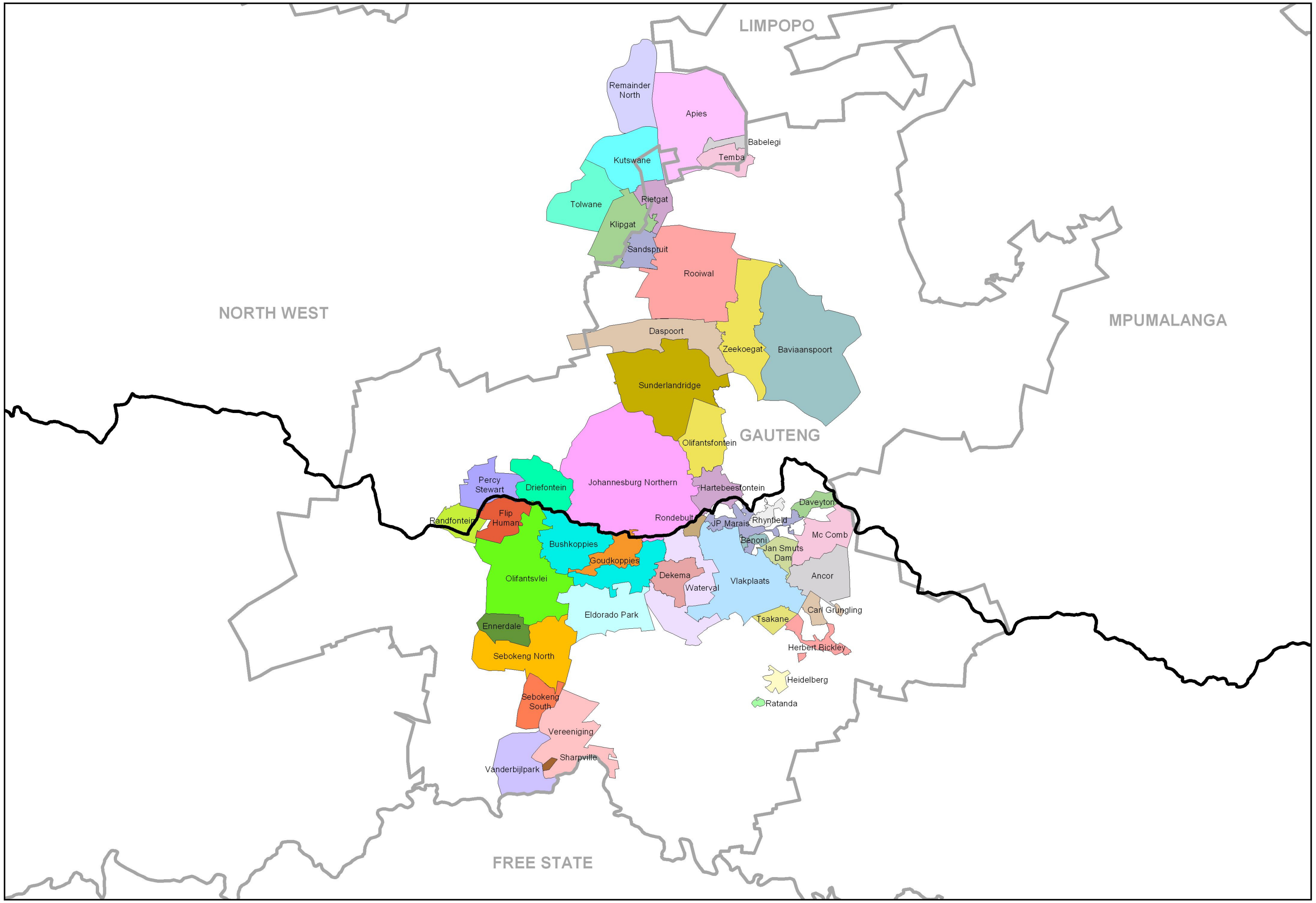


Figure A.5.2: Location of the forty seven Sewage Drainage Areas

The methodology that was followed to compile the water requirement and return flow projections is described in the detailed water requirement and return flow report of this study (**DWAF, 2006a**). The results from these assessments were incorporated into a spreadsheet database to generate the data required by the Water Resource Planning Model (WRPM). The purpose of the subsequent sections is, therefore, to provide information on the water requirement and return flow projections incorporated in the WRPM configuration of the IVRS.

A.5.4.3.2 Water requirement and return flow scenario based on the August 2006 Population Projection for the Rand Water Supply Area

The August 2006 Population Projection Scenario data (described in **Section A.5.4.2.1**) were imported into the water requirement generation database model and water requirements and return flow scenarios were generated for the planning period up to the year 2030.

A summary of the water requirement projections are presented in **Figure A.5.3**Error! Reference source not found.**,** showing the water requirements for each municipality and a remainder component called "Other". The "Other" component includes water requirements of individual users including mines, industries and other small municipalities supplied from Rand Water. The assumptions for the other users were that they would increase by the same ratio as the water requirements of the municipalities.

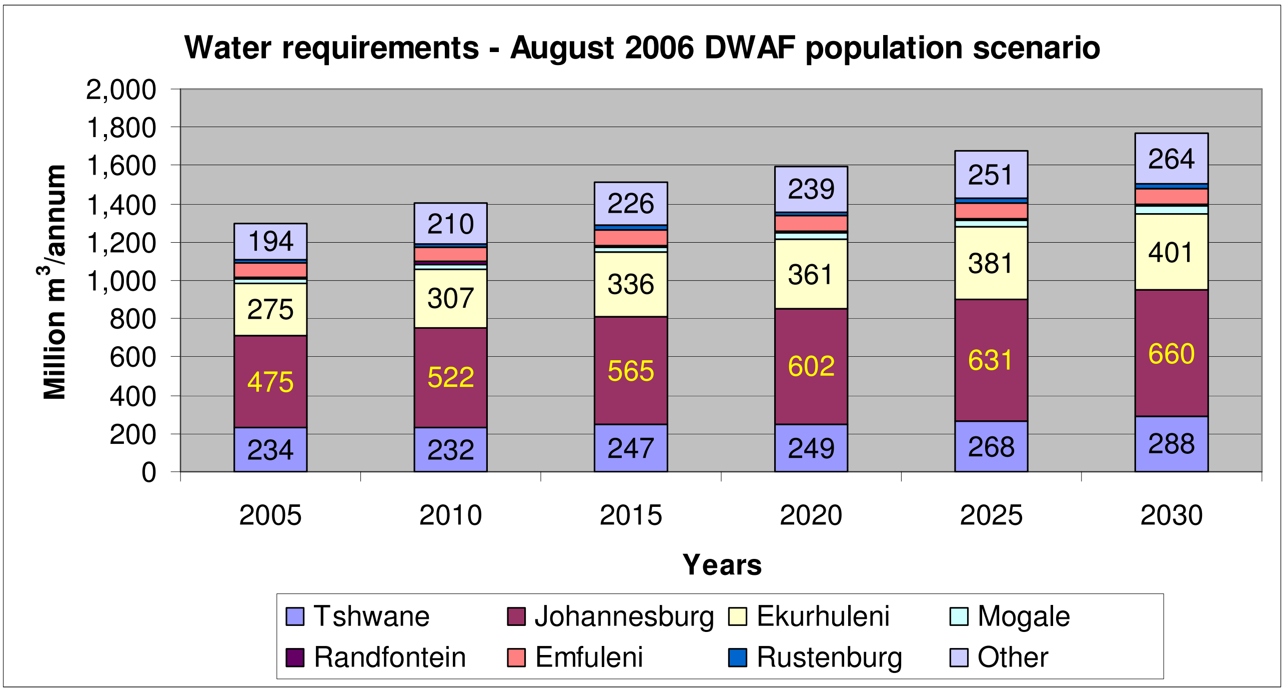


Figure A.5.3: Water requirements for the Rand Water supply area (base on the August 2006 Population Projection Scenario)

It should be noted that for both Rustenburg and Tshwane the water requirements presented in **Figure A.5.3**Error! Reference source not found. represent the supply from Rand Water and exclude water received from other sources.

The average annual growth rate of the water requirements between 2005 and 2030 is 1.23% compounded, with a slightly higher growth rate of 1.52% over the first ten years.

The total return flow projections (for the southern and northern SDAs) are presented in **Figure A.5.4**Error! Reference source not found., indicating an increase from about 650 million m^3/annum in 2005 to 925 million m^3/annum in the year 2030.

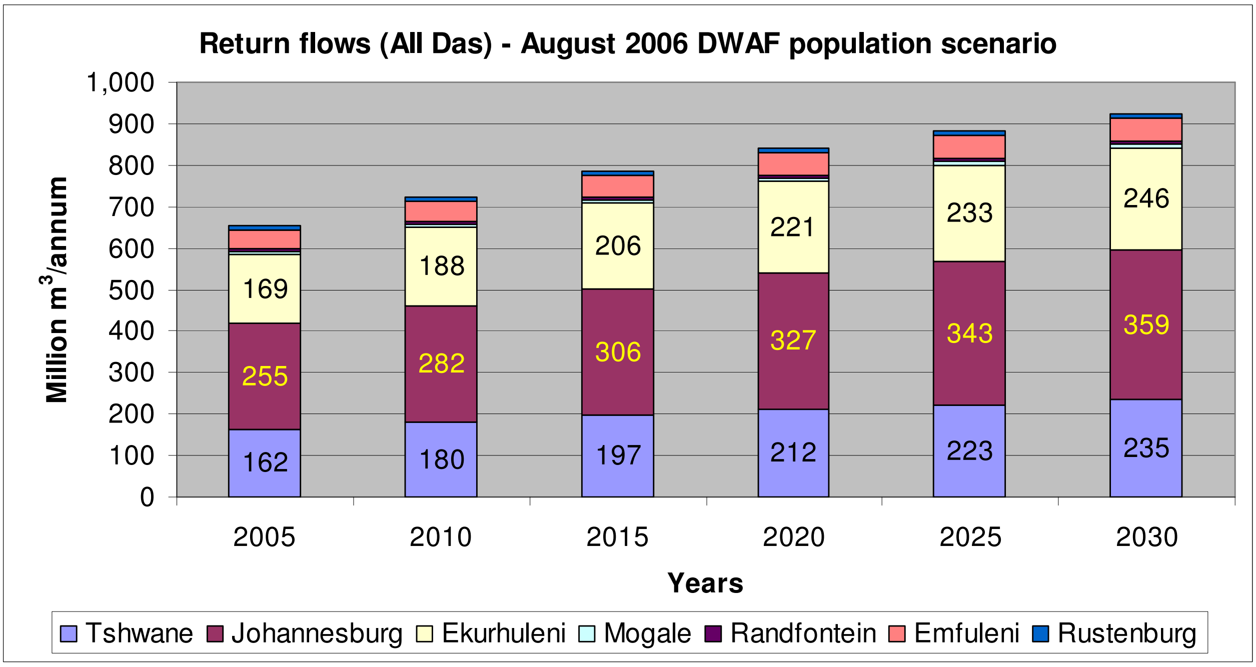


Figure A.5.4: Return Flows for the Rand Water supply area (base on the August 2006 Population Projection Scenario)

The projection for the return flows contributing to the water resources of the Vaal River System (southern SDAs) is shown in **Figure A.5.5**Error! Reference source not found. which is expected to increase from 330 million m^3/annum in 2005 to about 460 million m^3/annum in the year 2030.

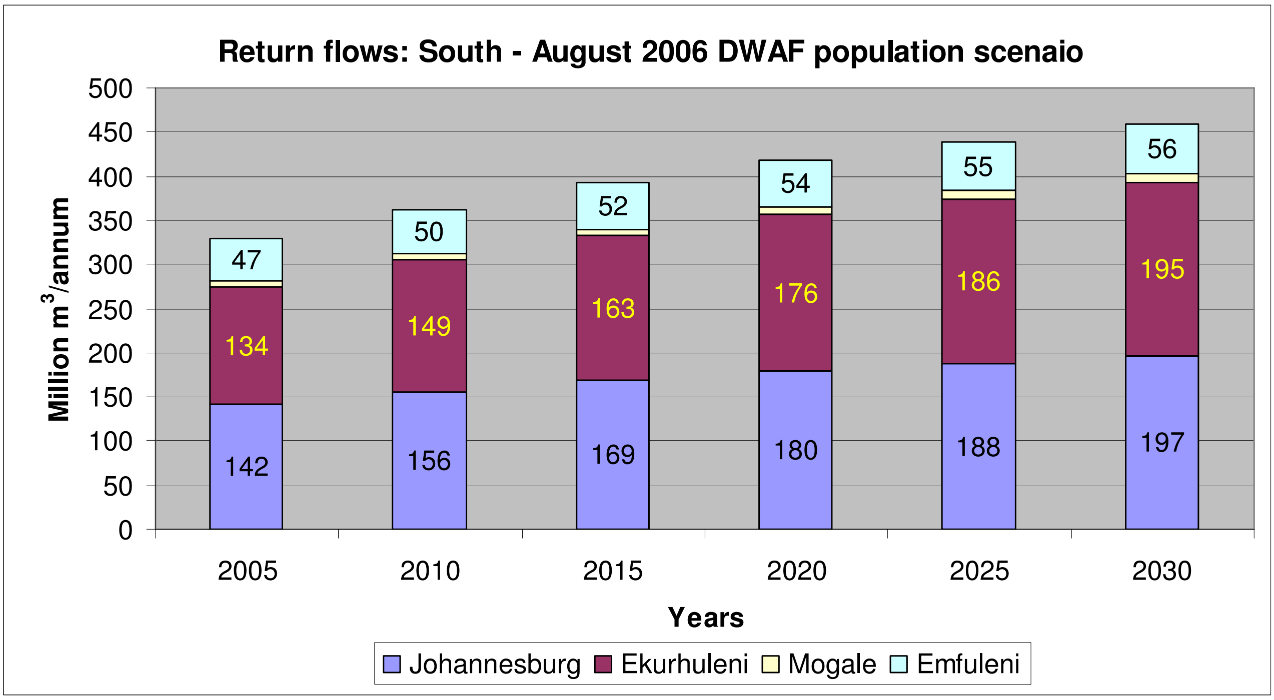


Figure A.5.5: Return Flows for the Southern SDAs of the Rand Water supply area (base on the August 2006 Population Projection Scenario)

A.5.4.3.3 Water requirement and return flow scenario based on the NWRS population projection

Following the same methodology as explained in the previous section, an alternative water requirement and return flow scenario was developed by applying the National Water Resource Strategy (NWRP) population projection scenario (see **Section A.5.4.2.2** for details). **Table A.5.14** presents a summary of the results of this scenario and, for comparison purposes, **Table A.5.15** provides the summarised data for the scenario presented in the previous section.

In the tables the scenarios are labelled **Scenario A** and **B** respectively and these labels are used to identify and reference the scenarios in subsequent sections in the report.

Table A. 5.14: Water requirement and return flow projection scenario summary based on the NWRS population projection (Scenario A)

Component Descriptions		Planning Years					
		2005	2010	2015	2020	2025	2030
Water Requirements (Supplied by Rand Water)	Northern Municipalities	542	560	600	633	683	742
	Southern Municipalities	564	590	617	639	662	687
	Other users	192	194	202	214	224	237
	Total	***1,300***	***1,352***	***1,431***	***1,496***	***1,582***	***1,681***
	Portion North	49.0%	48.7%	49.3%	49.8%	50.8%	52.0%
	Portion South	51.0%	51.3%	50.7%	50.2%	49.2%	48.1%
Return Flows (From all municipalities)	Northern Municipalities	323	351	376	396	421	451
	Southern Municipalities	328	343	359	372	386	400
	Total	***652***	***694***	***735***	***769***	***807***	***852***
	Portion North	49.6%	50.6%	51.1%	51.6%	52.2%	53.0%
	Portion South	50.4%	49.5%	48.9%	48.5%	47.8%	47.0%

Notes: (1) All volumetric values are given in million m^3/annum.

Table A. 5.15: Water requirement and return flow projection scenario summary based on the August 2006 Population Projection Scenario (Scenario B)

Component Descriptions		Planning Years					
		2005	2010	2015	2020	2025	2030
Water Requirements (Supplied by Rand Water)	Northern Municipalities	542	575	617	644	681	721
	Southern Municipalities	564	619	669	714	747	782
	Other users	194	210	226	239	251	264
	Total	***1,300***	***1,403***	***1,512***	***1,596***	***1,679***	***1,766***
	Portion North	47.5%	49.0%	48.1%	48.0%	47.4%	47.7%
	Portion South	52.5%	51.0%	51.9%	52.0%	52.6%	52.3%
Return Flows (From all municipalities)	Northern Municipalities	266	324	362	394	423	444
	Southern Municipalities	289	329	362	392	418	438
	Total	***556***	***653***	***724***	***785***	***841***	***882***
	Portion North	47.9%	49.6%	50.0%	50.1%	50.3%	50.3%

Component Descriptions		Planning Years					
		2005	2010	2015	2020	2025	2030
	Portion South	52.1%	50.4%	50.0%	49.9%	49.7%	49.7%

Notes: (4) *All volumetric values are given in million m^3/annum.*

A.5.4.4 Sedibeng Water

Sedibeng Water is the bulk service provider supply water to both urban and industrial (mining) water users. Sedibeng Water receives water from the Vaal River System from two abstraction locations. The first is Balkfontein on the Vaal River and, the second, from Allemanskraal Dam at their Virginia Works. Virginia Town, which falls within the Sedibeng Water supply area, has an allocation of 15.2 million m^3/a from Allemanskraal Dam. The water use in their supply area has decreased historically mainly due to the decaling mining activity in the region. Sedibeng Water provided projections in April 2006 which indicated that their water requirement will increase from 56 million m^3/annum in 2006 to 58 million m^3/annum in 2030. The portion of their total water use to be supplied from their Virginia Works (Allemanskraal Dam) is constant over the planning period at 15.2 million m^3/annum which is equal to their allocation from the resource.

A.5.4.5 MidVaal Water Company

Midvaal Water Co treats and supplies water to users in the Klerksdorp area and has experienced a decline in water use mainly due to the closing of several mining operations. Projections for Midvaal Water Co were received from them in May 2006 indicating that their water use will remain constant at 35 million m^3/annum over the planning period.

A.5.4.6 Other urban areas

The projections for all the other urban areas receiving water from the Vaal River System were determined using the growth rates from the National Water Resource Strategy. Where actual water use data was available the starting point (volume for the first year in the projection) was adjusted to match the actual value on which the future growths were applied. Adjustments were made for Lekwa LM, Amersfoort, Msukaligwa LM (former Ermelo), Bethlehem and “Small Users” comprising of Jim Fouche, Oranjeville, Vaal Marina, etc. The total water requirement in 2006 is projected to be 161 million m^3/annum for this group and increases to 168 million m^3/annum in the year 2030.

A.5.5 SUMMARY OF WATER REQUIREMENT AND RETURN FLOW SCENARIOS

A.5.5.1 System summary

In addition to the water requirements and return flows described in the above-mentioned sections, the WRPM configuration of the IVRS also makes provision for the modelling of different types of water losses (wetland losses, evaporation losses along river reaches, conveyance losses, operating losses, etc) from the river system. Allowance is also made for urban runoff (i.e. rainfall runoff from large paved areas typically found in urbanised areas) as well as flow resulting from mining activities. The Klip River, Suikerbosrand and Lower Barrage (Riet River) catchments have been identified as the only catchments with significant urbanisation. Projections regarding the increase in runoff due to growing urbanisation of the Vaal Barrage were, therefore, also incorporated in the demand database of the WRPM. Although mine dewatering impacts on the runoff in the Upper Vaal and along the main stem of the Vaal River downstream of Vaal Barrage, it has the most significant influence on the water quantity and quality of the Vaal Barrage and Mooi River incremental catchments.

Combining all the water requirements and return flows of all the sectors from the information of the previous sections and including other components such as losses and mine dewatering mentioned above, provides the summaries as presented in the tables below.

Table A.5.16 presents the summary information for **Scenario A** which was compiled with the NWRS population projection scenario and **Table A.5.17** for **Scenario B** where the August 2006 population scenario was applied.

Table A.5.16: Summary of water requirements and return flows (Scenario A)

Water users	Planning years					
	2006	2010	2015	2020	2025	2030
Water Requirements						
Rand Water	1297	1338	1417	1481	1568	1666
Mittal Steel	17	17	17	17	17	17
ESKOM (Including DWAF 3rd Party Users)	330	381	407	416	417	416
SASOL (Sasolburg)	24	27	30	33	37	41
SASOL (Secunda)	92	104	108	112	117	123
Midvaal Water Company	35	35	35	35	35	35

Water users	Planning years					
	2006	2010	2015	2020	2025	2030
Sedibeng Water (Balkfontein only)	41	41	41	41	42	43
Other towns and industries	161	163	167	167	167	168
Vaalharts/Lower Vaal irrigation	542	542	542	542	542	542
Other irrigation	722	599	500	500	500	500
Wetland / River Losses	325	326	327	329	330	331
Return Flows						
Southern Gauteng (Rand Water)	331	343	359	372	386	400
Midvaal Water Company	1	1	1	1	1	1
Sedibeng Water	2	2	2	2	2	2
Other towns and industries	61	65	69	72	76	80
Irrigation	60	48	38	38	38	38
Mine dewatering	114	105	121	123	121	121
Increased urban runoff	101	103	107	113	121	129
OVERALL GROSS SYSTEM DEMAND:	3587	3572	3590	3672	3771	3881
OVERALL NET SYSTEM DEMAND:	2917	2905	2893	2950	3025	3108

Notes: (2) All volumetric values are given in million m^3/annum.

Table A.5.17:Summary of water requirements and return flows (Scenario B)

Water users	Planning years					
	2006	2010	2015	2020	2025	2030
Water Requirements						
Rand Water	1308	1390	1498	1582	1665	1753
Mittal Steel	17	17	17	17	17	17
ESKOM (Including DWAF 3rd Party Users)	330	381	407	416	417	416
SASOL (Sasolburg)	24	27	30	33	37	41
SASOL (Secunda)	92	104	108	112	117	123
Midvaal Water Company	35	35	35	35	35	35
Sedibeng Water (Balkfontein only)	41	41	41	41	42	43
Other towns and industries	161	163	167	167	167	168
Vaalharts/Lower Vaal irrigation	542	542	542	542	542	542
Other irrigation	722	599	500	500	500	500
Wetland / River Losses	325	326	327	329	330	331
Return Flows						
Southern Gauteng (Rand Water)	335	362	392	418	438	459

Water users	Planning years					
	2006	2010	2015	2020	2025	2030
Midvaal Water Company	1	1	1	1	1	1
Sedibeng Water	2	2	2	2	2	2
Other towns and industries	61	65	69	72	76	80
Irrigation	60	48	38	38	38	38
Mine dewatering	114	105	121	123	121	121
Increased urban runoff	101	103	107	113	121	129
OVERALL GROSS SYSTEM DEMAND:	3597	3624	3672	3773	3868	3967
OVERALL NET SYSTEM DEMAND:	2923	2939	2942	3005	3071	3136

Notes: (1) All volumetric values are given in million m^3/annum.

When comparing the results of these two tables, it should be noted that, with the exception of the Rand Water requirements, the water use projections of the remaining water user groups are identical for both water requirement projections. More detailed summaries of the water requirement projections for **Scenarios A** and **B** are provided in **Tables D-1** and **D-2** of **Appendix D** respectively.

A.5.5.2 Summary and comparisons for the Rand Water supply area

Due to the importance of the water requirements of the Rand Water supply area, a summary of **Scenarios A** and **B** and how these projections compare to previous scenarios are presented graphically in **Figure A.5.6**Error! Reference source not found.**.**

The lines on the graph represent the following information:

- The thick line starting in the year 1970 shows the actual water use up to the year 2006. The impact of water restrictions due to drought conditions are shown during the early nineteen eighties as well as during 1995 and 1996.
- The blue (highlighted) line (**Sc A, 2006**) shows the water requirements for **Scenario A.**
- The red (highlighted) line (**Sc B, 2006**) shows the water requirements for **Scenario B**.
- **RW (2004 excl AIDS)**, is a projection scenario produced by Rand Water in 2004 and excluded the impact of HIV AIDS.

- **RW (2004 incl AIDS)**, is a projection scenario produced by Rand Water in 2004 and included the impact of HIV AIDS.
- **RW (2004 Questionnaire)**, is a projection scenario produced by Rand Water in 2004 that was compiled from information they received through a questionnaire to all the users supplied by Rand Water.
- **NWRS High-High**, was the water requirements derived as part of the National Water Resource Strategy based in the High population projection scenario and the High economic growth scenario.
- **NWRS Ratio**, scenario was developed as part of the National Water Resource Strategy and is referred to as the "base scenario" in the NWRS document.

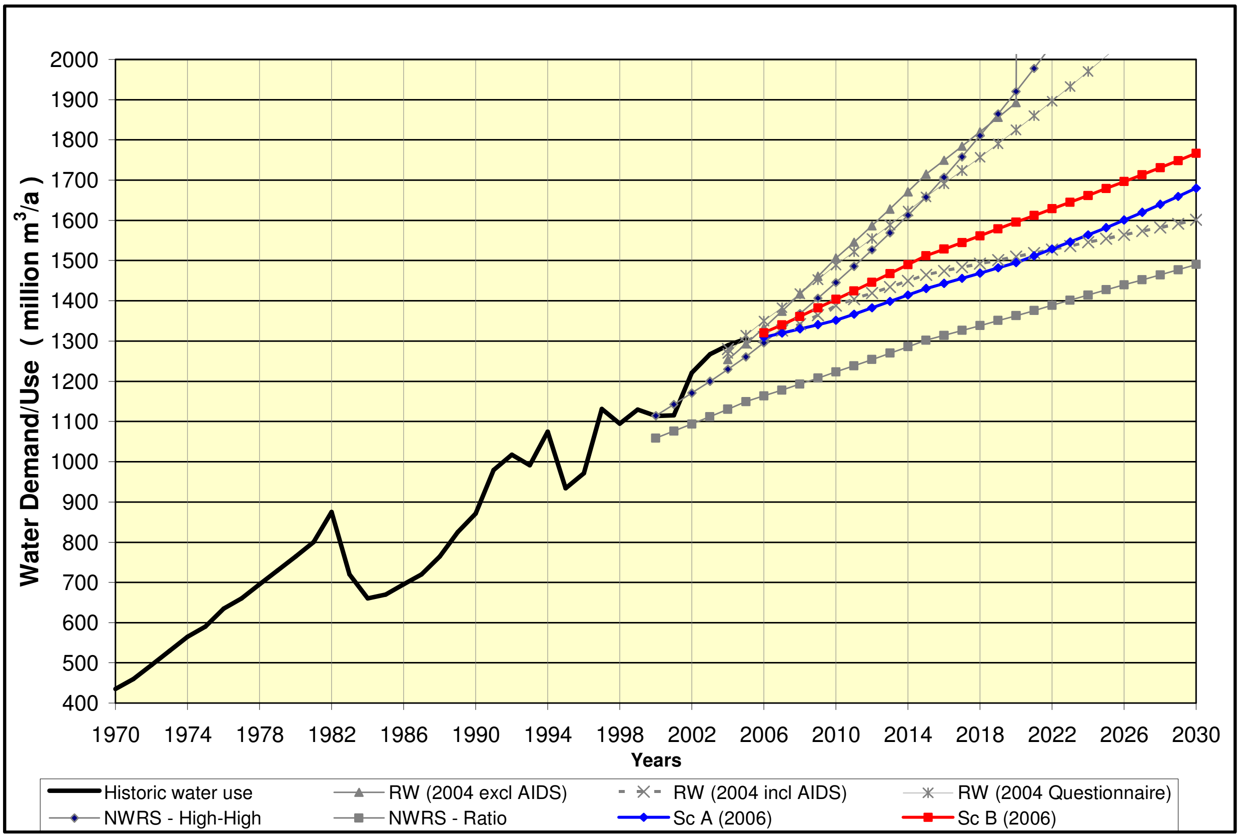


Figure A.5.6: Summary of water requirement scenarios for the Rand Water Supply Area

A.6 WATER CONSERVATION AND WATER DEMAND MANAGEMENT SCENARIOS

A.6.1 OVERVIEW

Three saving scenarios were compiled from the assessment of the potential for water conservation and water demand management in the urban sector. The savings were applied to the water requirement of **Scenario B** (see **Section A.5.5**) and were labelled **Scenarios C**, **D** and **E** respectively. The description and saving results from the scenarios are presented in the following section.

A.6.2 WATER CONSERVATION AND WATER DEMAND MANAGEMENT POTENTIAL SAVING SCENARIOS

A.6.2.1 Scenario description

*A.6.2.1.1 **Scenario C**: 5 Years water loss programme and efficiency improvement measures*

This scenario assumed that the water losses can be controlled within the next 5 years (2005 to 2010) and maintained afterwards as well as the implementation of water use efficiency by targeting the billed consumption. It was assumed that a 1% per annum efficiency can be gained from 2015 increasing to 30% in the year 2025.

This scenario is the most optimistic with regard to the savings that can be achieved and involves both savings from the Non-Revenue Water as well as savings from the Revenue Water which are assumed to take place over 5 years and 10 years respectively.

The savings from the Non-revenue water concentrate on issues such as leakage detection and repair in areas where consumers have high levels of payment and any losses after the customer meter are basically considered to be part of the customer demand – normally these losses are relatively small since the customer will identify any household leakage and repair the leaks quickly.

In the medium and high income areas, the main WC/WDM measures that can be used to reduce wastage (reduction in customer demand is not considered at this stage) concentrated on the reduction in losses from physical leakage before the customer meter. In these areas, most of the water supplied to consumers is both metered and paid for by the consumer and therefore wastage inside the properties tends to be relatively small and is not the serious problem that exists in many of the low income areas. Although the physical leakage is considered to be the main problem issue in the middle and high income areas, the levels of leakage tend to be relatively small compared to the levels experienced in the low income areas and therefore the potential savings that can be achieved are also small.

In **Scenario C**, it was also assumed that some savings could be achieved through more efficient water practices inside the properties. This typically involves the use of water efficient appliances (washing machines, toilet cisterns etc) as well as low flow shower heads and water efficient gardens where irrigation is either not required or significantly reduced.

*A.6.2.1.2 **Scenario D**: Reduction in wastage over 5 years*

- Water losses can be controlled within the next 5 years (2005 to 2010) and maintained afterwards (same as for Scenario C).
- No water use efficiency is introduced.

Scenario D is basically the same as **Scenario C** with the exception that it only addresses the reduction in wastage and does not include any saving from more efficient water practices. This scenario assumes that certain actions can be implemented over a period of 5 years after which the capital costs will decrease and only maintenance costs will remain. This is potentially problematic for the water utilities since their capital costs and much of their operational costs are fixed while the income is dependant on the water sales. To reduce the overall demand can cause problems to the financial viability of a water utility.

*A.6.2.1.3 **Scenario E**: Reduction in wastage over 10 years*

- Water losses can be controlled within the next 10 years (2005 to 2015) and maintained afterwards.
- No water use efficiency is introduced.

Scenario E is basically the same as **Scenario D** and only addresses the reduction in wastage. This scenario, however, assumes that certain actions can only be implemented over a period of 10 years which is considered to be more realistic than **Scenario D** based on practical experience gained by the project team from many WC/WDM projects. This is a more favourable and realistic scenario than either of the two previous scenarios.

A.6.2.2 Potential savings and net system water requirements

The three tables below present the savings that can be achieved for each of the scenarios described above (savings are shown in **Row B** of each table). It was assumed that the WC/WDM measures will also impact on the return flows as reflected in **Rows C** of each table. The overall impact on the net system water requirement is determined in **Rows D,** and **Row E** provides the total system net water requirement.

Table A. 6.1: Savings and system net water requirements for Scenario C

Component description	Row	Calculation or Reference	Planning Years					
			2006	2010	2015	2020	2025	2030
Net system demand for **Scenario B**	A	From **Table A.5.17**	2923	2939	2942	3005	3071	3136
Reduction in Water Requirements **Sc. C**	B	Assessment		177	272	329	379	378
Reduction in Southern SDA Return Flows **Sc. C**	C	Assessment		69	91	110	126	135
Net reduction **Sc. C**	D	(B-C)	35	109	181	219	253	243
System net demand **Sc. C**	E	(A-D)	2888	2830	2761	2786	2818	2893

Notes: (2) All volumetric values are given in million m^3/annum.

Table A. 6.2: Savings and system net water requirements for Scenario D

Component description	Row	Calculation or Reference	Planning Years					
			2006	2010	2015	2020	2025	2030
Net system demand for **Scenario B**	A	From **Table A.5.17**	2923	2939	2942	3005	3071	3136
Reduction in Water Requirements **Sc. D**	B	Assessment		180	191	200	213	213
Reduction in Southern SDA Return Flows **Sc. D**	C	Assessment		68	75	81	87	93
Net reduction **Sc. D**	D	(B-C)	23	112	117	120	126	120
Net system demand **Sc. D**	E	(A-D)	2900	2827	2826	2885	2945	3016

Notes: (1) All volumetric values are given in million m^3/annum.

Table A. 6.3: Savings and system net water requirements for Scenario E

Component description	Row	Calculation or Reference	Planning Years					
			2006	**2010**	**2015**	**2020**	**2025**	**2030**
Net system demand for **Scenario B**	A	From **Table A.5.17**	2923	2939	2942	3005	3071	3136
Reduction in Water Requirements **Sc. E**	B	Assessment		110	176	193	206	208
Reduction in Southern SDA Return Flows **Sc. E**	C	Assessment		45	71	77	84	90
Net reduction **Sc. E**	D	(B-C)	13	65	105	115	122	118
Net system demand **Sc. E**	E	(A-D)	2910	2874	2837	2890	2949	3019

Notes: (1) All volumetric values are given in million m^3/annum.

It should be noted that the savings indicated in the above three tables are less than the total savings presented in the report "*Potential Savings through WC/WDM in the Upper and Middle Vaal Water Management Areas".* This difference is due to the assumptions made regarding the utilisation of "own sources" which are alternative sources of water to those of the Vaal River System.

These water requirements and return flows were used to compile the planning scenarios which are presented in **Section A.9.2**. Detailed summaries of the water requirement and return flow projections for **Scenarios C. D** and **E** are provided in **Tables D-3**, **D-4** and **D-5** of **Appendix D** respectively.

Detailed information on the WC/WDM scenarios and the recommendations made in terms thereof can be found in the relevant study report entitled "*Potential Savings through WC/WDM in the Upper and Middle Vaal Water Management Areas"* (**DWAF, 2006b**).

A.7 INFRASTRUCTURE INTERVENTION OPTIONS

The Vaal Augmentation Planning Study (VAPS), completed in 1996, concluded that either a further phase of the Lesotho Highlands Water Project or further water resource developments in the Thukela River System could be considered as alternatives for augmenting the water resources of the Vaal River System.

A.7.1 THUKELA WATER PROJECT (TWP)

Subsequent to the VAPS, DWAF undertook the Thukela Water Project Feasibility Study (TWPFS) to determine the most feasible scheme configuration for development in the Thukela River System. The study concluded that two proposed dams, one on the Bushman's River (Mielietuin Dam) and the other on the main stem of the Thukela River (Jana Dam), with transfer infrastructure, would be the most feasible scheme configuration to provide a nominal transferable yield of 15m^3/s (473 million m^3/annum).

A further study, the "*Thukela Water Project Decision Support Phase (TWPDSP)*" study, was carried out to, among other things, undertake a Comprehensive Reserve Determination Study for the Thukela River System and compile an implementation programme for the TWP. The results from this study indicated that the first water could be delivered twelve years after the decision is taken to proceed with the development. The Historic Firm Yield of the TWP, incorporating the Ecological Water Requirements (EWR), for the largest dam sizes was determined to be 454 million m^3/annum.

For the reconciliation options discussed in **Section A.9.7** a phased approach was adopted for the implementation of the two dams. The Historic Firm Yield (HFY) of 136 million m^3/annum was adopted for the Mieletuin Dam and its associated transfer link whereas the HFY for Jana Dam was taken as 318 million m^3/annum.

A.7.2 LESOTHO HIGHLANDS FURTHER PHASES (LHFP)

A joint feasibility study by the South African and Lesotho governments were commissioned in 2005 with the purpose of identifying the most feasible further phases of the scheme. Results from the first phase of the study were made available to the Reconciliation Study Team which indicated that the proposed Polihali Dam with transfer infrastructure was the preferred option. The implementation period required for the scheme was estimated to be ten year after the decision is taken to proceed with the scheme. (If the decision is taken today, however, a further three year preparation phase has to be added to the ten years. This is to complete the current feasibility study and to investigate funding options.) The Historical Firm Yield of the Polihali Dam options was determined to be 458 million m^3/annum.

The second phase of the LHFP Feasibility Study commenced in October 2006 and the reconciliation results presented in this report will be used to determine the optimal configuration during that study.

A.8 UPDATING OF WRPM CONFIGURATION

A.8.1 OVERVIEW

The WRPM configuration resulting from the 2006-2007 Annual Operating Analysis of the IVRS was adopted as basis for this study. This configuration included the updated short-term yield reliability curves determined for the Usutu Sub-system during 2006. The revised curves were based on the increased capacity of the transfer link between Morgenstond and Jericho dams. The inter-reservoir operating rules for the Usutu dams were also re-assessed at the same time and the adopted rules were included in the 2006-2007 AOA (refer to **Section A.9.3** for details).

Revised catchment development information obtained as part of this study prompted several changes to be made to the WRPM configuration to ensure realistic modelling of the water resources system and its associated water requirements. The necessary changes made to the WRPM configuration is described in the following sections and the resulting schematic diagrams of the IVRS are provided in **Appendix A** (**Figures A-1** to **A-12**).

As shown in these schematic diagrams, the IVRS comprise of the following sub-systems:

- Komati Sub-system (**Figure A-12**);
- Usutu Sub-system (**Figure A-1**);
- Heyshope Sub-system (**Figure A-1**):
- Zaaihhoek and Upper Thukela Sub-systems (**Figure A-1**);
- Upper Vaal Sub-system (**Figure A-1**);
- Thukela Sub-system downstream of Spioenkop Dam (**Figure A-2**);
- Senqu and Upper Orange Sub-systems (**Figure A-3**);
- Vaal Barrage Sub-system (**Figure A-4**);
- Middle Vaal Sub-system (**Figure A-5**);
- Lower Vaal Sub-system which includes the Riet-Modder Sub-system (**Figure A-6**);

- Witbank Dam Sub-system in Upper Olifants River catchment(**Figure A-7**);
- Middleburg Dam Sub-system in Upper Olifants River catchment (**Figure A-8**);
- Loskop Dam Incremental Sub-system in Upper Olifants River catchment (**Figure A-9**);
- Lower Orange Sub-system (**Figure A-10**); and
- Fish River Sub-system in Namibia (**Figure A-11**).

A.8.2 DEMAND CENTRE CONFIGURATION FOR RAND WATER

In the original WRPM configuration the Southern Gauteng demand supplied from Rand Water (RW) was modelled by means of a single Demand Centre Module (DCM). The DCM simulates the water and salt mass balances in areas of concentrated industrial and commercial activity. The DCM has the functionality of modelling the consumptive volumetric water requirements and its associated salt loss as well as the volumetric return flow volume and its associated salt concentration. Although the DCM allows for the modelling of more than one effluent stream to be discharged from the DCM, only one average return flow factor is specified. The proportion of the total return flow, as well as the proportion of the additional salt load through each of the return flow routes, is also specified by the user. The original DCM setup within the WRPM configuration, however, did not allow for the return flow factors to be changed over time (i.e. a constant return flow factor is applied throughout the analysis period).

The detailed level of information that was available for this study enabled modelling of the urban water requirements and return flows at a much more refined scale. The Sewage Drainage Areas (SDAs) draining to the south, i.e. those SDAs contributing to the Vaal River System were grouped according to their waste water discharge locations. Five groups were defined as shown in **Table A.8.1**.

It was found that the return flow proportion as well as the growth in return flows over the planning period are different for each group of SDAs. Consequently it was decided to set up a DCM configuration for each of these groups of SDAs. Enhancements were made to the DCM configuration within the WRPM to enable modelling of changes in the return flow factors over the planning horizon.

Table A. 8.1: Definition of Demand Centre Modules for Southern Gauteng SDAs

DCM Number	Description	Supply Channel Number	Consumptive Abstraction Channel Number	Return Flow Channel Number	Average Return Flow Factor for 2006
40	SDAs with effluent discharges being made to the Klip River (WRPM Node Number 46)	1023	69	864	0.602
293	SDAs with effluent discharges being made to the Suikerbosrand River (WRPM Node Number 261)	1024	1017	865	0.603
294	SDAs with effluent discharges being made to the Upper Riet River (WRPM Node Number 267)	1025	1029	866	0.575
295	SDAs with effluent discharges being made to the Lower Riet River (WRPM Node Number 270)	1026	1047	867	0.352
296	SDAs with effluent discharges being made to the Mooi River (WRPM Node Number 252)	1027	1048	75	0.663

Note: For WRPM reference numbers refer to the schematic diagram provided in **Figure A-4** of **Appendix A**.

A.8.3 ASSESSMENT OF ADDITIONAL SALT LOADS FOR INDIVIDUAL DCMs

The average salt concentration of the water supplied to the DCM is determined by the salt concentrations of the relevant water resources. While a degree of consumptive water usage takes place in the DCM, the effluent flow is loaded with an additional salt load. This additional salt load accounts for increases in the salt concentration of effluent water due to consumer/man made activities such as cleaning detergents used for household purposes and chemicals used in industries.

For the WRPM analyses it is necessary to project the TDS load that has to be added for each future month simulated by the WRPM. The additional salt load is specified as a monthly time series file in tonnes/month allowing for increased salt loads over time which is then added to the salt load originating from the water supply. In the past, the general assumption has been made that the added TDS load of the demand centre will grow in relation to its water demand projection.

The configuration of the original DCM representing the entire Southern Gauteng supply area of Rand Water was based on the water quality calibration results obtained as part of the VRSAU Study (work done by Dr C Herold). Information from this DCM definition was, therefore, used for determining the additional salt load files that were required for each of the DCMs listed in **Table A.8.1.**

The methodology adopted for the assessment of the individual salt load files of the five DCMs was as follows:

- The average annual salt load factor (additional salt load/water use) or TDS concentration derived for the original Southern Gauteng DCM was calculated based on the historical water use and additional salt loads covering the period 1977 to 1994. The resulting TDS concentration was found to be in the order of 258.28 mg/l.

- The total projected annual water requirements of the five DCMs were determined for demand projection **Scenario A**. These annual demands were then multiplied with the average annual TDS concentration of 258.28 mg/l to produce the total projected additional annual salt loads.

- The additional salt load proportions of the five return flow routes as specified in the original DCM (calibration results provided by C Herold as part of the VRSAU Study) were applied to the total projected additional annual salt load that was calculated for the year 2005 to obtain the additional annual salt load associated with each of the five return flow routes/DCMs.

- The individual 2005 additional annual salt loads were then divided by the corresponding 2005 return flow values to obtain the TDS concentrations to be associated with each of the DCMs.

- The TDS concentrations (mg/l) determined in the previous step were then multiplied with the relevant annual return flows (million m^3/a) to obtain a projection of additional annual salt loads (tonnes/a) for each of the DCMs.

- The average monthly demand distribution was then determined based on the historic water use data and this distribution pattern, together with the estimated future additional annual salt loads were used to create projected monthly additional salt loads for each of the demand centres.

The average monthly demand distribution used for the disaggregation of annual salt loads is shown in **Table A.8.2** and the results for each of the DCMs are summarised in **Table A.8.3**.

Table A.8.2: Average monthly demand distribution based on historic water use

Historic Demand Distribution (% of annual demand)											
Oct	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
8.64	8.50	8.08	8.53	7.86	8.33	8.11	8.24	8.08	8.23	8.57	8.83

Table A.8.3: Projected additional salt load information

DCM Number	Average annual TDS Concentration (mg/l)	Projected additional salt load data file
40	424.51	DC40.SLD
293	533.85	DC293.SLD
294	456.74	DC294.SLD
295	243.95	DC295.SLD
296	735.85	DC296.SLD

A.9 FUTURE INTERVENTION REQUIREMENTS

A.9.1 OVERVIEW

Given the water requirement and return flow scenarios provided in **Chapter A.5** and the potential saving scenarios through WC/WDM measures presented in **Chapter A.6** the need for intervention (when further WC/WDM measure and/or the development of an augmentation scheme is required) can be determined by assessing the water reconciliation (water balance) situation over the planning period. This was undertaken by firstly defining the planning scenarios and, secondly, carrying out scheduling analysis to determine the date further intervention should be required.

The planning scenarios are described in **Section A.9.2,** the basic assumptions adopted for all the scenarios are summarised in **Section A.9.3** and the results of the scheduling analysis are presented in **Section A.9.3**. It should be noted that the WRPM run labels given in brackets are for reference purposes only and identify the computer file names for each scenario.

A.9.2 DESCRIPTION OF PLANNING SCENARIOS

Seven planning scenarios were formulated for analysis and evaluation, covering a range of possible future conditions and interventions as described in the following sections.

A.9.2.1 Scenario A (VT06R03): NWRS high population growth - based on 2001 census

- **Urban water requirements and return flows**: This scenario is based on the NWRS high population growth rates applied to the 2001 census population as the base or starting population for the Rand Water Supply Area.
- **Irrigation Scenario 1**: Curtailment of unlawful irrigation water use was applied (see **Section A.5.2.8** for details).
- Error! Reference source not found. presents the water requirements and return flows of all the water users for this scenario.

A.9.2.2 Scenario B (VT06R04): Aug '06 DWAF population scenario

- Urban water requirements and return flows: Implements the August 2006 population projection scenario as discussed in **Section A.5.4.2.**

- **Irrigation Scenario 1**: Curtailment of illegal irrigation water use was applied, see **Section A.5.2.8** for details.

- Error! Reference source not found. presents the water requirements and return flows of all the water users for this scenario.

A.9.2.3 Scenario C (VT06R05): WC/WDM: Implement all identified measures (based on Scenario B)

- This scenario is based on the water requirements for **Scenario B** as presented in Error! Reference source not found..

- The savings through WC/DM measures presented in Error! Reference source not found. is applied in **Scenario C**.

A.9.2.4 Scenario D (VT06R08): WC/DM: Implement waste management initiatives over 5 years (based on Scenario B)

- This scenario is based on the water requirements for **Scenario B** as presented in Error! Reference source not found..

- The savings through WC/DM measures presented in Error! Reference source not found. is applied in **Scenario D**.

A.9.2.5 Scenario E: WC/DM: Implement waste management initiatives over 10 years (based on Scenario B)

- This scenario is based on the water requirements for **Scenario B** as presented in Error! Reference source not found..

- The savings through WC/DM measures presented in Error! Reference source not found. is applied in **Scenario E**.

A.9.2.6 Scenario F: Illegal irrigation water use continues (based on Scenario B)

- This scenario is based on the water requirements for **Scenario B** as presented in Error! Reference source not found..

- **Irrigation Scenario 2** is implemented where the illegal water use is assumed to continue to increase according to the recent observed trend, see **Section A.5.2.8** for details.

A.9.2.7 Scenario G (VT06R02): Water balance for Ecological Water Requirement scenario (preliminary assessment)

This scenario was based on the water requirements for **Scenario B** and applying the Ecological Water Requirement information that was available from the Directorate: Resource Directed Measures. The EWR information were mainly determined through low confidence determination methods and the scenario results only serve as a preliminary indication of what the reconciliation situation is if the EWRs are implemented. EWR sites were identified downstream of all the major dams within the IVRS and a total of 28 sites were included in the WRPM configuration.

It should be noted that DWAF has at the end of 2006 commissioned a Comprehensive Reserve Determination Study for the Vaal River System and that the reconciliation options will have to be reviewed once these results become available.

In order to assess the impact of the ER this scenario was run twice: once without the EWR in place and secondly with the EWR incorporated in the WRPM configuration.

A.9.2.8 Summary of planning scenarios

The planning scenarios described in **Sections 9.2.2** to **9.2.7** are summarised in Error! Reference source not found.. It should be noted that planning **Scenarios E** and **F** were not analysed with the WRPM. The intervention requirements of these two scenarios were inferred based on the results of **Scenarios A** to **D**.

Table A.9.1: Summary of planning scenarios

Planning Scenario	WRPM Run Reference	Urban Demand Projection	Future Irrigation Scenario	WC/DM Initiatives Implemented
A	VT06R03	Scenario A	Scenario 1	None
B	VT06R04	Scenario B	Scenario 1	None
C	VT06R05	Scenario B	Scenario 1	Al identified measures (Error! Reference source not found.)
D	VT06R08	Scenario B	Scenario 1	Waste management initiatives over 5 years (Error! Reference source not found.)
E	-	Scenario B	Scenario 1	Waste management initiatives over 10

				years (Error! Reference source not found.)
F	-	Scenario B	Scenario 2	None
G	VT06R02	Scenario B	- (1)	None

Note: (1) The irrigation water requirements adopted for **Scenario G** are based on that of the 2006-2007 AOA and were, therefore, not updated with the irrigation water use presented in **Section A.5.2** of this report.

A.9.2.9 System net water requirements (Scenarios A to E)

Combining the respective water requirements and return flow components for **Scenarios A** to **E** produced the net system demand graph as presented in **Figure A.9.1.** A similar trend is observed for all scenarios for the first six years, showing an increase over the first three years and a decrease for the remaining three. This is due to the implementation of **Irrigation Scenario 1** (see **Section A.5.2.8**) in all the indicated scenarios.

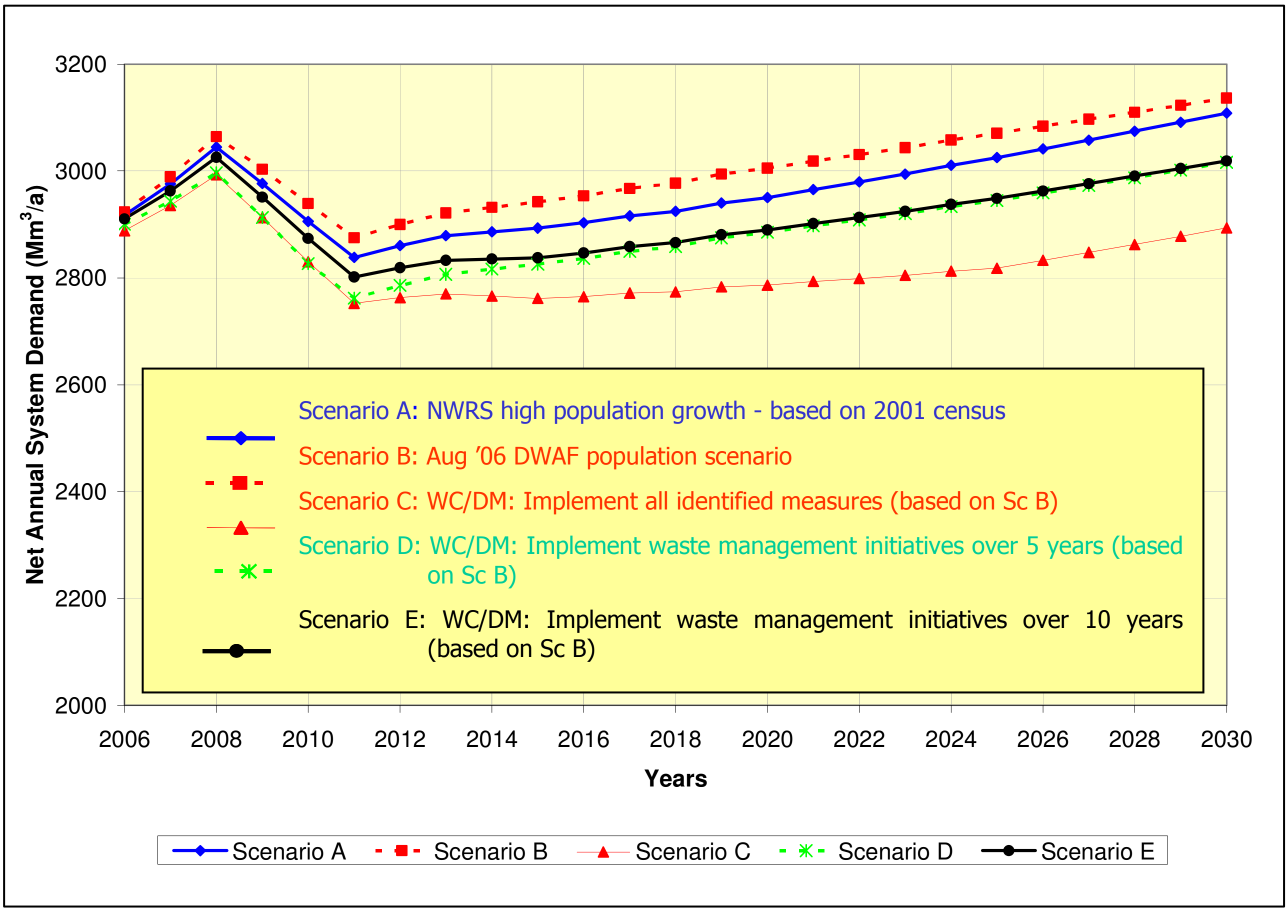


Figure A. 9.1: System net demand for the indicated scenarios

A.9.3 BASIC ASSUMPTIONS FOR PLANNING SCENARIOS

The operating scenario (VT06H01) of the 2006-2007 Annual Operating Analysis (AOA) of the IVRS was adopted as basis for the analysis undertaken as part of this study. All analyses were undertaken for 1000 stochastic sequences. The basic assumptions that were common to all the scenarios described in **Section A.9.2** are listed below. It should be noted that some of the operating levels selected for the dams situated in the Vaal River Eastern Sub-system are linked to the commissioning date of the Vaal River Eastern Sub-system Augmentation Project (VRESAP).

The basic assumptions were as follows:

- **Starting conditions:** The actual dam storages and TDS concentrations as recorded on 1 May 2006 were adopted as the starting conditions for the WRPM analysis. The total Vaal River System storage trajectory over the past six planning years is shown in **Figure A.9.2**. The total system storage is based on the actual storage of major dams within the Integrated Vaal River System (IVRS). Although impoundment at Mohale Dam commenced in November 2002, storage within the dam was only reflected in the total system storage since May 2004. **Figure A.9.2** illustrates the fact that the starting storage condition for the 2006/2007 planning year represents the highest system storage state ever recorded for the IVRS.

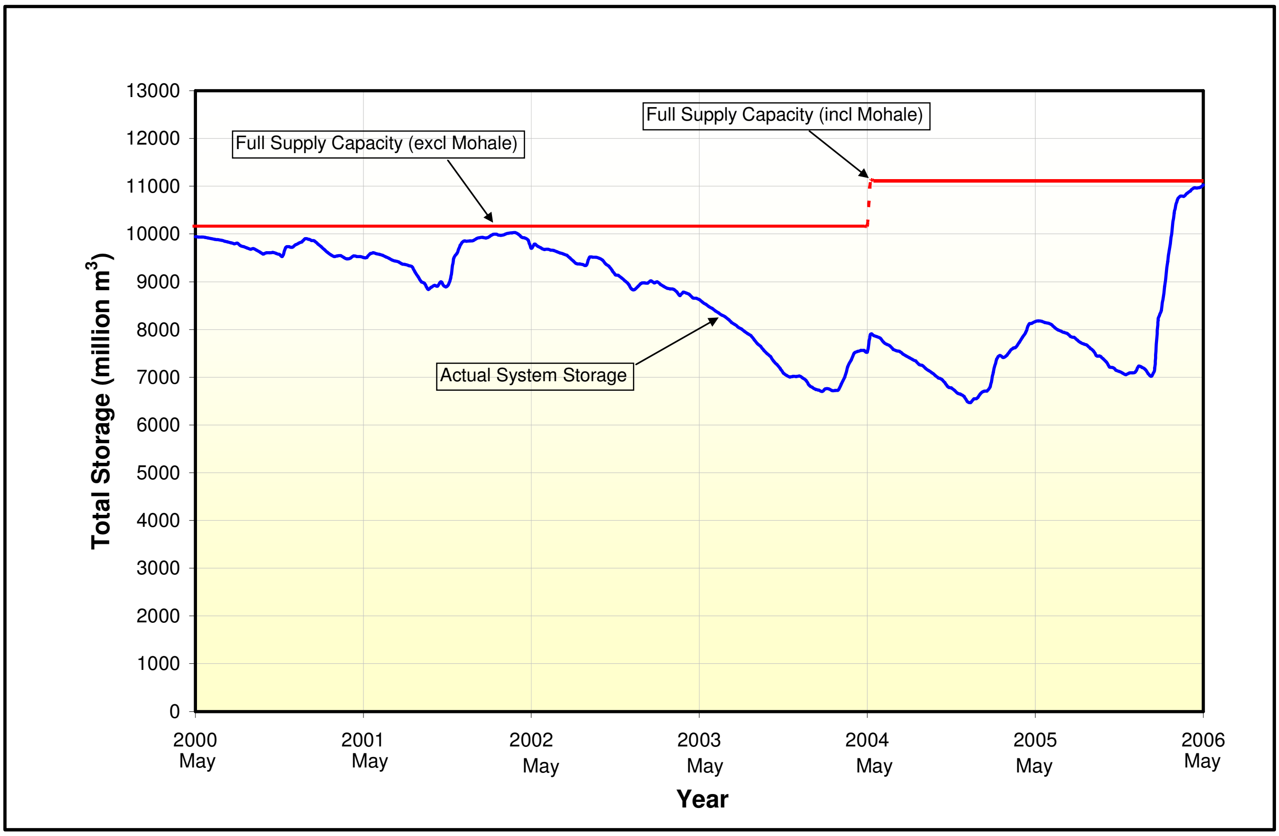


Figure A.9.2: Total Vaal River System Storage (from May 2000 to April 2006)

- **Thukela-Vaal transfer**: No pumping from the Thukela (Woodstock Dam) to Sterkfontein Dam was assumed during the first two years of the planning period.
- **Heyshope-Zaaihoek-Grootdraai transfer**: The 75% rule was adopted for the first planning year only and the 90% rule adopted for the remaining period of analysis (i.e. transfer from Heyshope and Zaaihoek dams to Grootdraai Dam when storage within Grootdraai Dam is below the 75% or 90% level respectively).
- **Morgenstond-Jericho transfer:** The new pipeline and pump station (commissioned during 2004) is fully operational. A revised transfer relationship was subsequently derived for the total transfer from Morgenstond Dam to Jericho Dam based on information obtained from Mr P Jacobs at Jericho Dam. This revised relationship with a maximum transfer capacity of 3.182 m^3/s (100.4 million m^3/a) was adopted for the analysis.
- **Revised Usutu inter-reservoir operating rules**: The newly adopted inter-reservoir operating rules were adopted for the analysis (Draw down sequence: Westoe-Jericho-Morgenstond; Draw down levels: 50%-70%-21%). The inter-reservoir operating rule is illustrated in **Figure A.9.3**Error! Reference source not found.. A new minimum operating level (1368.32m with associated storage of 10.763 million m^3) was included for Morgenstond Dam representing the last water to be used in the Usutu Sub-system.

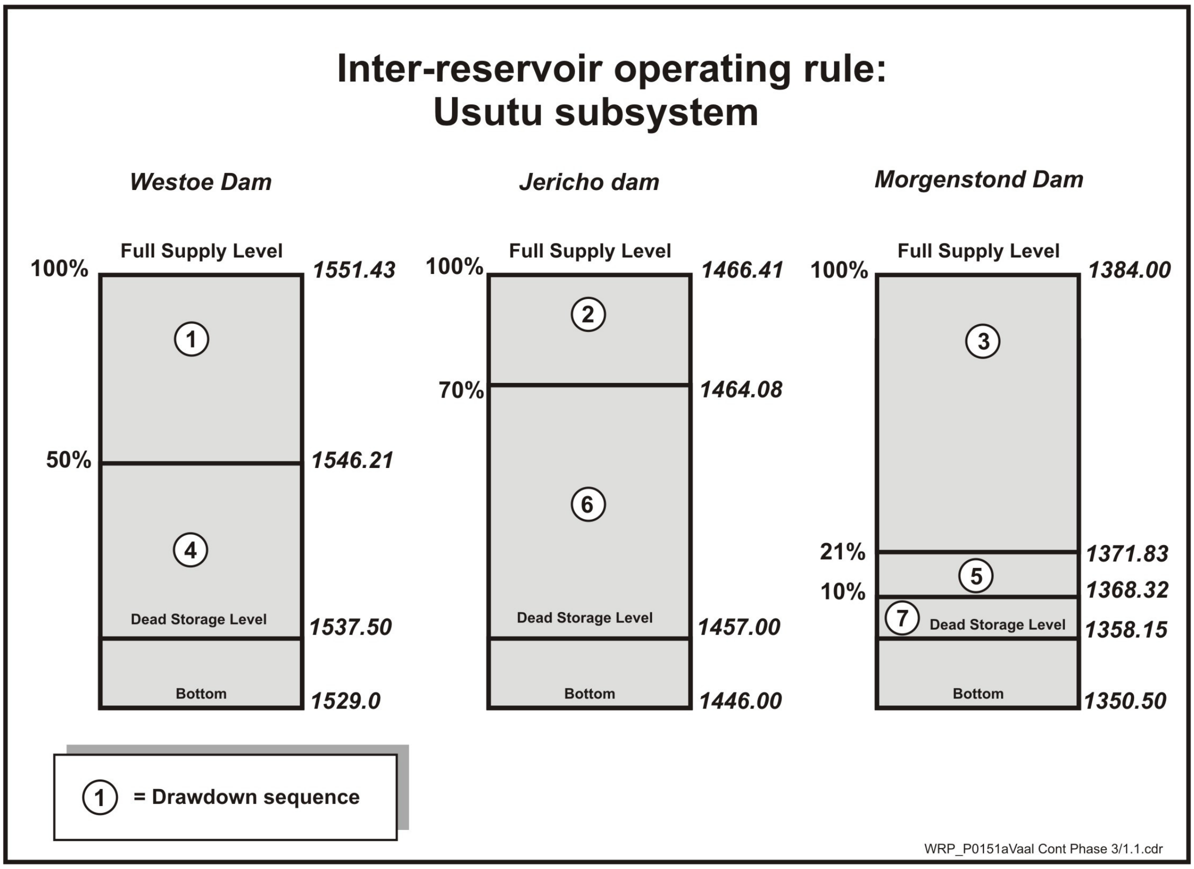


Figure A.9.3: Usutu Sub-system Inter-reservoir Operating Rules

- **Revised short-term curves for Usutu Sub-system**: The short-term yield reliability curves based on the newly adopted inter-reservoir operating rules (refer to Error! Reference source not found.) were incorporated in the WRPM configuration.
- **Heyshope-Morgenstond transfer:**
  - May 2006 to November 2007: Transfer when Morgenstond Dam is below 35 million m^3 (level of 1375.0 m).
  - November 2007 onwards: Transfer when Morgenstond Dam is below 80 million m^3 (level of 1381.34 m).
- **Heyshope buffer storage:**
  - May 2006 to November 2007: Reserve storage below 58 million m^3 (level of 1289.63 m).for transfer to the Usutu.
  - November 2007 to May 2018: Reserve storage below 150 million m^3 (level of 1294.54 m).for transfer to the Usutu.
  - May 2018 to end of analysis period: Reserve storage below 58 million m^3 (level of 1289.63 m) for transfer to the Usutu.

- **Grootdaai Dam buffer storage:** Reserve storage below 90% from November 2007 onwards (i.e. from VRESAP commissioning date onwards).
- **Transfer from Westoe to Jericho:** Link between two dams out of commission for six weeks as from 15 June 2006. No support to Jericho was therefore assumed during June and July 2006.
- **Region B Users**: Modelled within Olifants sub-systems with no support from Vaal for the full period of analysis.
- **Blending rule**: Rand Water supplied from Vaal Dam with constant release of 52.9 million m^3/a from Vaal Dam to limit the TDS concentration to 600 mg/l downstream of Vaal Barrage (Based on the dilution releases of the year 2004/2005).
- **LHWP scheduled transfers**: The monthly scheduled transfers amounting to an annual total of 780 million m^3/a for 2006 was obtained from the LHDA and incorporated in the analysis.
- **Compensation releases**:
    - Vygeboom Dam: Release 0.65 m^3/s during the full period of analysis.
    - Nooitgedacht Dam: Release 0.15 m^3/s for full period.
    - Grootdraai Dam: Releases based on normal flow (20 million m^3/a)
    - Zaaihoek Dam: Releases based on normal flow (11.4 million m^3/a)
    - Releases from Katse and Mohale dams modelled by means of the revised IFR structure based on the updated Ecological Reserve requirements.
- **Vaalharts Weir**: Operate at 90% level (level of 1189.67m).
- **Bloemhof Dam**: Minimum operating level at 6% (Level of 1219.32m with associated storage of 74.55 million m^3).
- **Vaal River Eastern Sub-system Augmentation Project (VRESAP):**
    - Date of implementation: 1 November 2007.
    - Maximum transfer capacity of Vaal pipeline: 160 million m^3/a.
- **Allemanskraal Dam**: Users restricted to 35% of their quota.
- **Erfenis Dam**: No restrictions were imposed on users due to the high storage state of the dam.

A.9.4 PLANNING SCENARIO RESULTS

A.9.4.1 General

The behaviour of selected system components (e.g. projected reservoir storages and simulated flows through transfer routes) is presented as probabilistic distribution plots (box plots). A typical box plot indicating the various lines that depict specified exceedance probabilities of a probability distribution is provided in **Figure A.9.4**Error! Reference source not found..

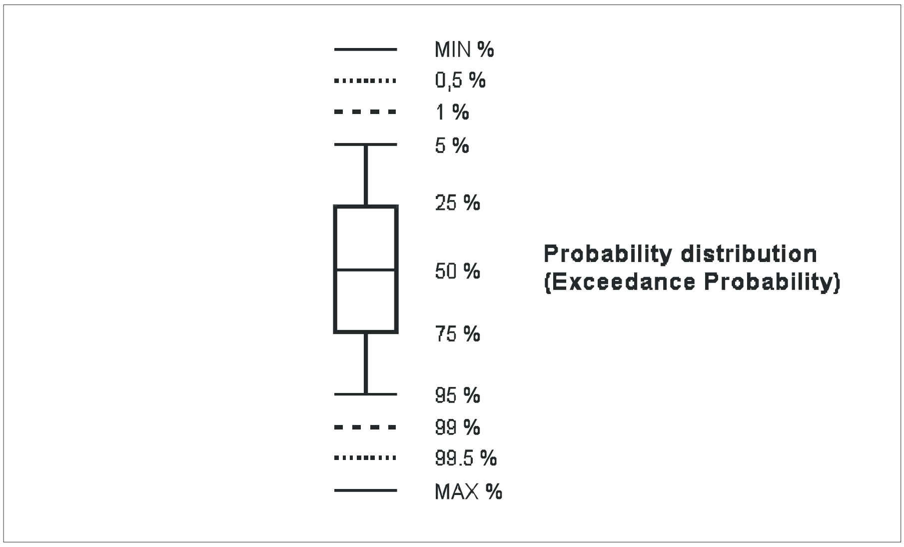


Figure A.9.4: Graphical depiction of a probability distribution or box plot.

The graphical results of the five scenario analyses undertaken with the WRPM are given in **Appendices E, F, G, H,** and **I,** and the most significant results are highlighted in the sections below. The evaluation of results is based on the criteria that the assurance of supply to all users in the Integrated Vaal River System is maintained at the 99.5% exceedance probability.

A.9.4.2 Scenario A (VT06R03): NWRS high population growth - based on 2001 census

A planning period of 20 years was considered for this scenario and the graphical results are shown in **Appendix E.** The curtailment levels, demand-supply and annual total system storage trajectories are shown in **Figures E-1**, **E-2** and **E-3** respectively. From **Figure E-1** it can be seen that the first violation of the reliability criteria occurs in the year 2016 where both level 1 and level 2 curtailments are unacceptable. This indicates that intervention is required by the year 2016. The top line on the demand-supply graph (**Figure E-2)** shows the demand whereas the projected supply resulting from the curtailments imposed by the allocation procedure of the WRPM is depicted by the box and whiskers appearing below this demand line. **Figure E-3** indicates that the lowest projected system storage at the 99.5% exceedance probability level occurred in the year 2024 and amounted to 4426 million m^3. Finally, the support from Vaal Dam to the Eastern Sub-system through the Vaal Dam pipeline is shown in **Figure E-4.** From **Figure E-4** it can be seen that the pipeline is utilised up to its maximum transfer capacity at the 5% exceedance probability level from the year 2011 onwards.

A.9.4.3 Scenario B (VT06R04): Aug '06 DWAF population scenario

The graphical results for this scenario are shown in **Appendix F.** From the curtailment level results presented in **Figure F-1** it can be seen that the first violation of the reliability criteria occurs in the year 2013 where the level 2 curtailments are unacceptable. Compared to the results for Scenario A (**Figure E-1)** the curtailments of Scenario B are overall higher. This is due to the higher system demands adopted for Scenario B as shown in **Figure F-2**. The resulting total system storages are shown in **Figure F-3**. The lowest projected system storage at the 99.5% exceedance probability level occurred in the year 2024 and amounted to 4341 million m^3 (i.e. 85 million m^3 lower than that of Scenario A). Similar to the results of Scenario A, it can be seen from **Figure F-4** that the Vaal pipeline is utilised up to its maximum transfer capacity at the 5% exceedance probability level from the year 2011 onwards.

A.9.4.4 Scenario C (VT06R05): WC/WDM: Implement all identified measures (based on Scenario B)

It should be noted that the analysis for this scenario was undertaken for a 25 year planning period. The graphical results are shown in **Appendix G** and from **Figure G-1** it can be seen that the first violation of the reliability criteria occurred in the year 2021. As shown in **Figure G-2** the overall system demand for Scenario C is significantly lower than that of both Scenarios A and B (.demand in 2025 amounting to 2696 million m^3/a whereas the 2025 demands for Scenarios A and B were 2977 and 3074 million m^3/a respectively. The lowest projected system storage at the 99.5% exceedance probability level occurred in the year 2029 and amounted to 4481 million m^3 (see **Figure G-3**). The projected support to the Eastern Sub-system through the Vaal pipeline is shown on **Figure G-4**.

A.9.4.5 Scenario D (VT06R08): WC/WDM: Implement waste management initiatives over 5 years (based on Scenario B)

The graphical results for this scenario are shown in **Appendix H** covers the planning period 2006 to 2025 (i.e. a 20 year period). **Figure H-1** shows that the first violation of the reliability criteria occurred in the year 2018. The overall system demand shown in **Figure H-2** is similar to that of Scenario C over the first 5 years. Thereafter the Scenario D demands increased to a demand of 2861 million m^3/a in the year 2025 whereas the 2025 demand for Scenario C was 2696 million m^3/a. From **Figure H-3** it can be seen that the lowest projected system storage at the 99.5% exceedance probability level, amounting to 4494 million m^3, occurred in the year 2024. The projected support to the Eastern Sub-system through the Vaal pipeline is shown on **Figure H-4.**

A.9.4.6 Scenario G (VT06R02): Water balance for Ecological Water Requirement scenario (preliminary assessment)

The water stored in Sterkfontein Dam represents the last water in the Vaal River system. Consequently the projected storage levels of Sterkfontein Dam were evaluated in order to assess the impact of implementing the preliminary EWR. For the analysis excluding the ER, the simulated reservoir trajectories of Sterkfontein Dam are shown in **Figure I-1** of **Appendix I**. Based on the adopted criteria that a failure occurs when the dam is drawn down to its minimum operating level at the 99.5% exceedance probability level, it can be seen from **Figure I-1** that, without implementing the ER, a failure at Sterkfontein Dam occurred for the first time in the year 2022. **Figure I-2** of **Appendix I** shows the simulated reservoir trajectories of Sterkfontein Dam after implementation of the preliminary EWR. The results shown in **Figure I-2** indicate that the first failure at Sterkfontein Dam occurred in the year 2017. Implementation of the EWR has therefore caused the first failure of the Vaal River system to take place 5 years earlier. This implies that the date at which intervention is required, has been moved ahead by 5 years due to the incorporation of the ER.

A.9.5 SCHEDULING ANALYSIS RESULTS

Projection analyses were carried out with the Water Resource Planning Model (WRPM) for the scenarios and based on the assessment of the risk of curtailments (refer to the scenario results presented in **Section A.9.4**) the supply capability of the system was determined to be 2921 million m^3/annum (i.e. the net system demand in 2013 for **Scenario B**). **Figure A.9.5**Error! Reference source not found. shows the net water requirements of **Scenario A** to **E** in relation to the system supply capability.

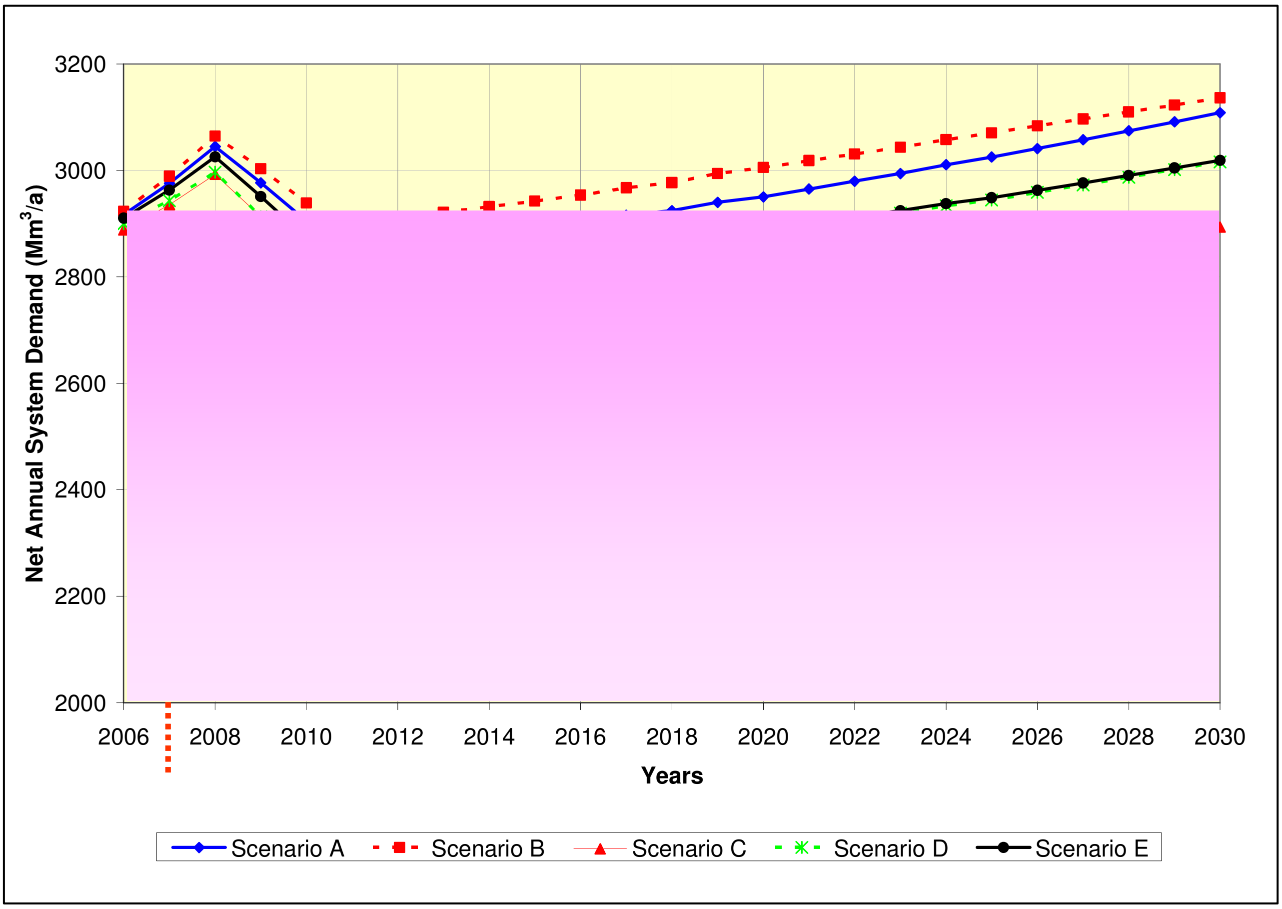


Figure A.9.5: Net system demand and system supply capability

The following observations can be made from **Figure A.9.5**Error! Reference source not found.:

- The unlawful water use in the irrigation sector results in the system being in a deficit situation from 2007 to 2009 for all the scenarios. This illustrates the importance of curbing the unlawful irrigation water use in order to maintain a positive water balance in the system and prevent excessive curtailments during drought periods.
- Based on the projected balance situation for **Scenario B**, it is shown that the system will require intervention by the year 2013.
- If the potential savings through WC/WDM of **Scenario C** is achieved, no further intervention is required for the planning period until after the year 2030.

- The balance situation for **Scenarios D** and **E** shows that by eliminating wastage through WC/WDM further intervention is only required in the year 2023.

A.9.6 ECOLOGICAL WATER REQUIREMENT SCENARIO RESULTS (SCENARIO G)

Risk analysis showed that the supply capability of the Vaal River System would decrease by 138 million m^3/annum, and according to the balance situation provided in **Figure A.9.6**Error! Reference source not found., only **Scenario C** will achieve a positive water supply balance between 2011 and 2020.

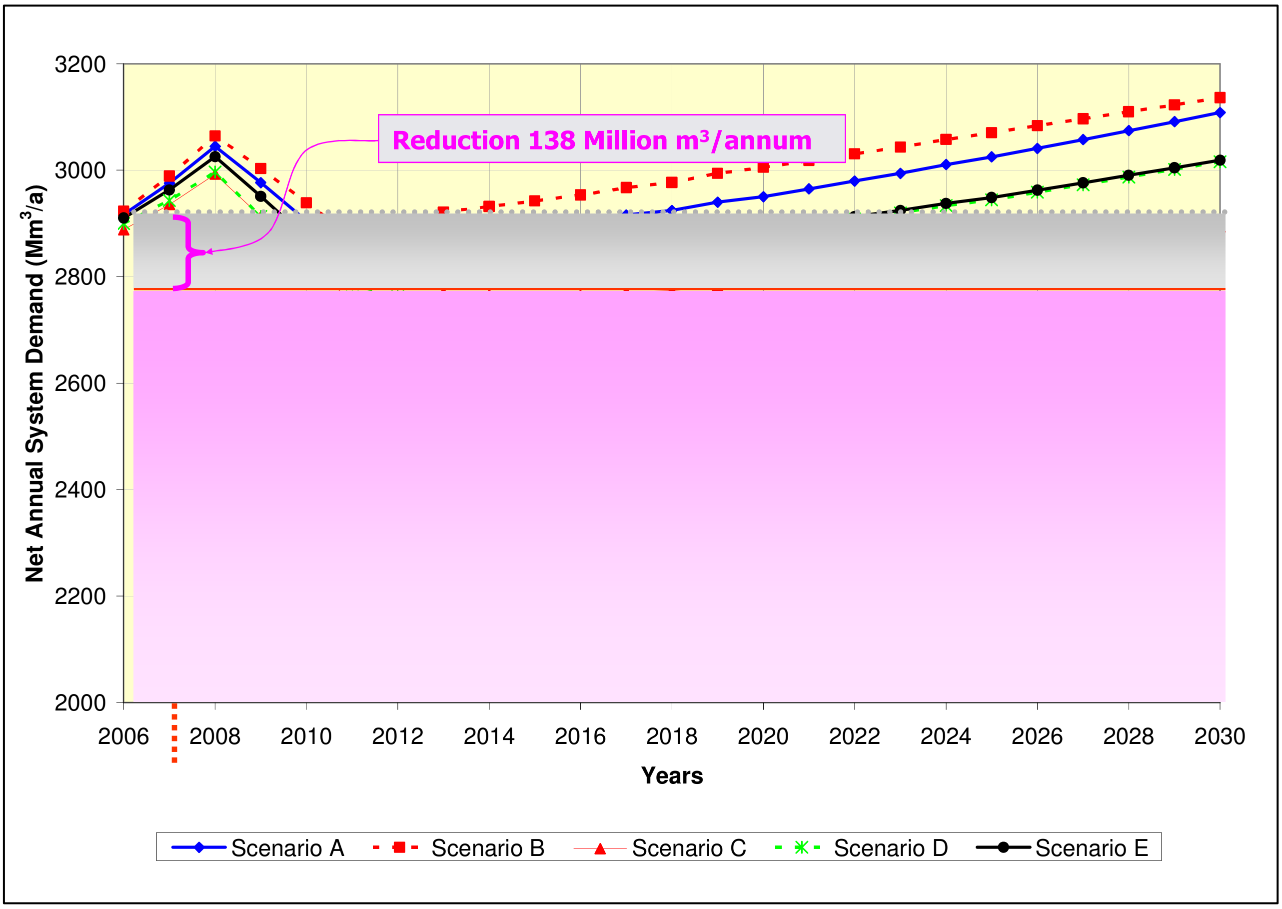


Figure A.9.6: Net system demand and supply capability with EWR releases

A.9.7 RECONCILIATION OPTIONS

Several reconciliation options were formulated based on the scenarios described in **Section A.9.2** and the augmentation options presented in **Section A.7**. These options are presented and discussed in the study report entitled “First Stage Reconciliation Strategy” (**DWAF, 2006g**).

A.9.8 WATER QUALITY MANAGEMENT

Water quality management is being investigated in detail as part of the parallel "*Integrated Water Quality Management Plan*" (IWQMP) study and will be reported on in a separate series of reports. At the time of writing this report, the IWQMP study was still in progress and only initial preliminary results were available for consideration in the First Stage Reconciliation Strategy. A preliminary perspective on water quality management is provided in the report "First Stage Reconciliation Strategy" (**DWAF, 2006g**).

A.10 CONCLUSIONS

Given the planning scenario results and the scheduling analyses as presented in the previous chapters the following main conclusions can be drawn:

- Unlawful irrigation water use, particularly in the catchments of Wilge and Liebenbergsvlei rivers (upstream of Vaal Dam), is a major impediment to the assurance of supply in the Vaal River System and represent an unsustainable situation that requires management intervention (results of **Scenario F**).
- Assuming that curtailment of unlawful irrigation water use (as described for **Irrigation Scenario 1**) materialises, it was found that a deficit situation occurred over the medium term (from 2007 to 2009) for all the scenarios analysed (see Error! Reference source not found.).
- The **Scenario B** results indicated that intervention is required in the year 2013. This means that, without WC/WDM the decision to proceed with an infrastructural intervention measure has to be taken immediately.
- The planning scenario results for **Scenarios D** and **E** showed that intervention is required in the year 2023. Therefore, saving water through the reduction of wastage by means of water conservation and demand management measures in the urban sector has the benefit that the decision to proceed with an augmentation scheme can be postponed to the year 2012.
- The second phase of the Lesotho Highlands Further Phases Study should be completed based on the water balance results of **Scenarios B** and **D**. Once the optimal LHFP scheme has been identified it will be required to undertake a comparison with the optimal TWP options before a decision can be made on which of the two alternative schemes should be recommended for implementation.
- The augmentation requirement for **Scenario B** in 2030 of 215 million m^3/annum is substantially lower than the TWP scheme target of 454 million m^3/annum that was used for the optimisation of the scheme configuration in the TWP feasibility study. It is therefore proposed that the TWP option should be re-evaluated to determine the most optimal configuration and size for a target augmentation volume of 215 million m^3/annum.

- The implementation of the preliminary ER reduced the supply capability of the Vaal River system by 138 million m^3/annum causing the date at which intervention is required to move forward by 5 years (refer to results of **Scenario G**).

- The Comprehensive Reserve Determination Study (commissioned by the DWAF Directorate Resource Directed Measures (RDM) in August 2006) will produce Ecological Water Requirement Scenarios and the implication thereof on the reconciliation options will have to be determined and evaluated.

A.11 RECOMMENDATIONS FOR THE SECOND STAGE RECONCILIATION STRATEGY

Based on the results and conclusions presented in this report, it is recommended that the following aspects be considered in the development of the Second Stage Reconciliation Strategy:

- Re-evaluate system balance once the validation studies and the comprehensive reserve determination study produce information.
- The irrigation return flows determined with the Water Requirement and Return Flow database model (**DWAF, 2004e**) should be incorporated in the WRPM configuration.
- To ensure that the water quality downstream of the irrigation areas is modelled correctly, it is recommended that the irrigation water use be modelled with the irrigation block modules. This process would involve the recalibration of the exiting irrigation modules to obtain the required volumetric abstractions and return flows whilst at the same time maintaining the salt balance which resulted from the VRSAU Study calibrations.
- The revised Senqu short-term yield reliability curves (refer to **Section A.4.1.4**) as well as the operating rule finally adopted for the Mohale-Katse transfer tunnel (refer to **Section A.4.1.3**) should be included in the WRPM configuration.

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Vaal River System: Large Bulk Water Supply Reconciliation Strategy

Water Resource Analysis: Part B

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ANNEXURES

ABBREVIATIONS

Acronym	Meaning
BP	Business Plan
CMA	Catchment Management Agency
CMS	Catchment Management Strategy
DCM	Demand Centre Module
Dir: HI	Directorate: Hydrological Information
Dir: NWRP	Directorate: National Water Resource Planning
CMS	Catchment Management Strategy
Dir: OA	Directorate: Option Analysis
Dir: PSC	Directorate: Policy and Strategic Co-ordination
Dir: WRPS	Directorate: Water Resource Planning Systems
Dir: RDM	Directorate: Resource Directed Measures
Dir: WCDM	Directorate: Water Conservation and Demand Management
Dir: WDD	Directorate: Water Discharge and Disposal
Dir: WUE	Directorate: Water Use Efficiency
DWAF	Department of Water Affairs and Forestry
FSC	Full Supply Capacity
GDP	Gross Domestic Product
GGP	Gross Geographical Product
HFY	Historic Firm Yield
IDP	Integrated Development Plan
ISP	Internal Strategic Perspective
LHWP	Lesotho Highlands Water Product
LORMS	Lower Orange River Management Study
MAP	Mean Annual Precipitation
MAR	Mean Annual Runoff
masl	Metres above sea level
NAY	Nominal Annual Yield
NWA	National Water Act
NWRS	National Water Resource Strategy
ORRS	Orange River Replanning Study
WARMS	Water Authorisation Registration Management System
WDM	Water Demand Management
WC	Water Conservation
WMA	Water Management Area
WSDP	Water Services Development Plan
WRPM	Water Resource Planning Model
WRSAS	Water Resource Situation Assessment Study
WRYM	Water Resource Yield Model
WUA	Water User Association

Vaal River System: Large Bulk Water Supply Reconciliation Strategy

Water Resource Analysis: Part B

(Second Stage Reconciliation Strategy)

B.1 INTRODUCTION

B.1.1 BACKGROUND AND PURPOSE OF STUDY

The background to and purpose of the reconciliation study of the large bulk water supply system of the Vaal River commissioned by the Directorate: National Water Resource Planning (D:NWRP) are provided in **Sections A.1.1** and **A.1.2** of **Part A (First Reconciliation Strategy)** of this report respectively.

B.1.2 PURPOSE OF THE SECOND STAGE RECONCILIATION

Since the study was conducted over a period of 3 years, it was recognised that new information would become available during the course of the study and that the development of a Reconciliation Strategy would have to be undertaken in two stages. Consequently initial water resource analyses were undertaken for the development of the First Stage Reconciliation Strategy, the basic information and results of which are discussed in **Part A** of this report.

The purpose of the analyses undertaken as part of the Second Stage was, therefore, to develop a reconciliation strategy based on the recommendations from the First Stage assessments, whilst at the same time incorporating the most recent water requirement projections and further refinements to the Water Resource Planning Model (WRPM) configuration.

B.1.3 STUDY AREA

A geographical map of the Integrated Vaal River System (IVRS), which is the area of concern for the study, is shown in **Figure B-1** of **Appendix B**.

B.1.4 PURPOSE AND LAYOUT OF PART B

Part B of this report describes the water resource analyses undertaken for the Integrated Vaal River System (IVRS) as part of the Second Stage Reconciliation Strategy. The water resource analyses comprised of the following sub-tasks:

- Update hydrology of selected sub-catchments;
- Update the WRPM configuration by incorporating the water requirement and return flow projections of all the water user groups revised subsequent to the First Stage Reconciliation Strategy;
- Update the WRPM configuration to include all refinements made in terms of various sub-catchments;
- Undertake projection analyses with the Water Resource Planning Model (WRPM) to determine the need for intervention based on various assumptions; and
- Reporting.

The introduction to the Second Stage assessment given in **Chapter B.1**, is followed by a description of the methodology adopted for the required water resource analysis in **Chapter B.2**. **Chapter B.3** reports on the hydrology updates of selected catchments whilst the detail WRPM configurations of these catchments are discussed in **Chapter B.4**. **Chapter B.5** describes the water requirement and return flow projections of individual user groups which were used to compile the water demand scenarios for the Second Stage Reconciliation Strategy. The identified alternative water demand scenarios are presented in **Chapter B.6**. Infrastructure intervention options are discussed in **Chapter B.7** and the update of the Water Resource Planning Model (WRPM) configuration is described in **Chapter B.8**. Future intervention requirements which include descriptions of the WRPM scenarios analysed as part of the Second Stage Reconciliation Strategy, as well as the scenario results, are provided in **Chapter B.9**. Conclusions and recommendations are provided in **Chapters B.10** and **B.11** respectively and finally, the references used in the report are presented in **Chapter B.12**.

B.2 WATER RESOURCE ANALYSIS METHODOLOGY

B.2.1 APPROACH TO WATER RESOURCE ANALYSIS

Details on the study procedure in terms of the technical work, as well as the methodology adopted for the development of the Second Stage Reconciliation Strategy, are described in the report "Second Stage Reconciliation Strategy", compiled as part of this study (**DWAF, 2006h**).

The focus of the assessments for the First Stage Strategy included, inter alias, the following:

- Development of water requirement and return flow scenarios for the urban water use sector of the Gauteng Province (**DWAF, 2006a**);
- Determination of the potential for Water Conservation and Demand Management by concentrating on the main urban areas (**DWAF, 2006b**).
- Estimation of irrigation water requirements (**DWAF, 2006d**);
- Identification and assessment of potential large scale water reuse options that could have water quality and water supply benefits (**DWAF, 2006c**).

Not all the information regarding the above-mentioned aspects was readily available at the time when the First Stage Reconciliation Strategy was developed and various assumptions were made. It was, therefore, important for the Second Stage Strategy to incorporate updated information that became available during the course of the study.

The following approach was subsequently adopted for the water resource analysis task of the Second Stage Strategy:

- The Water Resource Planning Model (WRPM) configuration of the Integrated Vaal River System (IVRS), as well as the water requirement and return flow database resulting from the 2007-2008 Annual Operating Analysis (AOA), was adopted as starting point for the water resource assessment. This configuration, in turn, included all the changes that were made during the First Stage Reconciliation Strategy.

- All the revised irrigation water requirements obtained as part of this study (**DWAF, 2006d**) was modelled with the irrigation block modules to ensure that the water quality downstream of the irrigation areas are modelled correctly.

- The irrigation return flows determined with the Water Requirement and Return Flow database model (**DWAF, 2006e**) were incorporated in the WRPM configuration.

- The two alternative water requirement and return flow scenarios that were developed for the urban water use sector of the Gauteng Province (**DWAF, 2006a**) as part of the First Stage Reconciliation Strategy were incorporated in the water requirement and return flow database of the WRPM.

- The Water Resource Planning Model (WRPM) configuration was updated to enable realistic modelling of the revised water requirements of both the irrigation and the urban water use sector of the Gauteng Province.

- The WRPM configuration and hydrological database were updated to facilitate the modelling of the detailed Schoonspruit and Renoster sub-catchments. The configuration of the Upper Vaal catchment was refined to include modelling of the Waterval incremental catchment. The revised Senqu short-term curves (refer to **Section A.4.1.4**), as well as the operating rule finally adopted for the Mohale-Katse transfer tunnel (refer to **Section A.4.1.3**), were also included in the WRPM configuration.

- Planning scenarios were identified and analysed with the WRPM to assess the need for intervention (refer to **Section B.2.3** below) based on the following:

    - Two alternative water requirement and return flow projection scenarios for the urban sector in the Gauteng Province;

    - Water Conservation and Demand Management initiatives focussing on the nine largest urban water users in the Gauteng Province;

    - Water quality management options relating to blending, dilution and water reuse; and

    - Implementation of preliminary Ecological Water Requirements (refer to **Section B.2.2** below).

B.2.2 RECONCILIATION FOR A PRELIMINARY RESERVE SCENARIO

As mentioned in **Section A.2.2**, the Directorate: Resource Directed Measures (Dir: RDM) has commissioned studies during the end of 2006 for undertaking Comprehensive Reserve Determination Studies for the IVRS. It was anticipated that the results from the Comprehensive Reserve Determination Study would not be available for inclusion in this study.

In order to provide an interim perspective on the water balance concerning the Ecological Reserve as part of the First Stage Strategy, an analysis was carried out where all available Ecological Water Requirement (EWR) information was sourced from Dir: RDM and incorporated into the WRPM. Two scenarios were simulated, one with and the other without the EWRs, and in each case the date when system failure occurred were determined for a selected water requirement projection scenario that covers the planning period up to 2030. The analysis was, however, not repeated for the Second Stage Strategy.

B.2.3 DETERMINATION OF THE REQUIRED INTERVENTION DATES

Operational and planning decisions concerning the Integrated Vaal River System are informed by risk analysis techniques involving simulation of the water resource system using computer models. The analysis is undertaken by means of a suite of water resource simulation models which contains an extensive hydrological database that covers all the catchments and river systems comprising the Integrated Vaal River System. The suite of models consists of various supporting utilities all having the function of generating data and information require by the WRPM.

The WRPM is the main decision support system which through scenario analysis determines, among other things, the future date when intervention is required based on the probability (risk) of curtailments for a given set of variables and assumptions. The model contains an allocation procedure (algorithm) to simulate curtailment rules which reduce (curtail) the water requirements when the storage state of the system is depleted to such levels that the short-term yield (supply capability) is less than the water requirements.

The date when intervention is required, is determined by analysing a large number of possible hydrological inflows (runoff) and by implementing curtailments in each of the inflow sequence when droughts occur, an estimate of the probability of curtailments is obtained. These simulations are carried out for a planning period of about twenty years during which the water requirements increase over time resulting in more frequent curtailments being required from year to year. The most important result from the simulations is the annual projected risk of curtailments and the year in which the reliability criteria are violated, defines the date when intervention is necessary.

In this study the above described methodology were applied to the scenarios described in **Section B.9.2** and the scheduling results are presented in **Section B.9.5**.

B.3 UPDATE HYDROLOGY OF SELECTED SUB-CATCHMENTS

B.3.1 GENERAL

As mentioned in **Section A.3.1** the hydrological database of the Komati, Usutu, Buffalo, Assegaai, Vaal and Senqu Sub-systems incorporated in the WRPM configuration originates from the Vaal River System Analysis Update (VRSAU) Study (**DWAF, 2000**). The VRSAU Study was completed in 1999 and the resulting hydrological database covers the period October 1920 to September 1995.

No general update of the hydrology has been undertaken since the VRSAU Study. The hydrology of the Schoonspruit sub-catchment was, however, revised in 2006 (refer to **Section B.3.2** below) to account for improved surface-groundwater interaction. Furthermore, the Renoster catchment's hydrology (see **Section B.3.3**) , that was originally lumped together to represent only two sub-catchments, was refined at quaternary catchment level to allow for the modelling of the water requirements of the proposed Voorspoed Mine. Changes made to the hydrology of the Schoonspruit and Renoster catchments also influenced the hydrology of the Bloemhof incremental catchment (refer to **Section B.3.4** for details).

Although the update of the hydrology of the IVRS was not part of the TOR for this study, the update of the Schoonspruit, Renoster and Bloemhof incremental catchment hydrology, as discussed in the following sections, were incorporated in the WRPM database as part of the Second Stage Reconciliation Strategy.

B.3.2 SCHOONSPRUIT SUB-SYSTEM

The hydrology of the Schoonspruit catchment resulting from the VRSAU Study was lumped together to represent two sub-catchments, namely the Rietspruit (RIETS9) and Johan Neser (NESER9) incremental catchments (refer to **Figure A-5** of **Appendix A**). However, in view of allocation decisions that needed to be undertaken within the Schoonspruit Sub-system, the need was identified to refine the existing Schoonspruit Sub-system configuration. Furthermore, the strong interaction between groundwater and surface water resources due to dolomitic compartments that are located in the upper portion of the Schoonspruit catchment had not been explicitly simulated as part of the VRSAU Study's hydrological analyses. This was mainly due to the fact that information on the observed flows from the Schoonspruit Eye was not available at the time and certain assumptions had to be made for the purposes of the VRSAU Study. The hydrology of the Schoonspruit Sub-system has consequently been revised as part of the Schoonspruit Sub-system Analysis Study (**DWAF, 2006**).

Observed flows from the Schoonspruit Eye indicated an average flow of in excess of 50 million m^3/a, which is far more than the 28 million m^3/a assumed in the VRSAU Study. The hydrology for the Schoonspruit catchment was, therefore, re-calibrated and the groundwater surface water interaction model recently developed by K Sami was used to model the flow from the Schoonspruit Eye. The natural flows for key points within the Schoonspruit catchment were derived solely from the natural simulated flows as was done in the VRSAU Study. The Mean Annual Runoffs (MARs) of the natural simulated flows as derived from the Schoonspruit Sub-system Analysis Study (**DWAF, 2006**) are compared with those from the VRSAU Study in **Table B.3.1**.

Table B.3.1: Comparison of natural flows from Schoonspruit and VRSAU studies

Quaternary Catchment	**MAR (million m^3/a) for period 1920 to 1994 (#)**	
	Schoonspruit Study	**VRSAU Study**
Schoonspruit Eye	60.60	
C24C	0.00	27.58 (#)
C24D (Rietspruit Dam)	7.29	8.15
C24E	9.81	11.79
C24F	19.50	21.26
C24G	16.85	18.29
C24H	8.83	8.83
Total (excluding eye)	**62.28**	**68.32**
Total (including eye)	**122.88**	**95.90**

Note: (#) Represents the contribution from the catchment containing the Schoonspruit Eye

In the VRSAU Study runoff for the endoreic catchment C24C was included in an attempt to represent the flows from the Schoonspruit Eye. This, however, totally underestimated the flow from the eye under natural conditions, as evident from **Table B.3.1.** In the VRSAU Study the effect of the wetland in the catchment was not included. The Schoonspruit Sub-system Analysis Study indicated losses from the wetlands under natural conditions to be in the order of 18 million m^3/a. This means that under natural conditions the full 122.88 million m^3/a generated from the

Schoonspruit catchment will not reach the confluence of the Vaal River, but rather something in the order of 105 million m^3/a. This is about 9% higher than that indicated by the VRSAU Study.

From the VRSAU hydrology reports it was clear that the hydrologists struggled with a large number of negative flow values in the overall balance to Bloemhof Dam. Due to the relative high base flow from the Schoonspruit (as result of the flow from the Schoonspruit Eye) a fair amount of the negatives were absorbed in the Schoonspruit flows. When it was attempted to incorporate the updated Schoonspruit hydrology into the overall system up to Bloemhof Dam negative flows again resulted in the Schoonspruit hydrology. Consequently, for the purposes of the Schoonspruit Sub-system Analysis Study (**DWAF, 2006**), it was decided to model the Schoonspruit sub-system on its own.

Since the updated Schoonspruit hydrology was considered to be a definite improvement on the VRSAU hydrology and it was recommended to be used in future studies, it was finally included in the WRPM database adopted for the Second Stage Reconciliation Strategy. However, as explained above, this could not be done without the adjustment of the Bloemhof incremental hydrology (refer to **Section B.3.4** for details).

B.3.3 RENOSTER RIVER SUB-SYSTEM

B.3.3.1 General

The Renoster River catchment comprises of 10 quaternary catchments (C70A through to C70K). The hydrological analysis conducted as part of the Vaal River System Analysis Update (VRSAU) Study (DWAF, 1998a) collated, processed and documented information on a quaternary catchment basis. However, for the purposes of the yield analyses of the VRSAU Study (DWAF, 1998b), the WRYM configuration was set up to represent a simplified modelling of the Renoster River sub-system. Therefore, the hydrological and catchment development information presented for the individual quaternary catchments were lumped together to create data sets that are representative of the following sub-catchments:

- **Koppies Dam incremental catchment**: The incremental catchment upstream of Koppies Dam comprises of quaternary catchments C70A, C70B and C70C.

- **Proposed Rietspruit Dam incremental catchment**: The proposed Rietspruit damsite is situated at the outlet of quaternary catchment C70J. This incremental catchment, therefore, comprises of six quaternary catchments namely C70D, C70E, C70F, C70G, C70H and C70J.

- **Portion of Bloemhof Dam incremental catchment**: Quaternary catchment C70K was included in the incremental catchment of Bloemhof Dam.

Similar to the yield analyses, the lumped hydrology and land use information of the Renoster Sub-system resulting from the VRSAU Study was also included in the WRPM configuration to facilitate the modelling of the Koppies (KOP9) and proposed Rietfontein Dam (RIETF9) incremental catchments (refer to **Figure A-5** of **Appendix A**).

During 2003 the proposed Voorspoed Diamond Mine expressed its intention to buy out the water rights of existing irrigators operating under the Koppies GWS in order to obtain the necessary quantity of water required by the mine. Consequently, the refinement of the Renoster catchment's hydrology and system network was required to assess the assurance of bulk water supply to the proposed Voorspoed Diamond Mine.

B.3.3.2Refinement of Renoster Sub-system Hydrology

The refinement of the Renoster Sub-system hydrology was undertaken as part of the study entitled "System Analysis of the Renoster River for Voorspoed Mine Assurance of Supply" (**DWAF, 2003**).

For the purpose of the Voorspoed Mine analysis, the Renoster River was subdivided into eight sub-catchments representing the major river reaches of the river and the main tributaries as defined in terms of the quaternary catchment boundaries. The quaternary catchment was accepted as the smallest catchment unit to be considered for systems where license applications have to be evaluated. Consequently it was necessary to disaggregate the naturalised incremental catchment streamflow records into quaternary catchment flows. Details of the resulting naturalised quaternary catchment flows used for the Voorspoed Mine license application assessment are summarised in **Table B.3.2** It should be noted that for the incremental catchment upstream of Koppies Dam it was not deemed necessary to revert back to quaternary catchment level.

Since the Renoster sub-system is modeled as part of the Integrated Vaal River System, it is important to note that the detail Renoster Sub-system configuration and refined VRSAU hydrology could not be included in the WRPM configuration without making the required adjustments to the Bloemhof Dam incremental hydrology as described in **Section B.3.4.4**.

Table B.3.2: Summary of hydrology information for Renoster Sub-system

Hydrology reference No.	Incremental/quaternary catchment	Natural MAR (million m^3/a)	
		1925 to 1994	1920 to 1994
I13	C70ABC	59.46	59.14
I187	C70D	12.04	12.58
I188	C70E	11.50	11.96
I189	C70F	9.10	9.46
I190	C70G	13.46	13.95
I191	C70H	3.84	3.99
II16	C70J	8.26	8.58
I192	C70K	10.79	10.92
Total for Renoster catchment:		**128.45**	**130.58**

B.3.4 BLOEMHOF INCREMENTAL SUB-SYSTEM

B.3.4.1 General

The re-assessment of the Bloemhof Dam incremental hydrology in context of the updated Schoonspruit hydrology was identified as a possible activity to be undertaken as part of this study. Owing to time constraints, the re-assessment of the Bloemhof Dam incremental hydrology was not undertaken as part of the First Stage Reconciliation Strategy development and the updated Schoonspruit hydrology could not be used in combination with the rest of the existing Vaal River System due to the negative values. It was, therefore, recommended to update the hydrology for the Vaal River catchment between Vaal Dam and Bloemhof Dam for the Second Stage Reconciliation Strategy, taking into account the effects of updated hydrology developed for the Schoonspruit and Renoster sub-catchments (see **Sections B.3.2** and **B.3.3** respectively for details).

For the Renoster Sub-system the development of hydrology for each of the quaternary catchments was relatively simple, as the original WRSM90 system was already setup to be able to produce flows at a quaternary level. For the Schoonspruit Sub-system it was, however, found to be problematic, and a total new rainfall-runoff calibration was required as described in **Section B.3.2.**

Several difficulties were originally experienced when creating natural flow records during the VRSAU Study. This need to be briefly explained to be able to better understand the process followed in this study to re-assess the Bloemhof Dam incremental hydrology. There are two basic approaches which can be followed to provide time series of natural stream flow at key points in a river basin. The first approach is to naturalise selected observed records by adding back all the known abstractions and subtracting all accretions. These naturalised flow records are then extended using simulated natural flows based on a calibration of the WRSM90 model against the observed record.

The other approach is to rely solely on the simulated flows to represent natural hydrology. The advantage of this method lies in the absence of problems of imbalances among the various gauging points. The disadvantage of this method is that long, reliable records may be replaced with far less accurate simulated flow records. In the VRSAU Study the former approach was followed. Difficulties did, therefore, occur in the process to obtain a meaningful water balance between adjacent gauges along the Vaal River. This difficulty arises as a result of relatively small incremental run-off time series coupled with significant river losses, abstractions and return flows as well as inaccuracies at flow gauges.

The naturalisation of flow records according to the first approach was attempted only for incremental catchments of the main dams with reliable inflow records. The catchments selected for this purpose is as described in **Table B.3.3** (Also see **Figure K-1** in **Appendix K**)

The naturalised records for the incremental catchments C2R001 (Boskop Dam) and C9R002 (Bloemhof Dam) yielded a number of negative flows which were adjusted according to a specific procedure. When the process of eliminating negative flows was completed, naturalised flow records were available for each of the five sub-catchments listed in **Table B.3.3**.

Table B.3.3: **Sub-catchments selected for calibration and naturalisation**

Dam	**Gauge**	**Catchment**
Klerkskraal	C2R003	Total catchment of Klerkskraal Dam
Boskop	C2R001	Incremental catchment between Klerkskraal & Boskop dams
Koppies	C7R001	Total catchment of Koppies Dam
Allemanskraal	C4R001	Total catchment of Allemanskraal Dam

Dam	Gauge	Catchment
Erfenis	C4R002	Total catchment of Erfenis Dam
Bloemhof	C9R002	Incremental catchment d/s of Vaal Barrage, Boskop, Koppies, Allemanskraal and Erfenis and upstream of Bloemhof Dam.

The Bloemhof Dam incremental catchment, however, covers a large area and had to be sub-divided into smaller sub-catchments for system modelling purposes. These sub-catchments are listed in **Table B.3.4** and shown on **Figure K-2** in **Appendix K**.

Table B.3.4: **Summary of sub-catchments within the large Bloemhof incremental catchment**

Sub-catchment Description (Catchment Reference Number)	Gross Area (km^2)	MAR for Period 1920 – 1994 (million m^3/a)
Sand-Vet catchment u/s of Bloemhof and d/s of Allemanskraal & Erfenis Dams (R21)	10 800	159.13
Klipbank catchment which is the Vals River u/s of the Possible Klipbank Dam site (R14)	7 871	155.05
The Possible Rietfontein Dam catchment includes the Renoster River catchment u/s of C7H006 and d/s of Koppies Dam (R19)	3 605	60.52
Kromdraai catchment is the main Vaal River catchment d/s of Vaal Barrage and u/s of the Possible Kromdraai Dam site (R17).	2 028	42.84
Klipdrift catchment is the total catchment u/s of Klipdrift Dam (R15).	890	21.08
Rietspruit catchment: The total catchment u/s of Rietspruit Dam (R20)	1 714	36.04
Johan Neser Dam catchment is the incremental catchment between Johan Neser Dam and Rietspruit Dam (R18).	3 930	51.68
Remainder of the Bloemhof incremental catchment (R10)	16 189	153.69
Total (Large Bloemhof incremental catchment)	**47 027**	**680.03**

The following procedure was used to split the large Bloemhof incremental catchment flows into the separate flow records for each of the sub-catchments listed in **Table B.3.4**.

Q_t = naturalised flow as obtained for the large Bloemhof incremental record

MAR_t = MAR of the natural simulated large Bloemhof incremental record

Q_p = required natural flow at the alternative point

MAR_p = MAR of the simulated natural record at the required alternative point

With Q_p = Q_t x MAR_p/MAR_t

The flow records as obtained for the eight sub-catchments within the larger Bloemhof incremental catchment were obtained as described above and used in the modelling of the Integrated Vaal River System.

B.3.4.2Hydrology Updates Affecting the Bloemhof Dam Incremental Record

The sub-catchments affected by the hydrology updates and refinements include the Rietfontein Possible Dam and the C70K quaternary catchment, both located in the Renoster River as well as the Rietspruit and Johan Neser sub-catchments in the Schoonspruit. An incremental record for the Lakeside Dam just downstream of Boskop Dam in the Mooi River was also added for the purpose of this study.

All the natural flow sequences as generated for these sub-catchments in the VRSAU Study were based on a proportion of the naturalised large Bloemhof incremental record. This means that the monthly flow distribution pattern for each year for all these flow sequences are the same as that for the large naturalised Bloemhof incremental record.

As mentioned in **Section B.3.3.1** , the hydrological analysis conducted as part of the VRSAU Study collated, processed and documented information on a quaternary catchment basis. For the purposes of the VRSAU Study yield analysis (**DWAF, 1998b**), however, the WRYM and WRPM were set up representing a simplified modelling of the Renoster River sub-system. For this purpose the hydrological and catchment development information as presented for the individual quaternary catchments (see **Figure K-3** in **Appendix K**) were lumped together to create data sets that are representative for the following sub-catchments:

- **Koppies Dam incremental catchment**: The incremental catchment upstream of Koppies Dam comprising of quaternary catchments C70A, C70B and C70C.

- **Proposed Rietfontein Dam incremental catchment**: The proposed Rietfontein Dam site is situated at the outlet of quaternary C70J. This incremental catchment, therefore, comprises of six quaternary catchments namely C70D, C70E, C70F, C70G, C70H and C70J.

- **Portion of the Bloemhof Dam incremental catchment**: Quaternary catchment C70K was included in the small incremental catchment of Bloemhof Dam.

For the purpose of the detailed Renoster analysis (for assessing the Voorspoed Mine licence) the simulated natural flows for the quaternary catchments within the proposed Rietfontein Dam catchment, as well as for C70K, were included in the WRYM and WRPM systems. This resulted in the reduction of the Bloemhof Dam incremental records (see **Figure K-3** in **Appendix K**).

The Schoonspruit Sub-system's hydrology (developed from the VRSAU Study) was considered to be unacceptable for the purpose of determining the Ecological Reserve as well as to develop catchment management strategies for the Schoonspruit Sub-system. This was due to the monthly distribution patterns that were based on that of the larger Bloemhof Dam incremental catchment as well as the incorrect flows from the Schoonspruit Eye used previously.

The hydrology for the whole of the Schoonspruit was, therefore, redone as part of a different study funded by DWAF (**DWAF, 2006**). The recently developed groundwater model developed by K Sami was also used in the study to calibrate on the observed outflow from the Schoonspruit Eye and to simulate the flow from the eye under natural and developed conditions. The quaternary level based flows for the Schoonspruit from the 2006 study differed significantly from the flows as used in the VRSAU Study and will obviously affect the large and small Bloemhof Dam incremental flow records.

The incremental catchment between Lakeside Dam and Boskop Dam represents only 76.5% of the total catchment area of quaternary C23H (see **Figure K-3** in **Appendix K**). The simulated flow from the VRSAU Study for quaternary C23H was used and scaled down to represent 76.5% of the flow for the total quaternary C23H. Including this incremental catchment also resulted in a small reduction in the runoff of the Bloemhof Dam incremental catchment.

B.3.4.3 Methodology followed in the Re-assessment of the Bloemhof Dam Incremental Catchment Hydrology

The WRSM90 data sets resulting from the VRSAU Study were used to simulate natural flow records for each of the quaternary catchments within the original larger Bloemhof Dam incremental catchment. The naturalised flow record for the original larger Bloemhof Dam incremental catchment was obtained by adding together the incremental flow files for all the sub-catchments located within the larger Bloemhof Dam incremental catchment (see **Table B.3.4**). These two flow records as well as the new flow records for the sub-catchments in the refined Renoster system and the updated and refined Schoonspruit system were used as the basis for the re-assessment of the Bloemhof Dam incremental catchment hydrology. The process followed included the following steps:

- Determine the new reduced larger Bloemhof Dam incremental natural and naturalised flow records. This was undertaken by reducing the original records with the new flows as obtained for the Schoonspruit and Renoster sub-systems.
- Adjust any negative monthly flows that might occur by using a similar approach as followed in the VRSAU Study.
- Sub-divide the new larger Bloemhof incremental catchment naturalised flow record into flow records for the remaining sub-catchments within the new larger Bloemhof Dam incremental catchment.
- Check that the total flow from the new larger Bloemhof incremental catchment still agrees with the total of the original flows.

The process as described above was initially followed. The results from this process, however, showed that the monthly distributions as obtained for most of the sub-catchment flows did not compare well with the simulated natural flows (See **Section 3.4.4** for more detail). This need to be improved and the methodology was adjusted as follows:

- Sub-divide the flow records for each of the sub-catchments into two parts. The first part covering the period 1920 to 1959 and the second part the period 1960 to 1994.
- Use simulated flow for quaternary catchments of the calibrated WRSM90 model setup from the VRSAU Study to produce the natural simulated records of the first part of the record (1920 to 1959).

- Sub-divide the observed naturalised flow record at Bloemhof Dam into monthly flow records for each of the sub-catchments on the basis of the total average monthly flow over the period 1960 to1994 and not on the average annual flow.

Add the two records together for each sub-catchment to obtain a monthly flow record that contains data to cover the total period from 1920 to 1994.

B.3.4.4Re-assessment of the Bloemhof Dam Incremental Catchment Hydrology

The Large Bloemhof Dam incremental catchment as used in the VRSAU Study comprises of a total gross catchment area of 47 027km^2 with a MAR of 689.03 million m^3/a. The flow record for this Large Bloemhof Dam incremental record covers the period 1920 to 1994 hydrological years. The first part of the record from 1920 to 1959 comprises of the simulated natural flow based on the calibration at Bloemhof Dam and the latter period (1960 to 1994) is the observed naturalised flow at Bloemhof Dam.

A summary of the original flows for the sub-catchments within the Large Bloemhof Dam incremental catchment is given in **Table B.3.5**.

Table B.3.5: Summary of previous hydrology (DWAF, 1998a) as used in WRPM & WRYM analyses

Sub-catchment	Gross Area (km^2)	Net Area (km^2)	MAR (million m^3/a)	% of Total MAR
Bloemhof Dam	16,189	13,894	153.69	22.6
Possible Klipbank Dam	7,871	6,765	155.05	22.8
Klipdrift Dam	890	890	21.08	3.1
Possible Kromdraai Dam	2,028	2,028	42.84	6.3
Johan Neser Dam	3,930	2,829	51.68	7.6
Possible Rietfontein Dam	3,605	3,605	60.52	8.9
Rietspruit Dam	1,714	1,714	36.04	5.3
Lower Sand/Vet River	10,800	8,463	159.13	23.4
Total	**47,027**	**40,188**	**680.03**	**100.0**

In order to account for the inclusion of the revised hydrology for the Schoonspruit and Renoster river catchments, the Large Bloemhof Dam incremental catchment was reduced by the following sub-catchments as given in **Table B.3.6**.

Table B.3.6: Sub-catchments to be excluded from the Large Bloemhof incremental catchment

Catchment	Quaternary Catchment	Gross Area (km^2)
Schoonspruit	C24C to C24H	6,484
Renoster	C70D to C70K	4,496
Lakeside Dam in Mooi	0.765*C23H	345
Total including Lakeside	**-**	**11,325**
Total excluding Lakeside	**-**	**10,980**

Note: It was only later in the study that it was decided to create a separate flow record for the Lakeside Dam incremental catchment. For the initial calculations with regards to the new reduced Large Bloemhof Dam incremental catchment, the Large Bloemhof Dam incremental catchment was reduced by only 10 980 km^2 , which excludes the Lakeside Dam incremental catchment.

Two flow records needed to be created for the new reduced Large Bloemhof Dam incremental record. The first record is referred to as the natural simulated flow and the second record as the naturalised flow record. The simulated natural flow record was simply obtained by running the original VRSAU Study calibrated WRSM90 model setup and storing the simulated natural flow records for the relevant quaternary catchments. Results from this analysis are given in **Table** B.3.7.

The naturalised flow record for the reduced Large Bloemhof Dam incremental record was obtained by using the original Large naturalised Bloemhof Dam incremental record and subtracting the new monthly flow records generated for the Schoonspruit and Renoster sub-catchments, as listed in **Table B.3.6**. Negative monthly flows that occurred as part of this process were dealt with by using a similar approach as followed in the VRSAU Study. The MAR for the reduced Large Bloemhof Dam naturalised incremental flow record was determined as 507.19 million m^3/a in comparison with the 680.03 million m^3/a (gross area of 47 027 km^2) for the original Large Bloemhof Dam incremental catchment.

Table B.3.7: Simulated natural flows for new Large Bloemhof Dam incremental catchment

Sub-catchment	Natural Simulated Flow (million m^3/a)	% of the Large Bloemhof incremental	Naturalised Flow (million m^3/a)
Bloemhof incremental	138.1	26.8	135.78
Kromdraai	42.63	8.3	41.92
Klipdrift	20.73	4.0	20.38
Possible Klipbank Dam	155.05	30.1	152.45
Lower Sand/Vet River	159.33	30.9	156.66
New Large Bloemhof incremental	**515.84**	**100.0**	**507.19**

The percentage split of the new Large Bloemhof Dam incremental flow for the sub-catchments given in **Table B.3.7** was used as the basis to subdivide the new Large Bloemhof Dam naturalised flow record. The naturalised flow records obtained in this manner for each of the sub-catchments were produced in a similar way than used in the VRSAU Study. Checks on the average monthly distribution pattern for the individual sub-catchment records however revealed that significant differences were obtained between the monthly distribution patterns of the simulated natural and naturalised flow records. This is as a result of the variation in rainfall patterns and MAP over the New Large Bloemhof incremental catchment. Using the total naturalised flow from the New Large Bloemhof incremental catchment and subdividing it on a percentage based means that the average monthly distribution pattern of this record is carried onto all the sub-catchment flow records.

To overcome this problem the following methodology was used.

- Subdivide the flow records of each of the sub-catchments into two sections. The first part covers the period 1920 to 1959. This period in the Large Bloemhof Dam incremental catchment comprises of simulated natural flow. The simulated natural flow for the particular sub-catchment was then used for the first part of the sub-catchment flow record and thereby conserving the correct monthly distribution for this part of the record (1920 to 1959).

- The second part of the Large Bloemhof Dam incremental record (1960 to 1994) comprises of the observed naturalised flow record. In stead of sub-dividing this record on the percentages based on the annual simulated average flows the percentage based on the average monthly flow was used to be able to conserve the monthly distribution obtained from the simulated natural flow. As this adjustment is only applicable to the 1960 to 1994 part of the record period, the average monthly flows from the simulated natural flow was obtained for this period and used in the calculation.

The improvement in the monthly distribution of the naturalised flow records for the individual sub-catchments can clearly be seen in two examples shown in **Figure B.3.1** and **Figure B.3.2** with month 1 being October.

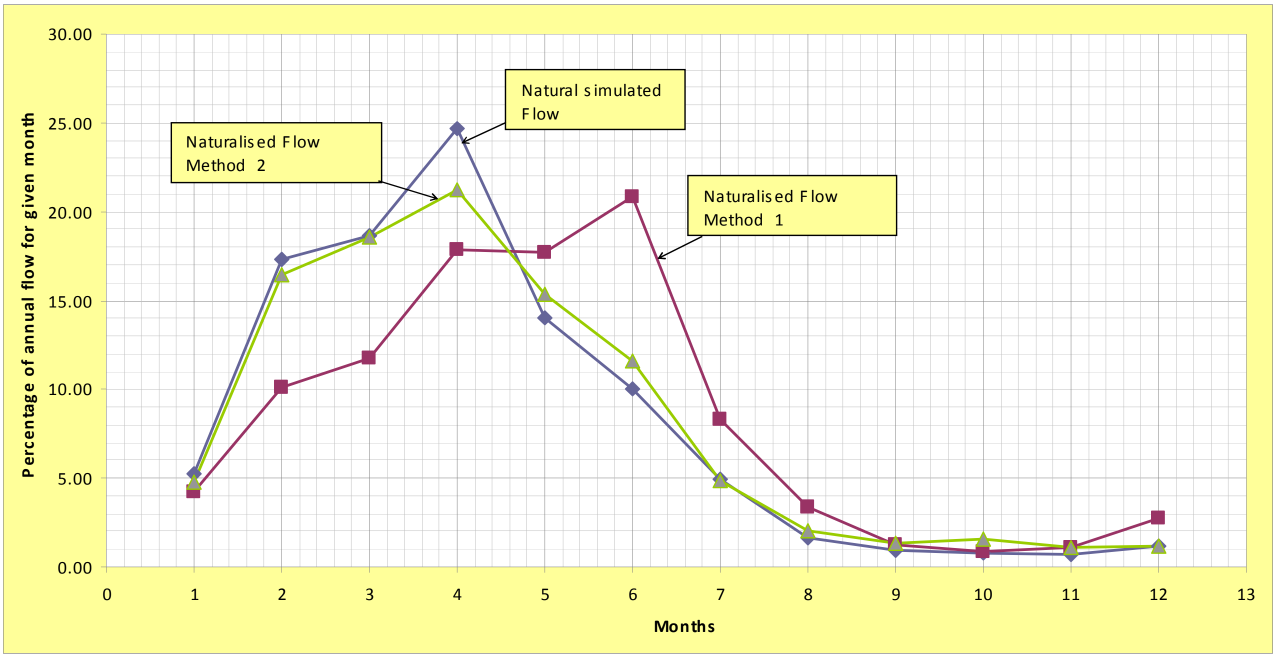


Figure B.3.1: **Monthly flow distribution of three different flow records generated for the Kromdraai sub-catchment**

From **Figure B.3.1** it is clear that the monthly flow distribution as obtained from method 1 (used in the VRSAU Study) is significantly different from the simulated natural flow distribution pattern. The Kromdraai sub-catchment is located in the upper part of the Large Bloemhof incremental catchment just downstream of the Vaal Barrage. The MAP in the Kromdraai catchment is 613 mm/a and in the small Bloemhof incremental catchment only 494 mm/a, which already indicates the difference in the rainfall characteristics that is also evident in the monthly distribution pattern. Using method 2 resulted in a monthly distribution pattern much closer to that of the simulated natural flow record and is therefore much more acceptable for use in the current system analysis.

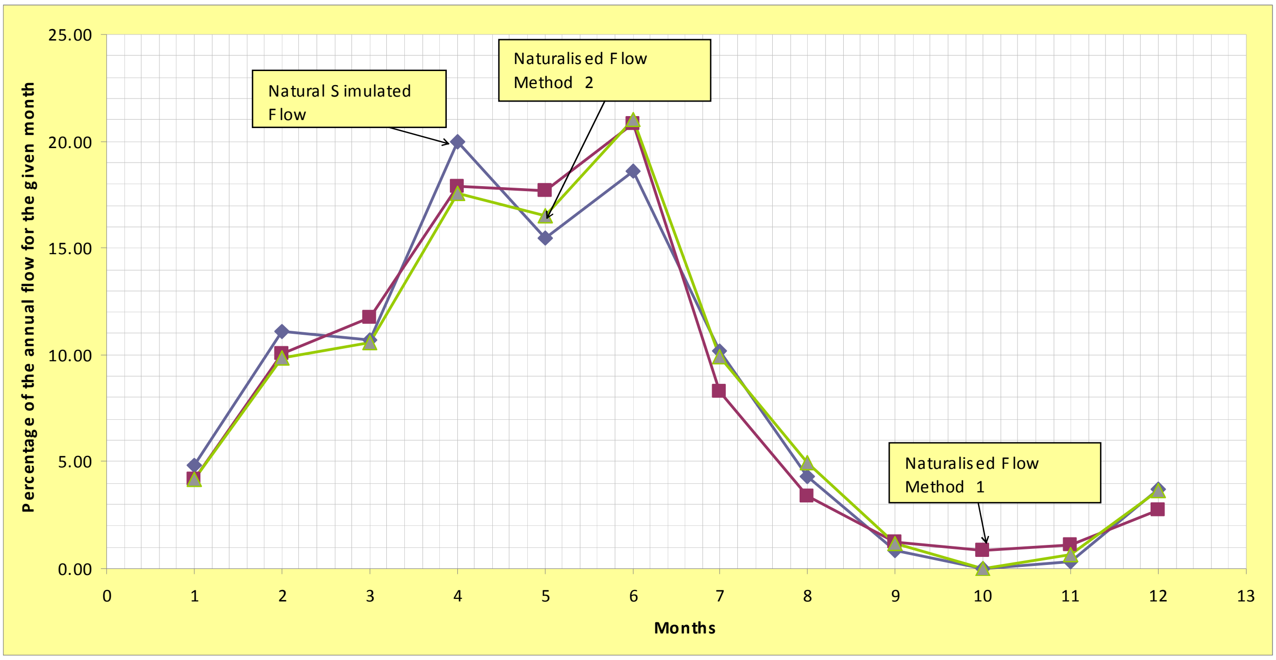


Figure B.3.2: Monthly flow distribution of three different flow records generated for the Lower Sand sub-catchment

From **Figure B.3.2** it can be seen that the monthly distribution pattern for the Lower Sand River sub-catchment does not differ significantly among the three generated flow records. This is most probably due to more similar rainfall characteristics in this area in comparison with most of the lower Bloemhof incremental catchment. It is, however, important to note that method one resulted in a too high base flow in the winter months which has been corrected by using method 2.

This will be of importance in particular when environmental flow requirements need to be determined for this sub-catchment.

Using the second approach a flow record for the incremental Lakeside Dam catchment was also created. This further reduced the area and resulting flow from the remaining small Bloemhof Dam incremental catchment.

B.3.4.5Bloemhof Dam Incremental Catchment Summary of Updated Flow Records

The final natural flow records for each of the sub-catchments as described in **Section 3.4.4** comprises of two distinctive parts. The first part covering the period 1920 to 1959 is obtained from simulated natural flows, generated from the calibrated WRSM90 model. The second part covering the remainder of the simulation period 1960 to 1994 is based on the naturalised record of Bloemhof Dam, which has been sub-divided into the sub-catchments as described in **Section 3.4.4**.

A summary of the characteristics of the final sub-catchment flow records within the Large Bloemhof Dam incremental catchment is given in **Table B.3.8**.

The unit runoff ranges between 9.2mm and 27.1 mm and clearly shows the reduction in runoff as one move towards the western side of the catchment. The MAR for the incremental sub-catchments as obtained for this study decreased in comparison with those obtained from the VRSAU Study. The reason for the reduction is two fold:

- Firstly as result of the reduction in the original Large Bloemhof incremental catchment area due to additional sub-catchments added to the Schoonspruit and Renoster River catchments and were therefore taken away from the Bloemhof incremental catchment and moved to the Schoonspruit and Renoster sub-systems. This applies also to Lakeside Dam incremental catchment in the Mooi River catchment which was previously part of the Bloemhof incremental catchment and is now modelled as separate sub-catchment; and

- Secondly the update of the Schoonspruit catchment resulted in higher flows from the Schoonspruit catchment due to the Schoonspruit Eye flows that was not fully taken into account in the VRSAU Study. If more flow is generated from the Schoonspruit catchment it just implicates that less flow must be generated from the Large Bloemhof Incremental catchment to be able to maintain the water balance at Bloemhof Dam.

Table B.3.8: **Summary of final updated incremental natural flows for sub-catchments within the new Large Bloemhof Dam incremental catchment**

Sub-catchment	File name	Gross Area (km^2)	MAR - 1920-94 (million m^3/a)	Std Dev (million m^3/a)	CV	Unit runoff (mm)
Bloemhof Dam (small)	Bloemn3.inc	14,113	129.27	156.39	1.21	9.2

incremental						
Kromdraai	Kromn3.inc	2,028	40.86	40.91	1.00	20.1
Klipdrift	Klipdn3.inc	890	20.26	23.13	1.14	22.8
Klipbank	Klipbn3.inc	7,871	150.77	149.35	0.99	19.2
Lower Sand/Vet River	Sandn3.inc	10,800	156.60	168.70	1.08	14.5
Lakeside Dam incremental	Lakesn3.inc	345	9.36	7.62	0.81	27.1
New Large Bloemhof incremental		**36,047**	**507.12**			14.1

B.4 CONFIGURATION UPDATES OF SELECTED SUB-SYSTEMS

B.4.1 SCHOONSPRUIT SUB-SYSTEM

B.4.1.1 Background

The configuration of the WRPM for the Integrated Vaal River System (IVRS) used for the Annual Operating Analysis (**DWAF, 2007**) and the First Stage Reconciliation Strategy contained a simple representation of the Schoonspruit sub-system infrastructure and hydrology (refer to **Figure A-5** of **Appendix A**) . A more detailed representation in the form of a Water Resources Yield Model (WRYM) set-up was available from the Schoonspruit Sub-System Analysis Study (**DWAF, 2006**). Updating of the WRPM has involved the incorporation of the WRYM set-up and adjustment of salt parameters to maintain the previously defined salt balance of the sub-system at specified locations. A summary of significant changes is given in the sections below and the updated model configuration is shown in **Figure J-5** of **Appendix J**.

B.4.1.2 Infrastructure and WRPM configuration

The original WRPM configuration contained three reservoir nodes representing Rietspruit Dam, Johan Neser Dam and a so-called dummy dam representing the accumulation of storage in farm dams for the catchment between Rietspruit and Johan Neser dams. The updated WRPM configuration has been expanded to include a representation of the storage in the Kalk and Elandskuil dams. The combined farm dam storage has been disaggregated into five individual units representing a new configuration of catchments detailed in the section on catchment hydrology.

The original WRPM includes a simplified linkage between storage and demand. Within the updated model this has been enhanced by an explicit representation of conveyance structures such as canals.

B.4.1.3 Catchment hydrology

Details of the updated Schoonspruit hydrology incorporated into the WRPM database can be found in **Section B.3.2**. Catchment runoff within the original model consisted of three sub-divisions of the Schoonspruit basin referenced to two sets of hydrological time series (Riets9 and Neser9). This has been increased to eleven sub-divisions referenced to five sets of hydrology (C24D, C24E, C24F, C24G, C24H). Outflow from Schoonspruit Eye is now modeled explicitly by a specified inflow (refer to WRPM Channel 1668 on **Figure J-5** of **Appendix J**) with an average of 47.9 million m^3/a. For the purposes of the WRPM configuration it was necessary to create a time series file representing the outflows from the eye over the period 1920 to 2050. Consequently the average monthly flows were calculated based on the historic record period and these monthly averages were then adopted to create the time series file EYECURF.FLO. The associated TDS concentrations were set at 252 mg/l and were specified in the time series file EYECURF.TDS.

Modifications to the representation of outflows from Schoonspruit Eye and the re-calibration of catchment hydrology have resulted in changes to the inflow to Rietspruit and Johan Neser dams both in terms of magnitude and monthly variation.

Details of the updated hydrology can be found in **Section B.3.2**. **Figure B.4.1** compares the inflow for Johan Neser Dam resulting from the original and updated models. The disaggregation of runoff into a larger number of sub-catchments has caused changes to the variability of annual runoff although the overall trend remains consistent with the original model's hydrology.

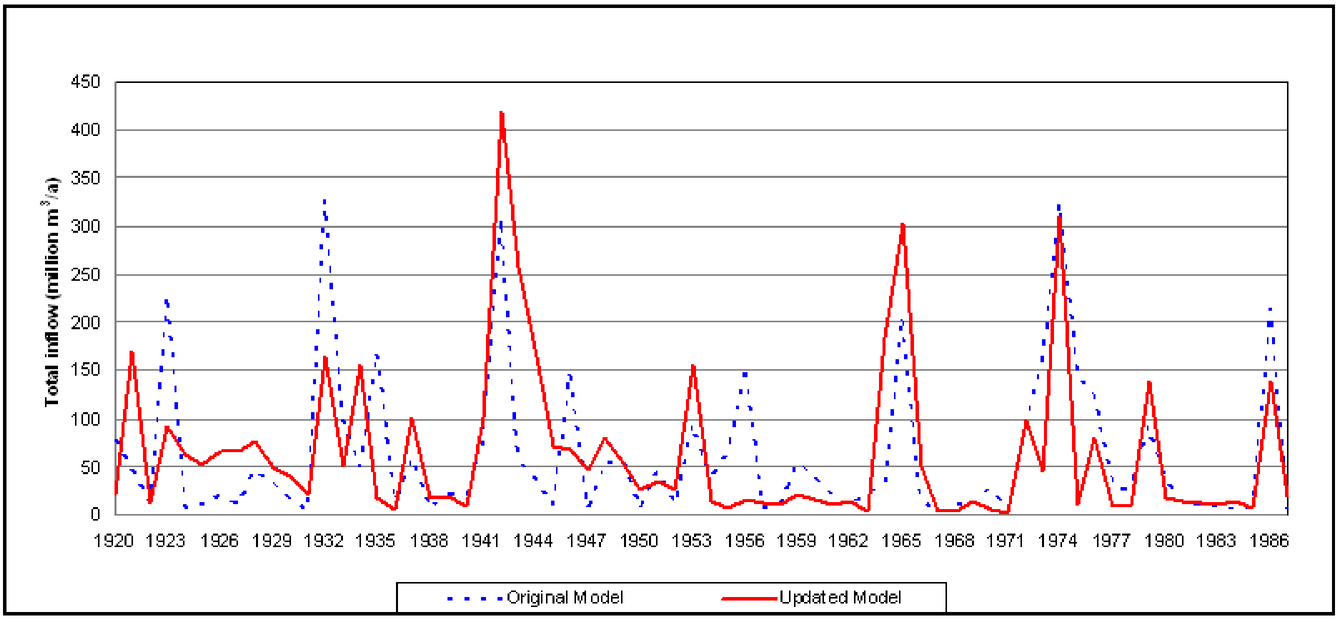


Figure B.4.1: Comparison of modelled inflow to Johan Neser Dam

B.4.1.4Demands and return flows

Demands in the original sub-system comprised three irrigation modules supplied directly from storage with one run-of-river abstraction. In the updated sub-system one additional irrigation module has been added which is supplied from storage and six run-of-river irrigation abstractions. All irrigation demands in the original and updated models include return flows. Information on the irrigation water requirements and return flows are provided in **Section B.5.2.3** .

A run-of-river abstraction to supply the urban demand within the small town of Ventersdorp has also been included in quaternary catchment C24E. Ventersdorp is the only urban abstraction from the Schoonspruit with a relatively small water use of 1.5 million m^3/a in 2002/2003. It was assumed that 50% of the Ventersdorp demand will return to the Schoonspruit as effluent. The water requirements of Klerksdorp are supplied by Midvaal Water Company, but the treated effluent is discharged back into the Schoonspruit River downstream of Johan Neser Dam. The Klerksdorp water demands are, therefore, included in the Midvaal water requirement projections discussed in **Section B.5.6.4**. The treated effluent from the Klerksdorp Waste Water Treatment Works (WWTW) entering the Schoonspruit River in quaternary catchment C24H amounted to 6.72 million m^3/a for the year 2002/2003.

Furthermore, the updated WRPM configuration accounts for the losses (average of 17.15 million m^3/a) and attenuating effects (average of 4.41 million m^3/a) of wetlands upstream of Johan Neser Dam which were absent from the original model configuration. Since these impacts are modelled by means of time series files, it was necessary to create representative time series files covering the period 1920 to 2050. To this end, the average monthly values, calculated from the historic time series files extending over the period 1920 to 1994, were used to create the files WETF.DEM and WETF.LAG representing the wetland losses and attenuating effects respectively.

B.4.1.5Salt loads

Salt loads are determined from catchment salt washoff, return flows from irrigation and wastewater treatment works. Salt concentrations throughout the sub-system are then altered by the magnitude of river flow and the operation of storage and demands.

The number and location of salt washoff modules reflects the number and distribution of catchment hydrological inputs. This has increased from three in the original model to eleven in the updated model. Irrigation return flows have increased from four to eleven with two new return flows from urban areas. As mentioned previously the number of storage bodies has increased from three to nine. A Total Dissolved Solids (TDS) concentration of 252 mg/l was associated with the outflow from the Schoonspruit Eye.

Given these changes to the configuration of the sub-system, salt loads have needed adjustment to maintain the same quantity of salts simulated by the original model. The inflow point to Johan Neser Dam was chosen as a calibration point for an assessment of required adjustments.

The required adjustments included changes to the parameters describing salt load and initial salt concentration within irrigation modules. Parameters within salt washoff modules retained the same values as those used in the original model. Initial salt storage and recharge rates are expressed in mass per unit area and are therefore applicable regardless of an area's disaggregation. Other parameters such as salt washoff efficiency and infiltration are proportional amounts and are not influenced by area.

With adjustments to the updated model it has been possible to re-produce the original model's simulated mean annual salt load flowing into Johan Neser Dam to within four percent. **Figure** B.4.2 compares the salt loads from the original and updated models entering Johan Neser Dam. The revised salt load parameters are summarised in **Table B.4.1**.

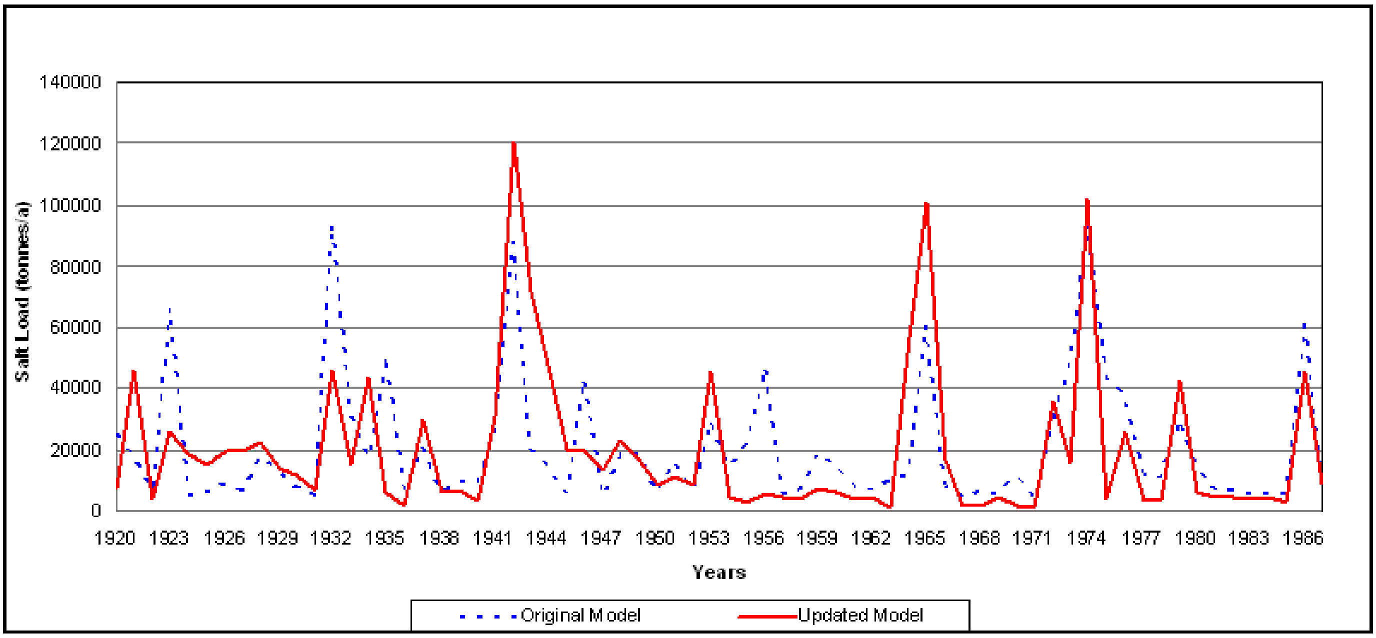


Figure B.4.2: Comparison of modelled salt loads flowing into Johan Neser Dam

Table B.4.1: Revised salt load parameters for Schoonspruit Sub-system irrigation

Catchment	Source of Supply	WRPM Irrigation Module Number	Return Flow Factor	Deep Percolation Factor	Salt Loss to Deep Storage Factor
C24D	Rietspruit Dam	RR529	0.0480	3.0	0.0028
C24E	Canal	RR525	0.0498	3.0	0.0032
	Run-of-river	RR442	0.0498	3.0	0.0032
C24F	Farm dams	RR533	0.0000	6.0	0.0120
	Run-of-river	RR534	0.0000	6.0	0.0150
C24G	Run-of-river	RR539	0.0045	6.0	0.0255
	Farm dams	RR447	0.0494	3.0	0.0157
	Run-of-river	RR446	0.0495	6.0	0.0222
C24H	Johan Neser Dam	RR452	0.0163	6.0	0.0214
	Canal	RR542	0.0100	6.0	0.0243
	Run-of-river	RR540	0.0356	6.0	0.0153
	Run-of-river	RR457	0.0630	6.0	0.0174

Note: Other significant salt parameters are constant

B.4.2 RENOSTER SUB-SYSTEM

B.4.2.1 Background

The configuration of the WRPM adopted for the Integrated Vaal River System Annual Operating Analysis (**DWAF, 2007**) contained a simplified representation of the Renoster sub-system infrastructure and hydrology. A more detailed representation of the catchment was included in the WRYM configuration that was used for the assessment of the assurance of bulk water supply to the proposed Voorspoed Diamond Mine (**DWAF, 2005**). The detail of the WRYM has been incorporated into the WRPM as part of the Second Stage Strategy and salt parameters were adjusted to maintain the previously defined salt balance at the outlet of the sub-system. A summary of significant changes is given below and the refined Renoster configuration is shown in **Figure J-5** of **Appendix J**.

B.4.2.2 Infrastructure and WRPM configuration

Infrastructure represented in the original WRPM consisted of Koppies Dam, the proposed Rietfontein Dam and an accumulation of farm dams in two dummy dams. For the incremental catchment upstream of Koppies Dam the basic configuration of the updated WRPM remains the same as that of the original model. However, changes have been implemented in the catchment downstream of Koppies Dam where farm dam storage between Koppies Dam and the site of the proposed Rietfontein Dam has been disaggregated into five dummy dams instead of one, and an additional dummy storage dam has been positioned in the catchment between the proposed Rietfontein Dam and the sub-system outlet (i.e. within quaternary catchment C70K). This conforms to the more detailed scale of catchment hydrology described in **Section B.3.3** and outlined below. Operation of the proposed storage at Rietfontein Dam has not been implemented in the updated model.

B.4.2.3 Catchment hydrology

The catchment hydrology of the original model comprised four sub-divisions referenced to two sets of hydrological time series (KOP9, RIETF9). This configuration has been increased to 16 sub-divisions referenced to eight sets of hydrology (C70ABC, C70D, C70E, C70F, C70G, C70H, C70J, C70K). Details of the updated hydrology can be found in **Section B.3.3**. **Figure B.4.3** compares the hydrology at the sub-system outlet from the original and updated models.

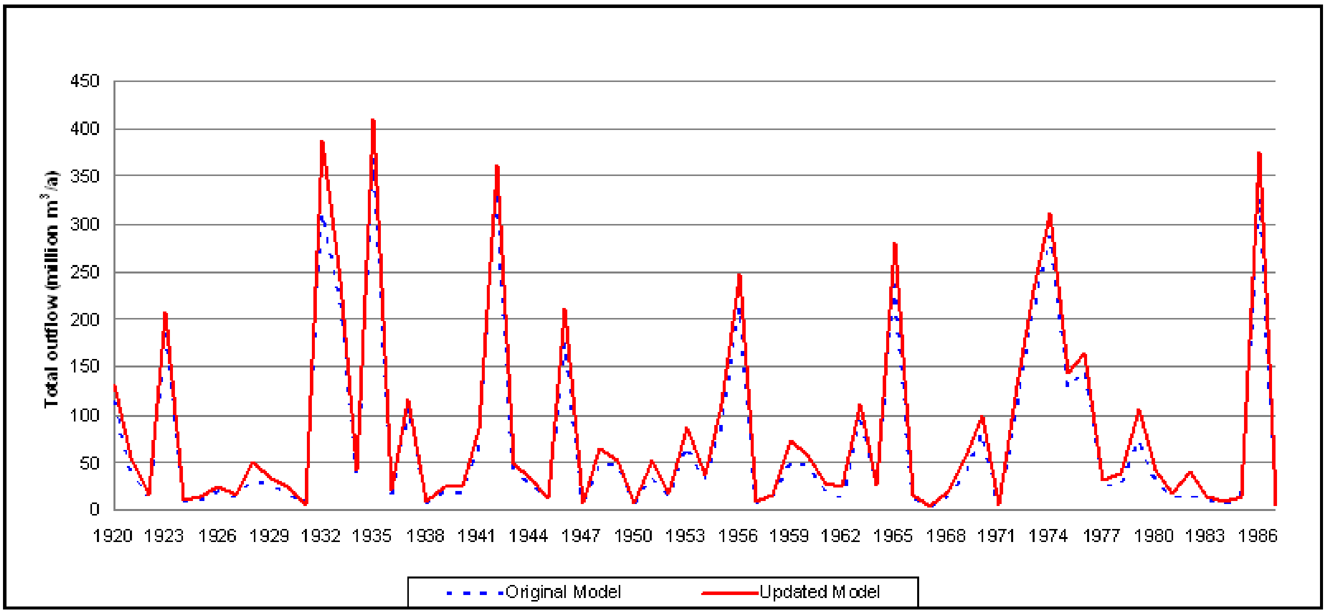


Figure B.4.3: **Comparison of modelled outflow from the Renoster sub-system**

From the results shown in **Figure B.4.3** it is evident that, despite the increased disaggregation of the river basin, the pattern of outflow from the sub-system remains consistent with the original model.

B.4.2.4Demands and return flows

Demands in the original sub-system comprised four irrigation abstractions two of which are supplied directly from storage and two from run-of-river off-takes. In the refined sub-system configuration irrigation demands have been defined in greater detail with the addition of fourteen off-takes making a total of eighteen irrigation demands. Owing to the magnitude of the individual irrigation demands, only twelve irrigation modules were configured to facilitate proper modelling of the water quality downstream of these irrigation areas. Since the remaining six irrigation demands were relatively small, the impact thereof on the water quality was considered to be insignificant. The net demands of these small irrigation areas were modelled as abstractions from the relevant water resources. Detail information on the irrigation water requirements and return flows is provided in **Section B.5.2.3**.

There are five towns within the Renoster River catchment. Only two of the towns, Koppies and Viljoenskroon abstract water from the Koppies Dam and Renoster River respectively. The other three towns, Edenville, Petrus Steyn and Heilbron depend on groundwater and/or obtain water from external sources. The water requirements of Heilbron Town are supplied from Rand Water. The urban demand of Koppies Town supplied from Koppies Dam and amounting to 0.97 million m^3/a in 2007, has been retained in the updated model. Provision for the supply of water to Voorspoed Mine and Viljoenskroon has been included in the updated model. A water requirement of 2.64 million m^3/a was adopted for Voorspoed Mine and conveyance losses were assumed to be in the order of 50%. Viljoenskroon Town has a permit to abstract up to 1.94 million m^3/a from the Renoster River if available. The town's abstraction is not supported by releases from Koppies Dam and in times of shortages in the Renoster River, the town must pump water from the Vaal River as a second source of supply. The demand for Viljoenskroon to be supplied from the Renoster River was, however, set to zero as this demand has already been included in the lumped urban demand projection for small towns in the Middle Vaal catchment (refer to WRPM channel number 117 in **Figure J-5**). River and canal losses (estimated at 20% and 25% respectively) associated with the supply of urban and irrigation demands from Koppies Dam have also been incorporated in the updated model.

Return flows have been implemented for all but six of the relatively small irrigation demands. As mentioned above, the magnitude of these six demands does not warrant the simulation of return flows by means of irrigation modules. Heilbron Town returns treated effluent into the Renoster catchment upstream of Koppies Dam. These return flows are, however, subject to losses and usage by farmers along the river. It was, therefore, assumed that only 50% of the Heilbron return flow, amounting to 0.27 million m^3/a, could be considered as inflow to Koppies Dam.

B.4.2.5Salt loads

Salt loads are determined from catchment salt washoff and return flows from irrigation. There are no wastewater treatment works within this sub-system. Salt concentrations are altered by the magnitude of river flow and the operation of storage and demands.

The number and location of salt washoff modules reflects the number and distribution of catchment hydrological inputs. This has increased from two in the original model to eight in the updated model. Irrigation return flows have increased from four in the original model to twelve in the new model in addition to the return flow from the Heilbron urban area. The TDS concentrations associated with the Heilbron return flows were assumed to be equal to that of the urban areas within the Vaal Dam catchment. As mentioned previously the number of storage bodies has doubled from three to six in addition to the proposed storage at Rietfontein.

Changes to the configuration of the sub-system have required an adjustment to salt loads to maintain the same outflow of salt as that simulated by the original model. The outlet of the sub-system was chosen as a calibration point for an assessment of the required adjustments.

The required adjustments included changes to the parameters describing salt load and initial salt concentration within irrigation modules. Parameters within salt washoff modules retained the same values as those used in the original model. Initial salt storage and recharge rates are expressed in mass per unit area and are therefore applicable regardless of an area's disaggregation. Other parameters such as salt washoff efficiency and infiltration are proportional amounts and are not influenced by area.

With adjustments to the updated model it has been possible to re-produce the original model's simulated mean annual salt load flowing out of the sub-system to within four percent. **Figure B.4.4** compares the salt loads from the original and updated models flowing out of the Renoster Sub-system. The revised salt load parameters for irrigation are summarised in **Table B.4.2**.

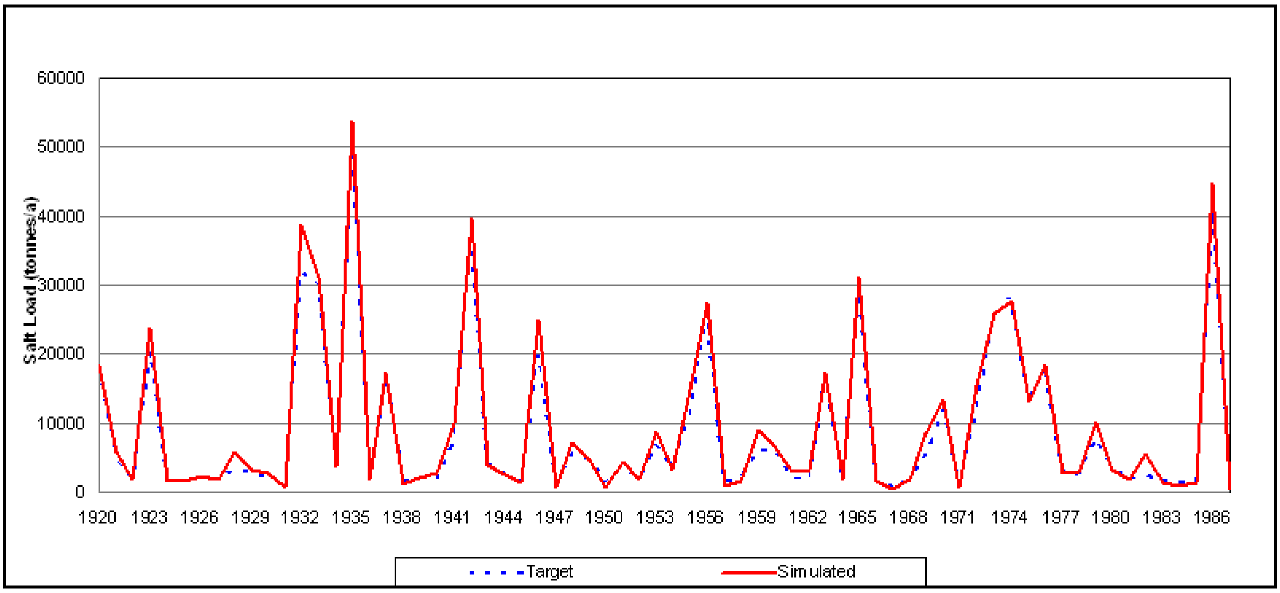


Figure B.4.4: Comparison of modelled salt loads flowing out of the Renoster Sub-system

Table B.4.2: Revised Salt Load Parameters for Renoster Sub-system Irrigation

Catchment	Source of supply	WRPM Irrigation Module Number	Return Flow Factor	Deep Percolation Factor	Salt Loss to Deep Storage
C70ABC (KOP9)	Farm dams Run-of-river	RR15 RR16	0.0240 0.0265	3.0 3.0	0.0058 0.0077
C70D	Farm dams Run-of-river Koppies Dam: Canal Koppies Dam: River	RR33 RR34 RR32 RR31	0.0000 0.0000 0.0290 0.0320	6.0 6.0 6.0 6.0	0.0120 0.0150 0.0200 0.0230
C70E	Farm dams	RR36	0.0070	6.0	0.0165
C70F	Farm dams Run-of-river	RR35 RR18	0.0000 0.0230	6.0 6.0	0.0150 0.0255
C70H	Farm dams	RR40	0.0600	6.0	0.0200
C70J	Farm dams	RR17	0.0000	6.0	0.0150
C70K	Farm dams	RR42	0.0710	3.0	0.0000

B.4.3 MOOI SUB-SYSTEM

B.4.3.1 Background

The configuration of the WRPM for the Vaal River System Annual Operating Analysis (**DWAF, 2007**) contained a detailed representation of the Mooi sub-system infrastructure and hydrology. Updating of the WRPM has involved only minor changes to the existing model set-up and adjustment of salt parameters to maintain the previously defined salt balance of the sub-system at specified locations. A summary of significant changes is given below and the updated system configuration is shown in **Figure J-5** of **Appendix J**.

B.4.3.2 Infrastructure and WRPM configuration

The Mooi Sub-system originally comprised of the Mooi River catchment upstream of Boskop Dam. However, in practice Klerkskraal, Boskop and Lakeside dams are being operated as a sub-system. One of the significant changes to the original WRPM set-up adopted for the First Stage Strategy (refer to **Figure A-5** of **Appendix A**) has, therefore, been the addition of Lakeside Dam which is located downstream of Boskop Dam. Abstractions for Potchefstroom Municipality are made from Lakeside Dam (also known as Potchefstroom Dam) and the dam also provides water for agricultural irrigation. Furthermore, since Lakeside Dam is used for recreational purposes, it has to be maintained at a reasonably high storage level. Releases are, therefore, made from Boskop Dam to ensure that Lakeside Dam is operated at a storage level of 90%. Refinements were also made in terms of the explicit modelling of the outflow from the Gerhardminnebron Eye and the Gerhardminnebron irrigation abstractions. The representation of storage in Klerkskraal Dam, Boskop Dam and the dummy storage dam for farm dams in the incremental catchment of Boskop Dam (i.e. the Boskop Dummy Dam) remained unchanged. For the Second Stage Strategy the Mooi Sub-system has, consequently, been redefined as the Mooi River catchment upstream of Lakeside Dam (refer to **Figure J-5** of **Appendix J**).

B.4.3.3 Catchment hydrology

The Mooi River catchment hydrology has been changed to include an additional hydrology set that is representative of the natural runoff from the Lakeside incremental catchment. The original model consisted of four sub-divisions of the Mooi River basin referenced to two sets of hydrological time series (KLERK9, BOSK9). This has been increased to five sub-divisions referenced to three sets of hydrology (KLERK9, BOSK9, LAKESN3). An assessment had to be made of the natural runoff from the Lakeside incremental catchment which had originally been part of the Large

Bloemhof Dam incremental catchment. The calculation of the Lakeside hydrology is discussed in **Section B.3.4**.

Figure B.4.5 compares the Mooi Sub-system hydrology from the original and updated models just downstream of Lakeside Dam. Changes to hydrology, demands and the inclusion of additional storage have altered the magnitude of flow reaching the sub-system outlet (i.e. the Mooi River just downstream of Lakeside Dam). These changes have not had a significant impact on the annual variability of flow which remains consistent with that of the original model.

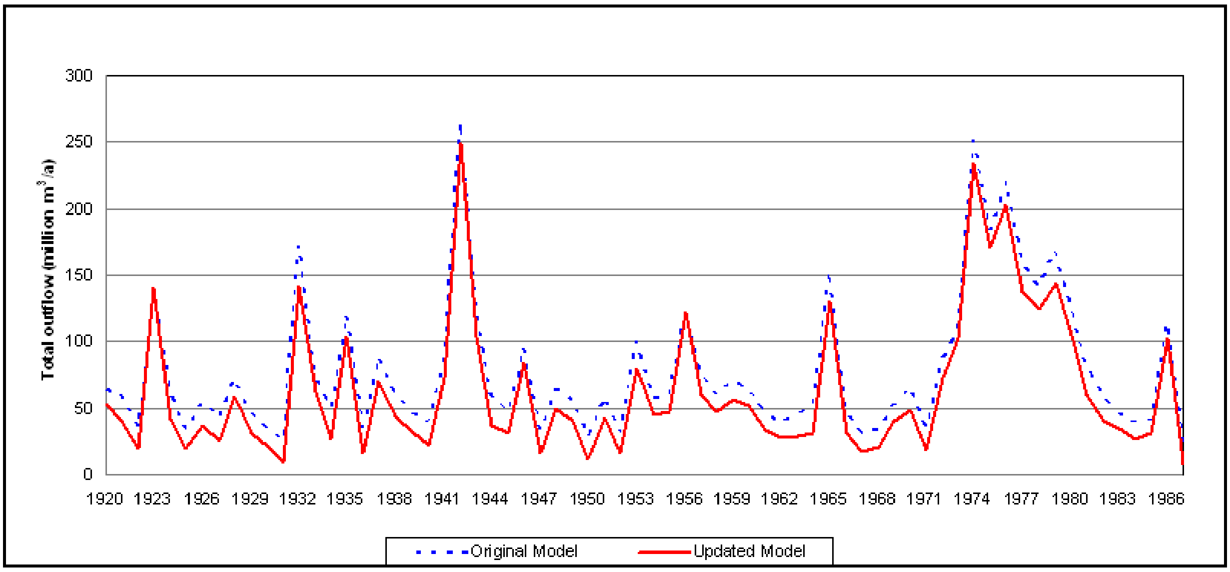


Figure B.4.5: **Comparison of modelled outflow from the Mooi Sub-system**

B.4.3.4Demands and return flows

The original sub-system model contained six irrigation demands and the Potchefstroom urban demand. In the updated sub-system an irrigation demand on Lakeside Dam was added, but the number of irrigation demands remains unchanged. The major change was, however, that the irrigation abstractions are now being modelled by means of irrigation modules. The urban demand of Potchefstroom that was supplied from Boskop Dam has now been moved to Lakeside Dam. The Potchefstroom demand, found to be 12.55 million m^3/a at the 1994 development level, is abstracted through WRPM channel number 104, whilst the growth in demand over and above this amount, is supplied through channel number 921.

The only irrigation return flow modelled by the original model was for a demand supplied from the Boskop Dummy Dam. With the exception of two diffuse irrigation demands (refer to abstractions through WRPM channels 1014 and 1018) all irrigation demands are modelled with return flows in the updated model. Return flows from urban areas and outflows resulting from mine dewatering remained unchanged.

Furthermore, the original and updated models are consistent in their representation of river bed losses in the incremental catchment upstream of Boskop Dam.

Information on the irrigation water requirements and return flows can be found in **Section B.5.2.3**.

B.4.3.5Salt loads

Salt loads are determined from catchment salt washoff and return flows from irrigation and wastewater treatment works in urban areas. Salt concentrations throughout the sub-system are then altered by the magnitude of river flow and the operation of storage and demands.

The number and location of salt washoff modules reflects the number and distribution of catchment hydrological inputs. It has been noted that the number of hydrological inputs has increased from four in the original model to five in the updated model. The main change occurred downstream of Boskop Dam. More significant are the changes to the number of irrigation return flows which have increased from one to five. Urban and mine water return flows remain unchanged. The number of storage bodies has increased from three to four through the addition of Lakeside Dam.

Given the changes to irrigation return flows and the addition of Lakeside Dam downstream of Boskop Dam, salt loads have required adjustment to maintain the same quantity of salts flowing out of the sub-system as simulated by the original model. Outflow from the sub-system was chosen as a calibration point for the assessment of required adjustments.

The required adjustments included changes to the parameters describing salt load and initial salt concentration within irrigation modules. Whereas parameters used by salt washoff modules retained the same values as those input to the original model, initial salt storage and recharge rates are expressed in mass per unit area and are therefore applicable regardless of an area's disaggregation. Other parameters such as salt washoff efficiency and infiltration are proportional amounts and are not influenced by area.

With adjustments to the updated model it has been possible to re-produce the original model's simulated mean annual salt load flowing out of the sub-system to within eight percent. The comparison of simulated salt loads downstream of Lakeside Dam is shown in **Figure B.4.6.**

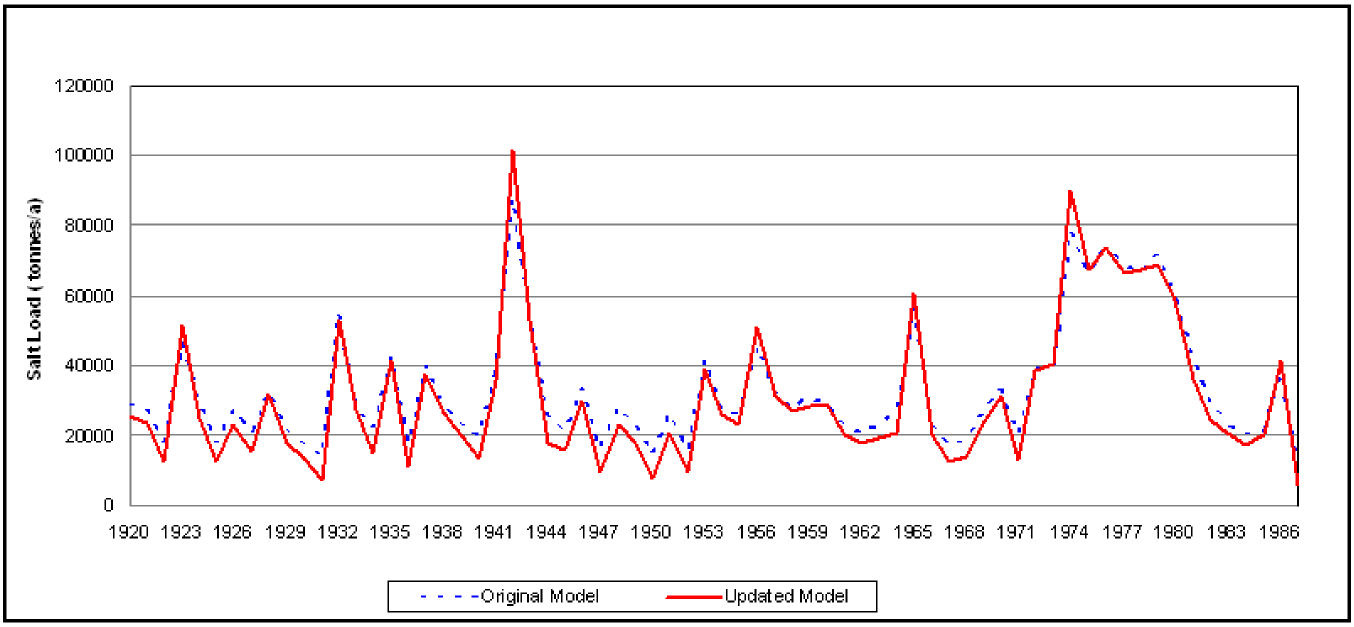


Figure B.4.6: **Comparison of modelled salt loads flowing out of the Mooi Sub-system**

The revised salinity parameters are summarised in **Table B.4.3**.

Table B.4.3: **Revised Salt Load Parameters for the Mooi Sub-system Irrigation**

Supply Source	WRPM Irrigation Module Number	Return Flow Factor	Deep Percolation Factor	Salt Loss to Deep Storage
Klerkskraal Dam	RR550	0.0020	5.0	0.0266
Boskop Dummy Dam	RR551	0.0034	5.0	0.0988
Gerhardminnebron canal	RR554	0.0020	5.0	0.0266
Boskop Dam	RR552	0.0060	6.0	0.0195
Lakeside Dam	RR553	0.0056	6.0	0.0192

Note: Other significant salt parameters are constant.

B.4.4 WATERVAL CATCHMENT

B.4.4.1 Background

The Waterval River is a tributary of the Vaal River upstream of the Vaal Dam. As part of the VRSAU Study, the Waterval catchment, which comprises of four quaternary catchments (C12D, C12E, C12F and C12G), was included in the Vaal incremental sub-catchment (referenced as VAAL9). The Vaal incremental sub-catchment lies upstream of Vaal Dam and downstream of Delangesdrift weir, Frankfort weir and Grootdraai Dam. It has an incremental catchment area of 10 792 km^2. However, owing to various urban and industrial activities that occur within the Waterval catchment, it was required to monitor the water quality associated with the outflow from the Waterval catchment. To this end, the WRPM configuration of the Vaal incremental sub-catchment was refined to explicitly represent the physical infrastructure of the Waterval catchment (refer to **Figure J-1** of **Appendix J**). The refinement of the Vaal incremental sub-catchment is described in the following sections.

B.4.4.2 Catchment development and WRPM configuration

Although there are no major impoundments in the Waterval River catchment, there are a number of smaller dams (farm dams) scattered throughout the catchment. Irrigation supported from these farm dams, as well as irrigation supplied from direct river abstractions (mainstream irrigation) are present in the Waterval River catchment. Apart from the irrigation abstractions, there are no other significant abstractions in this catchment. Industrial and urban return flows in the Waterval River catchment comprise inter-basin water transfers and effluent discharges from different centres within the catchment (refer to **Section B.4.4.4** for details). The impact of urbanisation (increased runoff due to paved/impervious urban areas) was also taken into account. These catchment developments and infrastructure were included in the WRPM configuration shown in **Figure J-1** of **Appendix J**

The area-capacity characteristics of the small dams (farm dams) situated in the Vaal incremental sub-catchment were originally combined to represent the characteristics of a single storage unit referred to as the Vaal Dummy Dam (Original WRPM Node 202). To enable realistic modelling of the Waterval catchment, it was necessary to set up a dummy dam with area-capacity characteristics that would represent all the small dams located within the Waterval catchment. Consequently, the characteristics of the Vaal Dummy Dam had to be adjusted accordingly. The information required to do this was obtained from the detailed water quality calibration database compiled as part of the VRSAU Study. The area-capacity characteristics of the resulting two dummy dams are provided in **Table B.4.4**.

Table B.4.4: Area-capacity characteristics of Waterval and Vaal dummy dams

New Waterval Dummy Dam (Node 557)			Adjusted Vaal Dummy Dam (Node 202)		
Level (m)	Storage (million m^3)	Surface Area (km^2)	Level (m)	Storage (million m^3)	Surface Area (km^2)
1490.0	0.000	0.000	1490.0	0.000	0.000
1490.5	1.542	0.963	1490.5	2.007	1.814
1491.0	6.771	4.248	1491.0	8.813	8.005
1491.5	9.801	6.157	1491.5	12.756	11.602
1492.0	15.277	9.612	1492.0	19.882	18.112
1492.5	19.892 (#)	10.832	1492.5	22.281 (#)	19.675

Note: (#) Full Supply Capacity of each dummy dam

B.4.4.3Catchment hydrology

The hydrology of the Vaal incremental sub-catchment (reference VAAL9) was not changed. However, the routing of the natural runoff from the catchment had to be adjusted to allow for the inclusion of the Waterval River. To this end, two additional Salt Washoff modules (SW556 and SW559) were included and the configurations of existing Salt Washoff modules were adjusted accordingly. The revised information is summarised in **Table B.4.5**.

Table B.4.5: **Runoff definitions for the Vaal incremental sub-catchment**

Description	WRPM node number	% of runoff routed through node	Salt Washoff Configuration	
			Reference Number	Catchment area (km^2)
Waterval Dummy Dam	557	6.2	556	662.7
Waterval Upper Node	555	8.3	71	901.0
Waterval Lower Node	560	7.2	559	771.5
Vaal Dummy Dam	202	31.3	10	3382.7
Vaal Node	205	47.0	8	5074.1
Total:	**-**	**100**	**-**	**10 792**

B.4.4.4Water requirements and return flows

The original configuration of the Vaal incremental sub-catchment included irrigation abstractions modelled by means of four irrigation modules. Two of these irrigation modules (RR1786 and RR1787) represent the unlawful irrigation abstractions that were identified as part of the Upper Vaal WMA Validation Study. For the purposes of defining the irrigation modules of the Waterval catchment, it was assumed that there is no unlawful irrigation water use within this catchment. An irrigation module abstracting water from the Waterval dummy dam (RR558) was set up based on the characteristics of the Vaal dummy dam's lawful irrigation module (RR13). Similarly, the configuration of the lawful mainstream irrigation module (RR14) was used for setting up the Waterval mainstream irrigation module (RR561).

Since the original Waterval irrigation modules were modelled separately during the water quality calibrations of the VRSAU Study, this detailed information was used to determine the proportions of the individual irrigation areas relative to the total irrigated area. These ratios were then applied to the updated irrigation areas that were derived as part of this study. Information relative to the newly defined Waterval irrigation modules, as well as the adjusted Vaal incremental sub-catchment irrigation modules, is provided in **Table B.4.6.**

Table B.4.6: **Information on Waterval and Vaal incremental sub-system irrigation modules**

Description	Irrigation Module No.	Abstraction Channel No.	Return Flow Channel No.	Irrigation Area (km^2)
Waterval Dummy Dam	RR558	1318	1321	10.586
Vaal Dummy Dam	RR13	770	771	0.172
Total for dummy dams:	**-**	**-**	**-**	**10.758**
Waterval Mainstream	561	1323	1325	14.269
Vaal mainstream	14	772	773	17.940
Total for mainstream:	**-**	**-**	**-**	**32.209**

Information on the industrial and urban return flows discharged into tributaries of the Waterval catchment and their associated TDS concentrations is summarised in **Table B.4.7**. The information provided in **Table B.4.7** was updated as part of this study and was based on the most recent observed data. It should be noted that the urban return flows entering the Vaal incremental sub-catchment (WRPM Channel 879) are simulated by the WRPM and only the associated TDS concentrations need to be specified. Consequently it was only necessary to update the TDS concentrations included in the file VAURBAN.TDS. This was done by using the observed TDS results of the Standerton WWTW.

Table B.4.7: **Urban and industrial return flows within the Waterval catchment**

Return Flow Centre	WRPM Channel No.	Return Flow (million m^3/a)	TDS Concentration (mg/l)	File associated with discharges
Embalenhle Township	1306	4.32	400	WAURBAN.Q
Nthorwae	1306	0.24	226	WAURBAN.Q
Evander	1306	1.8	310	WAURBAN.Q
Lesley	1306	0.36	320	WAURBAN.Q
Sasol Secunda (Industrial)	1306	2.64	380	WAURBAN.Q
Sasol (Urban)	1357	4.20	320	SASOL.Q
Seepage from Grootvlei Mine	774	0.12	-(1)	SEEPWA.Q
Total :	**-**	**13.68**	**-**	**-**

Note: (1) Varies between 1143 and 120608 mg/l.

B.5 WATER REQUIREMENTS AND RETURN FLOWS

B.5.1 INTRODUCTION

This chapter describes the water requirements and return flow scenarios that were developed as part of the Second Stage Strategy. The approach adopted for the presentation of the water requirement and return flow information is to reference the detail reports, as well as **Part A** of this report, where applicable and to provide a summary of the data finally accepted for inclusion in the WRPM scenario configurations. The information is presented according to the following headings:

- Irrigation water requirements **(Section B.5.2).**
- Bulk industrial water requirements **(Section B.5.5).**
- Urban water requirements and return flows **(Section B.5.6).**
- Summary of the water requirement and return flow scenarios **(Section B.5.7).**

B.5.2 IRRIGATION WATER REQUIREMENTS

B.5.2.1 Methodology adopted for irrigation modelling within the WRPM

Part A of this report presents the details of the methodologies that have been used in the past and in the First Stage of this study to simulate irrigation requirements. To summarise, these are as follows:

- 1999: Irrigation water requirements simulated as irrigation modules using results of VRSAU study (water quality considered);
- 1999: Loxton Venn Study produced updated irrigation demands (volumetric) for catchments upstream of Bloemhof Dam;
- 2000-2006: Irrigation water requirements upstream of Bloemhof Dam as determined by Loxton Venn study simulated as fixed annual net demands (water quality not considered);
- 2007: Update of irrigation demands as part of Vaal Reconciliation Study, information from validation study used for Upper Vaal, discussions with stakeholders used to determine most appropriate demands for Middle and Lower Vaal. Return flows determined more accurately using new modelling techniques.
- 2007: Updated irrigation water requirements as determined by Vaal Reconciliation Study

simulated as fixed annual net demands upstream of Bloemhof Dam. These fixed annual net demands were separated into lawful and unlawful uses. Irrigation modules scaled downstream of Bloemhof Dam to represent updated demands. Return flows still simulated as estimated 10% of water use (Vaal Recon return flow work not completed at time of simulations).

Part A of this report and the report titled "Irrigation Sector Demands and Economic Importance" compiled as part of this study present the detailed information on the updated irrigation water use and return flows.

B.5.2.2 Aims and Methodology

The main aims of the work carried out with respect to irrigation in this Second Stage of the study were to:

- Create irrigation modules based on the updated irrigation demands determined as part of Stage 1 of this study to replace the fixed annual net demands that were simulated in the First Stage by means of master control channels upstream of Bloemhof Dam. This work included creating separate modules for lawful and unlawful use;
- Confirm and/or calibrate the water quality produced from the new irrigation modules upstream of Bloemhof Dam with results from the VRSAU Study;
- Confirm and/or calibrate the water quality produced from the irrigation modules downstream of Bloemhof Dam that had been created in the Feasibility Study for the Utilisation of Taung Dam with results from the 2005/2006 Annual Operating Analysis study (**DWAF, 2006h**).

The model configuration used for the 2000 annual operating analysis was used to determine and test the new irrigation modules. This was because the main focus was to ensure that the modules were producing the correct water quality results. A significant amount of other configuration changes mainly in the form of updates in demands took place between 2000 and 2007. These changes may have resulted in different salt concentrations being available at the point of abstraction of the irrigation module, which in turn would result in different salt concentrations being produced by the module with regards to flows in the return flow channel. It would therefore have been incorrect to attempt to calibrate the new irrigation modules' water quality results using the 2007 configuration instead of those produced by the 2000 model configuration.

The basic methodology adopted was as follows:

- Carry out a simulation using the 2000 model configuration and the 2000 irrigation modules to determine the salt concentrations of each module's return flow channel. It should be noted that only the concentrations were considered as opposed to the total volume of salts flowing in the channel as the concentrations would be used for comparison due to changes in the irrigation demands.
- Carry out a second simulation using the 2000 model configuration and the 2000 irrigation modules but including a large "dummy" inflow just upstream of each irrigation module. This was to confirm that the requirement and return flow volumes of each module were in fact based on module demand as opposed to module supply (which could be less than the demand if insufficient water is available at the point of abstraction).
- Determine each of the 2000 irrigation modules' net demands by subtracting each return flow volume from each demand volume.
- Determine the ratio for each module of "2000 net demand" to "updated 2007 net demand".
- Scale the area of each 2000 irrigation module by the above determined ratio and substitute the new areas into the 2000 irrigation modules to produce new 2007 irrigation modules.
- Carry out a third simulation using the 2000 model configuration and the newly created 2007 irrigation modules, including the large dummy inflow. Subtracted the results of each modules' return flow from its demand to confirm that the net demand was correct compared to that previously modelled in 2007 by the master control channels.
- Carry out a fourth simulation using the 2000 model configuration and the newly created 2007 irrigation modules, however, with the large dummy inflow removed. Confirmed that the salt concentrations of the newly created modules were in line with the 2000 modules' previous salt concentrations.

While the above mentioned methodology was the overall approach used, slight variations were used based on the following geographic locations. Reasons for the variations are:

- Mooi, Schoonspruit and Renoster systems: lawful use, reconfigured WRPM to a finer level of detail, therefore new irrigation modules were created, used updated return flow information for Mooi and Schoonspruit, original WQT model from VRSAU Study used for calibration instead of WRPM;
- Erfenis and Allemanskraal systems: lawful use, used updated return flow information as part of calibration;
- Vaalharts scheme: Modules previously configured for WRYM, merely calibrated quality;
- All remaining lawful use, no change in procedure as described above;

- All unlawful use, Modules did not previously exist and needed to be created, original WQT model from VRSAU Study used for calibration instead of WRPM.

The remaining sub-sections of this section present further details and the results for the above areas. Note that the results tables only present information for irrigation which is simulated in the form of irrigation modules. Further diffuse irrigation does take place in some of the catchments and is simulated as irrigation demand files. These were not modified and the demands can therefore be viewed in Part A of this report. As a result, catchment sub-totals and totals are not presented in the tables as they are not a true reflection of the catchment (i.e. excluding the diffuse irrigation).

B.5.2.3Mooi, Schoonspruit and Renoster systems

The Mooi, Schoonspruit and Renoster systems were each modified in separate studies (Mooi: Stage 1 of this study, Schoonspruit: Schoonspruit Sub-System Analysis Study (**DWAF, 2006**) and Renoster: Assessment of the Assurance of Supply of Bulk Water from the Koppies Dam to Voorspoed Diamond Mine (**DWAF, 2005**)) in order to simulate the systems at a finer level of detail as well as to update the demands as a result of more recent information regarding crops and irrigation practices. **Table B.5.1** presents a summary per system of the previously modelled irrigation modules, and those that have now been incorporated into the WRPM. One can see in all cases that a significant breakdown took place.

Table B.5.1: **A comparison between previous and new irrigation modules on the Mooi, Renoster and Schoonspruit systems**

Sub-catchment	Previous Description as viewed in Part A	Previous WRPM Irrigation Module Number	New Description	New WRPM Irrigation Module Number
Schoonspruit	Rietspruit & Elandskuil dams: Irrigation	RR22	Schoonspruit canal: Irrigation	RR442
			Elandskuil dam: irrigation	RR525
			Rietspruit dam: irrigation	RR529
	Johan Neser: Irrigation from small dams	RR23	Quat C24G: irrigation from small dams	RR447
			Quat C24F: irrigation from small dams	RR533
			Quat C24G: irrigation from river	RR446
			Quat C24F: irrigation from river	RR534

Sub-catchment	Previous Description as viewed in Part A	Previous WRPM Irrigation Module Number	New Description	New WRPM Irrigation Module Number
	Johan Neser: Mainstream irrigation	RR24	Klerksdorp Irrig Board: main stream, u/s Johan Neser	RR539
	Irrigation from Johan Neser	RR25	Klerksdorp Irrig Board: pipeline	RR452
			Klerksdorp Irrig Board: main stream, d/s Johan Neser	RR540
			Klerksdorp Irrig Board: canal	RR542
			Irrigation from River, Quat 24H	RR457
Renoster	Koppies: Irrigation from small dams	RR15	Quats C70ABC: Irrigation from small dams	RR15
	Koppies: Mainstream irrigation	RR16	Quats C70ABC: Irrigation from river	RR16
			Quats C70J: Irrigation from small dams	RR17
	Rietfontein: Mainstream irrigation	RR18	Koppies GWS: river irrigation	RR31
			Koppies GWS: canal irrigation	RR32
			Mainstream irrigation d/s Koppies and quats C70D and C70F	RR18
	Rietfontein: Irrigation from small dams	RR17	Quats C70D: Irrigation from small dams	RR33
			Quats C70D: Irrigation from river	RR34
			Quats C70F: Irrigation from small dams	RR35
			Quats C70E: Irrigation from small dams	RR36
			Quats C70H: Irrigation from small dams	RR40
			Quats C70K: Irrigation from small dams	RR42
Mooi (1)			Klerkskraal irrigation	RR550
			Boskop irrigation	RR552
			Lakeside irrigation	RR553
			Gerhardminnebron canal irrigation	RR554
	Boskop: Mainstream Irrigation	RR19	Irrigation from small dams	RR551

Note 1: The majority of the Mooi irrigation demands were previously modelled as demand files and not irrigation modules.

The results for the demand and return flow volumes are presented in **Table B.5.2**. The demands updated in the first stage of this study were used as a target to produce the irrigation modules. The water quality parameters were determined based on calibrations with the original WQT model results.

Table B.5.2: **Details of new irrigation modules developed for Mooi, Schoonspruit and Renoster Systems**

Sub-catchment	Description	WRPM Irrigation Module Number	WRPM demand Channel Number	WRPM return flow Channel Number	Irrigation Details (million m^3/a)	
					Demand	Return flow
Schoonspruit	Schoonspruit canal: Irrigation	RR442	1679	1692	3.76	0.80
	Quat C24G: irrigation from river	RR446	1778	1781	0.55	0.08
	Quat C24G: irrigation from small dams	RR447	1777	1787	0.53	0.09
	Klerksdorp Irrig Board: pipeline	RR452	1716	1715	0.54	0.05
	Quat C24H: irrigation from river	RR457	1725	1726	1.11	0.16
	Rietspruit dam: irrigation	RR529	119	800	9.92	2.16
	Elandskuil dam: irrigation	RR525	1776	1775	4.59	1.14
	Quat C24F: irrigation from small dams	RR533	188	801	0.53	0.07
	Quat C24F: irrigation from river	RR534	189	802	0.53	0.08
	Klerksdorp Irrig Board: main stream, d/s Johan Neser	RR540	1719	1708	0.17	0.04
	Klerksdorp Irrig Board: canal	RR542	121	803	0.82	0.05
	Klerksdorp Irrig Board: main stream, u/s Johan Nesser	RR539	1713	1709	8.58	0.43
Total for Schoonspruit Sub-catchment:		**-**	**-**	**-**	**31.63**	**5.15**
Renoster	Quats C70ABC: Irrigation from small dams	RR15	173	775	2.39	0.31
	Quats C70ABC: Irrigation from river	RR16	776	777	0.66	0.09
	Quats C70J: Irrigation from small dams	RR17	184	780	2.31	0.38
	Mainstream irrigation d/s Koppies and quats C70D and C70F	RR18	781	782	2.73	0.28
	Koppies GWS: river irrigation	RR31	1274	1287	3.41	0.42
	Koppies GWS: canal irrigation	RR32	1275	1288	3.03	0.36
	Quats C70D: Irrigation from small dams	RR33	1254	1283	0.91	0.02

Sub-catchment	Description	WRPM Irrigation Module Number	WRPM demand Channel Number	WRPM return flow Channel Number	Irrigation Details (million m^3/a)	
					Demand	Return flow
	Quats C70D: Irrigation from river	RR34	1257	1284	0.35	0.004
	Quats C70F: Irrigation from small dams	RR35	1259	1285	0.37	0.004
	Quats C70E: Irrigation from small dams	RR36	1260	1286	0.57	0.02
	Quats C70H: Irrigation from small dams	RR40	1264	1305	0.22	0.04
	Quats C70K: Irrigation from small dams	RR42	1266	1307	0.43	0.07
Total for Renoster Sub-catchment:		**-**	**-**	**-**	**17.38**	**2.00**
Mooi	Klerkskraal irrigation	RR550	102	1790	6.66	0.28
	Irrigation from small dams	RR551	1015	1791	2.22	0.06
	Boskop irrigation	RR552	105	1755	3.68	0.11
	Lakeside irrigation	RR553	1119	1792	20.8	0.7
	Gerhardminnebron canal irrigation	RR554	1116	1793	3.59	0.31
Total for Mooi Sub-catchment:		**-**	**-**	**-**	**36.95**	**1.46**

B.5.2.4Erfenis and Allemanskraal systems

A significant amount of work had taken place as part of the First Stage of this study to accurately determine the return flows for the Sand-Vet irrigation schemes. For this reason, in addition to obtaining correct net demands for the modules representing these schemes, the return flow factors required modification to obtain correct return flows. The target percentage return flow values are presented in **Table B.5.3** and were sourced from the “Irrigation Sector Demands and Economic Importance” report.

Irrigation module RR29 was moved as it was found to be incorrectly configured into the network. The module should in fact be able to obtain water from both Erfenis and Allemanskraal spills. **Table** B.5.4 presents the details of the updated irrigation modules produced.

Table B.5.3: **Return flow percentage targets**

Irrigation Scheme	Target percentage return flow	WRPM Irrigation Module Number
Erfenis canal scheme	11	RR27
Erfenis river scheme	4	RR29
Allemanskraal canal scheme	19	RR26

Table B.5.4: **Details of the updated irrigation modules developed for Erfenis and Allemanskraal Systems**

Sub-catchment	Description	WRPM Irrigation Module Number	WRPM demand Channel Number	WRPM return flow Channel Number
Allemanskraal (Sand-Vet)	Irrigation from small dams	RR30	746	811
	Irrigation from Allemanskraal Dam	RR26	131	804
Erfenis (Sand-Vet)	Irrigation from small dams	RR331	585	812
	Irrigation from Erfenis Dam	RR27	133	805
Sand/Vet Incremental Catchment	Irrigation from small dams	RR28	743	806
	Mainstream irrigation	RR29	807	809

Table B.5.5 presents the modifications made to the original VRSAU Study's irrigation modules.

Table B.5.5: **Modifications made to the original irrigation modules in Erfenis and Allemanskraal Systems**

Sub-catchment	WRPM Irrigation Module Number	Previous Irrigation Module area (km^2)	New Irrigation Module area (km^2)	Previous Irrigation Module return flow factor	New Irrigation Module return flow factor
Allemanskraal (Sand-Vet)	RR30	7.7	4.8		
	RR26	50.5	27.9	0.03	0.08
Erfenis (Sand-Vet)	RR331	8.1	2.7		
	RR27	54.14	33.2	0.03	0.035
Sand/Vet Incremental Catchment	RR28	13.5	1.3		
	RR29	21.7	22.4	0.03	0.001

Table B.5.6 presents the results obtained from simulating the modules using the 2000 model configuration and the high dummy inflows as well as a comparison with the previous results in terms of the salt concentrations. It should be noted that the results may differ using the latest 2007 model configuration as a result of demand and supply issues. Differences in the demand channel salt concentrations are as a result of behavioural changes in the dams in the systems due to different abstraction volumes. Where the required demand is lower, more water remains in the dam which results in higher evaporation, resulting in higher salt concentrations in the dam as the salts do not evaporate along with the water.

Table B.5.6: **Results obtained from the updated irrigation modules in the Erfenis and Allemanskraal systems**

Sub-catchment	WRPM Irrigation Module Number	Irrigation Details (million m^3/a)			Salt concentrations (mg/l)			
		Demand	Return Flow	Net Demand (1)	Previous Demand channel	New Demand channel	Previous Return flow channel	New Return flow channel
Allemanskraal (Sand-Vet)	RR30	6.34	0.60	5.74	166.57	183.37	696.04	798.14
	RR26	36.76	7.02	29.74	132.53	159.89	507.61	479.48
Erfenis (Sand-Vet)	RR331	3.60	0.36	3.24	177.26	213.03	765.74	885.7
	RR27	43.60	4.77	38.83	152.38	166.19	639.06	674.31
Sand/Vet Incremental Catchment	RR28	0.60	0.14	0.46	228.23	283.4	564.12	673.7
	RR29	11.81	0.49	11.32	557.65	531.35	1301.02 (2)	2103.25
Total for Sand-Vet catchment:		**102.71**	**13.38**	**89.33**	-	-	-	-

Note 1: The differences between the net demands modelled by the irrigation modules and by the master control channels as presented in Part A of this report are as a result of the previously estimated return flow percentage of 10% as opposed to the more accurate return flow percentages now represented by the new return flow factors included in the modules.

Note 2: The large concentration difference for Module 29 is a result of the new return flow percentage of 4% of demand as opposed to the previous 10%.

B.5.2.5Vaalharts scheme and Lower Vaal

The variation of the overall methodology for the irrigation modules forming part of the Vaalharts scheme was as a result of the fact that the original 2000 WRPM configuration was only up to

Bloemhof Dam and did not include the irrigation modules downstream of Bloemhof Dam. These modules were only included in the 2005 WRPM configuration under the 2005/2006 Annual Operating Analysis of the IVRS (**DWAF, 2006h**). These 2005 modules were then updated in the Feasibility Study for the Utilisation of Taung Dam (**DWAF, 2007c**) and were included as irrigation modules in the WRYM (which has been updated to allow for simulation of irrigation using modules). As these WRYM modules were already correct in terms of their demands and return flows, the only modifications required were in terms of the salt concentrations as well as slight formatting modifications. **Table B.5.7** presents the details of the modules that form part of the Vaalharts scheme.

Table B.5.7: **Details of the updated irrigation modules developed for Vaalharts Scheme**

Sub-catchment	Description	WRPM Irrigation Module Number	WRPM Irrigation Module Number	WRPM demand Channel Number
Upper Harts (Harts River Upstream of Wentzel Dam)	Wentzel Dummy Dam Irrigation	RR357	612	614
	Mainstream irrigation: Upstream of Wentzel Dam	RR360	617	618
	Wentzel Dam Irrigation (Terminated)	RR362	621	625
Harts Remainder (Middle and Lower Harts)	Spitskop small dams irrigation	RR376	640	642
	Spitskop Dam irrigation	RR407	728	734
Bloemhof Dam to Douglas Weir (Vaal incremental)	Mainstream Irrigation: Bloemhof Dam to Vaalharts Weir	RR397	682	684
	Mainstream irrigation: Vaalharts to De Hoop	RR405	731	733
	Mainstream irrigation: De Hoop to confluence of Vaal and Harts	RR289	984	985
	Mainstream irrigation: Confluence of Vaal and Harts to Schmidtsdrift	RR290	998	999
	Mainstream irrigation: Schmidtsdrift to confluence of Vaal and Riet rivers	RR291	1001	1002
Vaalharts Scheme	Part of Taung irrigation	RR370	629	632
	North canal and part of Taung	RR379	646	644
	West and Barkley-West canals	RR383	654	652

Table B.5.8 presents the modifications made to the 2005 modules in the Vaalharts scheme. In addition to these changes, the crop details for most of the modules were also adjusted as a result of the new information from the Feasibility Study for the Utilisation of Taung Dam.

Table B.5.8: **Modifications made to the irrigation modules in the Vaalharts scheme**

Sub-catchment	WRPM Irrigation Module Number	Previous Irrigation Module area (km^2)	New Irrigation Module area (km^2)	Previous Irrigation Module proportion of salt lost to deep storage	New Irrigation Module proportion of salt lost to deep storage	Previous Irrigation Module return flow factor	New Irrigation Module return flow factor
Upper Harts (Harts River Upstream of Wentzel Dam)	RR357	1	1.17	0	0.0001	0.05	0.039
	RR360	3	3.49	0	0	0.05	0.04
Harts Remainder (Middle and Lower Harts)	RR376(1)	1.25	0.88	0.004	0.004	0.04	0.015
	RR407	0	9.41	Did not exist	0	Did not exist	0.06
Bloemhof Dam to Douglas Weir (Vaal incremental)	RR397	44.7	19.995	0.004	0.0052	0.04	0.0395
	RR405	30	17.333	0.004	0.002	0.04	0.0476
	RR289	0	16.74	Did not exist	0.002	Did not exist	0.048
	RR290	0	5.31	Did not exist	0.002	Did not exist	0.048
	RR291	0	1.585	Did not exist	0.002	Did not exist	0.05
Vaalharts Scheme	RR370(2)	11	6.73	0.01	0.028	0.1	0.0349
	RR379(3)	268.7	169.39	0.016	0.028	0.065	0.108
	RR383(4)	50	33.08	0.02	0.02	0	0.0629

Note 1: In addition to the changes presented the transfer canal: proportion of flow loss was modified from 0.3 to 0 and the irrigation efficiency factor was modified from 0.65 to 0.77.

Note 2: In addition to the changes presented the transfer canal: proportion of flow loss was modified from 0 to 0.34 and the irrigation efficiency factor was modified from 0.85 to 0.813.

Note 3: In addition to the changes presented, the transfer canal: proportion of flow loss was modified from 0 to 0.34 and the irrigation efficiency factor was modified from 0.67 to 0.709.

Note 4: In addition to the changes presented, the transfer canal: proportion of flow loss was modified from 0 to 0.29 and the irrigation efficiency factor was modified from 0.68 to 0.699.

Table B.5.9 presents the results obtained for the new irrigation modules as well as a comparison with the previous results in terms of the salt concentrations. The salt parameters were adjusted such that each module produced similar concentrations to the previous modules. Differences in the demand channel concentrations are a result of behavioural changes in the dams as explained before.

Table B.5.9: **Results obtained from the updated irrigation modules in the Vaalharts scheme**

Sub-catchment	WRPM Irrigation Module Number	Irrigation Details (million m^3/a)			Salt concentrations (mg/l)			
		Demand	Return Flow	Net Demand	Previous Demand channel	New Demand channel	Previous Return flow channel	New Return flow channel
Upper Harts (Harts River Upstream of Wentzel Dam)	RR357	1.20	0.15	1.05	766.7	761.9	6238.6	6201.9
	RR360	3.64	0.48	3.16	2839.8	2824.2	4340.6	4049
Harts Remainder (Middle and Lower Harts)	RR376	0.49	0.05	0.44	547.9	754.8	3262.9	3108.1
	RR407	12.81	1.55	11.26	Did not exist	1911.0	Did not exist	13382.0
Total for Harts catchment:		**18.14**	**2.23**	**15.91**	-	-	-	-
Bloemhof Dam to Douglas Weir (Vaal incremental)	RR397	27.42	2.3	25.12	477.6	536.9	4688.7	4745.3
	RR405	25.06	2.34	22.72	508.7	557	5245.3	5305.7
	RR289	24.2	2.27	21.93	Did not exist	626.5	Did not exist	5818.6
	RR290	7.67	0.72	6.95	Did not exist	981.81	Did not exist	9629.3
	RR291	2.4	0.22	2.18	Did not exist	1014.1	Did not exist	10107.5
Total for Vaal incremental:		**86.75**	**7.85**	**78.90**	-	-	-	-
Vaalharts Scheme	RR370	6.32	0.80	5.52	536.3	564.4	1700.6	1748.7
	RR379	270.04	49.77	220.27	536.4	564.1	1591.2	1620.21
	RR383	51.44	6.20	45.24	536.4	564.7	2145.8	2195.3
Total for Vaalharts Scheme:		**327.80**	**56.77**	**271.03**	-	-	-	-

B.5.2.6 Remaining lawful use

Table B.5.10 presents the details of all remaining irrigation modules that have not yet been reported on. It also shows the modifications that were made to the modules.

Table B.5.10: Details of the updated irrigation modules developed for the remaining catchment

Sub-catchment	Description	WRPM Irrigation Module Number	WRPM demand Channel Number	WRPM return flow Channel Number	Previous Irrigation Module area (km^2)	New Irrigation Module area (km^2)
Grootdraai	Mainstream Irrigation upstream of Grootdraai Dam	RR1800	765	766	12.572	13.909
Frankfort	Irrigation from small dams	RR9	705	760	31.343	23.605
	Irrigation from Saulspoort Dam and small dams upstream	RR10	761	762	19.564	1.320
	Mainstream Irrigation	RR11	763	764	22.06	35.437
Vaal Dam	Irrigation from small dams	RR13	770	771	9.025	10.758
	Mainstream Irrigation	RR14	772	773	28.049	32.209
Suikerbosrand	Mainstream Irrigation	RR1	58	59	6.03	0.602
	Mainstream Irrigation	RR335	838	839	29.28	2.634
Klip	Mainstream Irrigation	RR336	842	843	54.04	7.598
Riet	Mainstream Irrigation	RR337	852	853	6.67	8.351
Kromdraai	Irrigation from small dams	RR338	160	868	1.54	2.46
Vals	Irrigation from small dams	RR332	123	825	8.5	6.02
	Mainstream irrigation	RR334	826	827	12.22	22.74
Bloemhof Incremental Catchment	Irrigation from small dams upstream of Mooi River confluence	RR340	876	877	2.81	3.04
	Vaal River mainstream irrigation upstream of Schoonspruit confluence	RR339	872	873	13.35	10.18
	Irrigation from small dams upstream of Schoonspruit River confluence	RR341	741	875	4.42	2.75
	Vaal River mainstream irrigation downstream of Schoonspruit confluence	RR2	129	130	26.19	20.67

Table B.5.11 includes the results obtained for the new irrigation modules as well as a comparison with the previous results in terms of the salt concentrations. Differences in the demand channel concentrations are a result of behavioural changes in the dams as explained before.

Table B.5.11: **Results obtained from the updated irrigation modules developed for the remaining catchment**

Sub-catchment	Description	WRPM Irrigation Module Number	Irrigation Water Use (million m^3/a)		Salt concentrations (mg/l)			
			Demand	Return flow	Previous Demand channel	New Demand channel	Previous Return flow channel	New Return flow channel
Grootdraai	Mainstream Irrigation upstream of Grootdraai Dam	RR1800	12.53	1.49	196.30	196.63	777.72	774.49
Frankfort	Irrigation from small dams	RR9	17.78	2.03	151.41	151.61	280.47	280.80
	Irrigation from Saulspoort Dam and small dams upstream	RR10	0.99	0.11	70.64	70.94	152.83	153.37
	Mainstream Irrigation	RR11	26.69	3.05	92.64	91.23	187.67	185.26
Vaal Dam	Irrigation from small dams	RR13	9.37	3.66	136.48	136.47	196.87	196.87
	Mainstream Irrigation	RR14	28.07	10.95	197.17	196.64	255.43	254.61
Suikerbosrand	Mainstream Irrigation	RR1	0.74	0.16	476.72	475.74	2314.65	2322.34
	Mainstream Irrigation	RR335	3.26	0.46	412.92	389.25	626.40	637.61
Klip	Mainstream Irrigation	RR336	8.63	1.51	358.13	367.70	369.24	379.70
Riet	Mainstream Irrigation	RR337	10.69	1.40	396.24	405.10	993.76	1016.94
Kromdraai	Irrigation from small dams	RR338	3.26	0.60	393.04	355.77	2206.27	2018.48
Vals	Irrigation from small dams	RR332	6.51	0.70	333.65	400.6	1870.38	2212.97
	Mainstream irrigation	RR334	23.59	2.63	373.51	359.87	2052.27	1598.5
Bloemhof Incremental Catchment	Irrigation from small dams upstream of Mooi River confluence	RR340	4.46	0.70	638.02	615.39	4144.95	4013.23
	Vaal River mainstream irrigation upstream of Schoonspruit confluence	RR339	14.93	2.36	497.47	517.04	3189.36	3308.81

Sub-catchment	Description	WRPM Irrigation Module Number	Irrigation Water Use (million m^3/a)		Salt concentrations (mg/l)			
			Demand	Return flow	Previous Demand channel	New Demand channel	Previous Return flow channel	New Return flow channel
	Irrigation from small dams upstream of Schoonspruit River confluence	RR341	3.76	0.29	656.62	700.15	3617.91	3815.78
	Vaal River mainstream irrigation downstream of Schoonspruit confluence	RR2	31.83	4.80	839.3	904.9	4874.9	5169.15

B.5.2.7Unlawful use

Irrigation modules had not previously existed for the unlawful irrigation component in the Vaal catchment. This irrigation was, until the update in 2007, included as part of the total irrigation and simulated as net fixed annual demands. The lawful and unlawful irrigation was split for the first time in the First Stage of this study, however, the unlawful irrigation was still simulated as fixed annual demands. **Table B.5.12** presents the details of the unlawful irrigation modules that were created. The parameters in these modules were for the most part based on the lawful modules that were positioned in the same catchment. The table also presents the results for the demand and return flow volumes. The volumes determined as unlawful use in the First Stage of this study were used as a target to produce the irrigation modules. The water quality parameters were determined based on calibrations with the original WQT model results for lawful irrigation in the same area.

Table B.5.12: Details of the new unlawful irrigation modules developed

Sub-catchment	Description	WRPM Irrigation Module Number	WRPM demand Channel Number	WRPM return flow Channel Number	Irrigation Water Use (million m^3/a)		
					Demand	Return Flow	Net Demand
Grootdraai	Mainstream Irrigation upstream of Grootdraai Dam	RR1782	1000	1821	17.27	2.17	15.1
Delangesdrift	Diffuse irrigation in sub-catchment	RR1781	581	1820	7.38	2.7	4.68

Sub-catchment	Description	WRPM Irrigation Module Number	WRPM demand Channel Number	WRPM return flow Channel Number	Irrigation Water Use (million m^3/a)		
					Demand	Return Flow	Net Demand
Frankfort	Irrigation from small dams	RR1783	1004	1822	27.21	3.02	24.19
	Irrigation from Saulspoort Dam and small dams upstream	RR1784	1005	1823	0.68	0.08	0.6
	Mainstream Irrigation	RR1785	1006	1824	40.87(1)	4.59	36.28
Vaal Dam	Irrigation from small dams	RR1786	1007	1825	22.54	8.72	13.82
	Mainstream Irrigation	RR1787	1008	1826	67.13(1)	25.94	41.19
Suikerbosrand	Mainstream Irrigation	RR1788	1009	1827	11.45	2.48	8.97
	Mainstream Irrigation	RR1789	1011	1828	0	0	0
Klip	Mainstream Irrigation	RR1790	1012	1829	19.22	3.14	16.08
Riet	Mainstream Irrigation	RR1791	1013	1830	18.36	2.72	15.64
Kromdraai	Irrigation from small dams	RR1792	1016	1831	3.91	0.74	3.17
Mooi (Loopspruit)	Klipdrift diffuse irrigation	RR1802	1019	1833	0.35	0.01	0.34
	Klipdrift diffuse irrigation	RR1799	1022	1819	0.42	0.02	0.4

Note 1: These two unlawful volumes were split in different proportions in the First Phase of the Study.

B.5.2.8 Diffuse irrigation water use

Diffuse irrigation demands are modelled by means of time series files representing the relevant crop water requirements. When modelled in the WRPM these demands are taken off directly from the natural runoff from the catchment and therefore have first priority to the available natural resources of the catchment. Consequently, diffuse irrigation water use is defined as water use that can not be controlled. It is also assumed that there are no return flows from diffuse irrigation areas. **Table B.5.13** summarises the lawful diffuse irrigation demands in the Vaal River catchment that were included in the WRPM configuration of the IVRS.

Table B.5.13: Lawful diffuse irrigation water use in Vaal River catchment

Sub-catchment	WRPM Filename	Water use (million m^3/annum)
Grootdraai Dam	GROOTD9.IRR	0.034
Delangesdrift	DELA9.IRR	2.79
Klipdrift Dam	KLIPDN3.IRR	0.44
Allemanskraal Dam	ALLEM9.IRR	1.17
Erfenis Dam	ER9.IRR	1.28
Sand-Vet incremental	SANDN3.IRR	1.28
Total diffuse water use:	**-**	**7.30**

B.5.2.9Irrigation water use within supporting sub-systems of the IVRS

The most recent assessments of the irrigation water use of the supporting sub-systems of the IVRS were undertaken as part of the VRSAU Study. The VRSAU water use was incorporated in the WRPM configuration and is modelled as time series abstraction files. The irrigation water use of the supporting sub-systems adopted for this study is summarised in **Table B.5.14**.

Table B.5.14: Irrigation water use within supporting sub-systems of the IVRS

Sub-system	Description	WRPM Filename	WRPM Channel Number	Water Use (million m^3/a)
Komati	Nooitgedacht small dams irrigation	NOOI94N.CIR	724	2.16
	Gemsbokhoek diffuse irrigation	GEMS9.IRR	-	3.06
	Gemsbokhoek small dams irrigation	GEM94N.CIR	723	4.67
	Vygeboom diffuse irrigation	VYG9.IRR	-	2.85
	Vygeboom mainstream irrigation	VYG94N.CIR	725	9.74
Sub-total for Komati Sub-system:				**22.48**
Usutu	Morgenstond diffuse irrigation	MORG9.IRR	-	1.53
Heyshope	Irrigation from small dams	HEYD94N.CIR	714	6.82
	Mainstream irrigation	HEYM94N.CIR	716	1.71
Sub-total for Heyshope Sub-system:				**8.53**
Total diffuse irrigation water use for supporting sub-systems:				**7.44**
Total controlled irrigation water use for supporting sub-systems:				**25.10**
Total irrigation water use for supporting sub-systems:				**32.54**

B.5.3 SUMMARY OF IRRIGATION WATER USE FOR THE VAAL RIVER SYSTEM

Since validation of water use has only been undertaken for the Upper Vaal WMA, the irrigation water requirements of the Upper Vaal WMA summarised in **Table B.5.15**, are shown in terms of both the status of the water use and the sources of supply.

Table B.5.15: Irrigation water requirements in the Upper Vaal WMA

Status	Description	Recommended current (year 2005) water use (million m^3/a)	
		Gross	Net
Lawful	Diffuse irrigation	3.57	3.57
	Irrigation from dams	64.76	57.21
	Mainstream irrigation	94.20	74.87
Total lawful water use:		**162.53**	**135.65**
Unlawful	Diffuse irrigation	8.15	5.42
	Irrigation from dams	54.34	41.78
	Mainstream irrigation	174.30	133.26
Total unlawful water use:		**236.79**	**180.46**
Total water use for Upper Vaal WMA:		**399.32**	**316.11**

From the results presented in **Table** B.5.15 it can be seen that the unlawful irrigation water use comprises about 59% of the total irrigation water use within the Upper Vaal WMA.

Table B.5.16 provides a summary of the current (year 2005) irrigation water use included in the WRPM configuration for the Integrated Vaal River System excluding the Thukela and Orange River Sub-systems.

Table B.5.16: Summary of irrigation water use for the Vaal River System

Description	Recommended current (year 2005) water use (million m^3/a)	
	Gross	Net
Upper Vaal WMA	399.32	316.11
Middle Vaal WMA	240.53	204.79
Lower Vaal WMA (including consumptive canal losses) (1)	559.69	492.84
Sub-total for three Vaal WMA:	**1199.54**	**1013.74**
Supporting Sub-systems (2)	32.54	32.54
Total for the IVRS:	**1232.08**	**1046.28**

Note : (1) Includes Vaalharts canal losses of 127 million m^3/annum

(2) Excluding the Thukela and Orange River Sub-systems

B.5.4 SCENARIOS OF FUTURE IRRIGATION WATER USE

The information presented in the previous sections focused on the historical and current irrigation water use. However, what is required for planning purposes is to compile scenarios of future water use for the period up to 2030. Most of the increases in the water use since 1998 is considered to be unlawful and poses a significant challenge to the DWAF as the regulating authority. Given that the current (year 2005) water use estimates are significantly higher than the preliminary estimates of what is considered lawful, a scenario was compile where it was assumed that the current water use will be reduced over the medium term through legal interventions and water use compliance monitoring.

The **Irrigation Scenario 1** which was defined and adopted for all the WRPM scenarios analysed as part of the First Stage Reconciliation Strategy was also used for the Second Stage assessments. The assumptions used in this irrigation scenario are listed below.

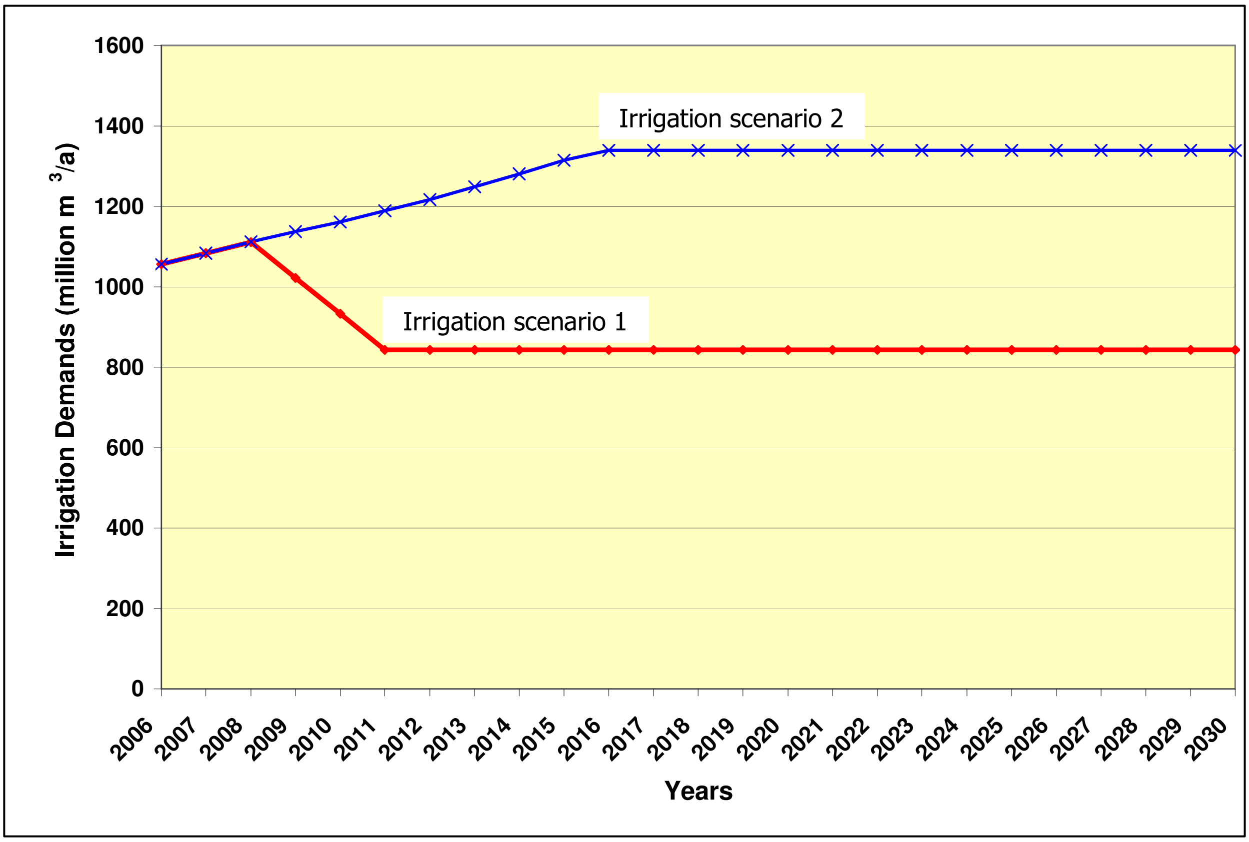
Irrigation Scenario 1: Curtailment of unlawful irrigation water use

- **Upper Vaal WMA**
    - Assume the growing trend, which was observed over the period 1998 to 2005, continues for two years until 2008. This implies the interventions will take two years to become effective.
    - Eradication of unlawful irrigation water use from 2008 onwards and assuming the water use will decrease over a period of 4 years.
    - The assumption is made that the interventions will reduce the irrigation to the lawful volume plus 15% and that this will be achieved in the year 2011. The additional 15% above the estimates of the lawful water use is a conservative assumption providing for possible under estimations from the current data.
- **Middle and Lower Vaal WMA**
    - Due to the absence of information from validation studies in these areas, it is assumed that the current suggested irrigation water use will remain constant over the planning period.

A second irrigation scenario was also defined, whereby it was assumed that no curtailment of unlawful use will take place and that the irrigation demand will continue to increase at the rate observed between 1998 and 2005 until the registered volume from the WARMS database is reached. Since **Irrigation Scenario 2** will create an unsustainable situation in the Vaal River System, it is not considered to be viable and was therefore not used for the WRPM analyses. This scenario is described in the irrigation report of this study (**DWAF, 2006d**) and was merely derived to illustrate the potential impact should interventions not be successful.

Figure B. 5.1 below presents the future irrigation water requirements for the two scenarios described above. It should, however, be noted that only the irrigation water requirements of **Irrigation Scenario 1** were used in the system planning scenarios which are described in **Section B.9.2**.

Figure B. 5.1: Irrigation water requirement scenarios for the Vaal River System



From **Figure B. 5.1** it can be seen that for **Irrigation Scenario 1** the total irrigation water use increases to a maximum of 1111 million m^3/annum in 2008 after which it decreases to 843 million m^3/annum in the year 2011. For **Irrigation Scenario 2** the total irrigation water use continues to increase until it reaches the maximum value of 1339 million m^3/annum (which is representative of the registered volume of the WARMS database) in the year 2016.

B.5.5 BULK INDUSTRIAL WATER REQUIREMENTS

B.5.5.1 Overview

As mentioned in **Part A**, there are three main industries receiving water in bulk from the Vaal River System, the electrical power utility Eskom, the petrochemical (coal to liquid fuel) industry Sasol and Mittal Steel (formally known as Iscor.) Since these industries revise their water requirement scenarios on a regular basis, they were requested to provide information on the future outlook of their respective operations and water management programs. These water requirement scenarios are presented in the subsequent sections.

B.5.5.2Eskom

Eskom currently operates 12 coal fired electrical power stations which receive water from the Integrated Vaal River System. Some of these stations were decommissioned and are now reinstated to increase supply in response to the growing demand for electrical power to fuel the South African economy. There are also plans to develop two new power stations envisaged to receive water from the Vaal River System. One of these are scheduled to receive water from Vaal Dam and current planning is that the second (referred to as “Bravo”) will be located close to the existing Kendal Power Station and receive water from the Vaal River Eastern Sub-system (a component of the Integrated Vaal River System).

Eskom revise their water requirement projections on an annual basis. Consequently, three projections, namely a Base-, High- and Drought Scenario, were provided by Eskom in April 2007. From these alternative scenarios Eskom recommended that the Base and High demand scenarios be considered for the 2007-2008 Annual Operating Analysis of the IVRS. The Base Scenario projections were, however, considered as the most probable projection scenario to be used for the purposes of this study.

Table B.5.17 provides a summary of the Base Scenario water requirements and lists all the power stations and their primary water source, as well as the projection of water requirements for the indicated years of the planning period. These requirements were used in most of the planning scenarios (refer to **Section B.9.2** for details) and relate to planning years running from 1 May of the indicated year to 30 April of the subsequent year.

A comparison between the Base Scenario projections adopted for the Second Stage of this study and the previous Eskom projections, as well as the historic (actual) water use is presented in **Figure L-1** of **Appendix L**. Furthermore, the Eskom water requirement projections to be supplied from the Eastern Sub-system of the IVRS are shown in **Figure L-2** of **Appendix L**.

It should be noted that there are several smaller users that are supplied with water along the Eskom water conveyance routes. These users are referred to as the so-called DWAF 3rd Party Users. The water requirements of these users are not included in the Eskom demand projections listed in **Table B.5.17** or shown in **Figures L-1** and **L-2** of **Appendix L**. The DWAF 3rd Party Users’ projections were derived as part of the original TR134 projections and were subsequently refined based on the actual water use information collated as part of the annual operating analysis of the IVRS. The DWAF 3rd Party Users' water requirement projections are provided in **Table** B.5.18.

Table B.5.17: Eskom power stations' base water requirements (projection dated April 2007)

Power Station	Primary Water Source	Water Requirements (million m^3/annum)					
		2007	2010	2015	2020	2025	2030
Hendrina	Komati Sub-system	30.9	30.9	31.7	31.7	30.4	30.4
Arnot		28.4	32.9	35.2	35.2	35.2	35.2
Duvha		49.6	49.7	50.4	51.6	51.6	51.5
Komati		6.4	14.8	14.6	11.9	11.6	11.0
Kriel	Usutu Sub-system	37.8	40.7	43.3	44.3	44.3	44.3
Matla		49.9	49.1	51.0	55.5	54.9	53.7
Kendal		3.2	3.2	3.3	3.3	3.3	3.3
Camden		12.8	24.0	22.9	15.2	15.1	14.8
Bravo (New coal-fired 1)		0.0	0.8	4.8	6.7	6.8	6.8
Majuba	Zaaihoek Sub-system	24.2	32.2	28.3	28.3	28.2	28.0
Tutuka	Grootdraai Sub-system	40.9	46.7	48.3	48.2	48.2	48.1
Grootvlei	Vaal Dam	4.9	16.7	15.6	9.9	9.2	9.2
Lethabo		47.1	46.5	47.1	47.1	47.1	47.0
New coal-fired 2		0.0	0.0	1.5	6.7	8.5	8.5
Total		**336.1**	**388.2**	**398.0**	**395.6**	**394.4**	**391.8**

Table B.5.18: Water requirement projections for DWAF 3rd Party users

Description of supply route	Water Requirements (million m^3/annum)					
	2007	2010	2015	2020	2025	2030
Komati pipeline	6.59	7.14	7.14	7.14	7.14	7.14
Hendrina-Duvha pipeline	4.21	4.56	4.56	4.56	4.56	4.56
Onverwacht, Camden-Rietspruit, Camden-Lilliput, Rietspruit-Davel, Davel-Kriel and Khutala-Kendal pipelines	6.10	6.70	6.70	6.70	6.70	6.70
Grootdraai-Tutuka, Rietfontein-Matla and Naauwpoort-Duvha pipelines	1.00	1.00	1.00	1.00	1.00	1.00
Total for DWAF 3rd Party Users:	**17.90**	**19.40**	**19.40**	**19.40**	**19.40**	**19.40**

B.5.5.3Sasol (Secunda and Sasolburg Complexes)

Sasol has two plants, the Sasol Secunda and Sasol Sasolburg complexes, receiving water from the Integrated Vaal River System. The Sasol Secunda Complex's primary source of water is Grootdraai Dam which will be supported through the Vaal River Eastern Sub-system Augmentation Project (VRESAP) once it becomes operational in 2008. To meet the interim water requirements, Sasol has entered into a five year contract with Rand Water (effective from 1 July 2005) whereby a maximum water supply of 40 Ml/d (14.61 million m^3/a) could be obtained from Rand Water (RW) for the Secunda Complex. The Sasol Sasolburg Complex is supplied from Vaal Dam which is supported from the Thukela-Vaal Transfer Scheme as well as the Lesotho Highlands Water Project (LHWP).

Sasol has submitted two water requirement projections in 2007 for their Secunda Complex of which the revised October 2007 projections were adopted for the Second Stage Reconciliation Strategy. The minimum contractual Rand Water intake requirement of 4 Ml/d (1.46 million m^3/a), to be supplied until June 2010, was allowed for in the revised October 2007 projections. A comparison of some of the more recent water requirement projections for Sasol Secunda is shown in **Figure L-3** of **Appendix L**. It should be noted that the interim reduced demands shown for the April 2004 projection over the period 2004 to 2007 were based on the intake of 40 Ml/d emergency supply from Rand Water. The June 2006 projection was included in the First Stage strategy analysis. From **Figure L-3** it can be seen that the May 2007 projection, which was used for the 2007/2008 AOA, was initially lower than the June 2006 projection, but from 2004 onwards it was higher with a difference of about 8.5 million m^3/a in the year 2030. Compared to the May 2007 projection, the revised October 2007 projection is significantly lower during the period 2007 to 2014. These lower projected demands correspond better to the actual water use which showed a decline over the last two years. Sasol explained that reduced electricity generation was the leading cause for consuming less water than anticipated. From 2014 onwards, the revised October 2007 projected water requirements grow steadily and in 2030 the demand is similar to that of the May 2007 projection.

Projections for the Sasol Sasolburg complex were not updated in 2007. Consequently, the revised information on projected raw water abstractions for the Sasol Sasolburg complex that was obtained during May 2006 was used for both the First and Second Stage analyses. **Figure L-4** of **Appendix L** shows a comparison between the previous (April 2001) and updated water requirement projections. The Sasolburg complex has a permit allocation of 96 Ml/d (35.1 million m^3/a) for raw water and 6 Ml/d (2.2 million m^3/a) for potable water. It should be noted that the potable water component, which is supplied by Rand Water, is not included in the projections shown in **Figure L-4**. Water supplied to the Sasolburg complex can be obtained from two point sources, namely Letabo Weir and Vaal Barrage. Owing to the poor water quality being experienced in the Vaal Barrage, it was also confirmed by Sasol that up to 60 Ml/d (21.92 million m^3/a) will be abstracted from the Letabo Weir before they start abstracting their additional requirement from Vaal Barrage.

The water requirements for the two complexes are presented in **Table B.5.19** for the indicated years of the planning period. These requirements were used in all the planning scenarios (see **Section B.9.2** for details).

Table B.5.19: Sasol's raw water requirements for the indicated complexes

Description	Water Requirements (million m^3/annum)					
	2007	2010	2015	2020	2025	2030
Sasol Secunda Complex(1)	91.0	94.7	107.3	114.8	122.6	130.4
Sasol Sasolburg Complex(2)	24.8	26.7	30.1	33.3	36.7	40.6
Total	**115.8**	**121.4**	**137.4**	**148.1**	**159.3**	**171.0**

Notes: (1) *Reference of projection October 2007 (Excludes 4 Ml/day supply from RW).*

(2) *Reference of projection June 2006 (Excludes 6 Ml/d (2.2 million m^3/a) for potable water to be supplied by RW).*

B.5.5.4Mittal Steel

Mittal Steel (previously known as ISCOR) receives its water from Vaal Dam. The water requirement projections for Mittal Steel incorporated in the WRPM configuration was updated in 2006 as part of the First Stage strategy (refer to **Section A.5.4.4**). As shown in **Figure L-5** of **Appendix L**, two water requirement projections (an Expected and High demand projection) were provided by Mittal Steel in July 2006. It should be noted that the projections shown in **Figure L-5** reflect the total water requirements and therefore include both the potable and raw water requirements that are supplied from Rand Water.

In their most probable projections (reference Expected July 2006) they are planning to decrease their water use from 17.4 million m^3/annum in 2006 to 16.6 million m^3/annum in 2010 from where onwards it remains constant for the subsequent years of the planning period. The latter projection was adopted for all the scenarios that were analysed as part of this study.

B.5.6 URBAN WATER REQUIREMENTS AND RETURN FLOWS

B.5.6.1 Overview

As mentioned in **Part A** of this report, the urban sector represents the largest portion of the Vaal River system's water use and in the Gauteng Province substantial increases in the water use occurred historically as a result of the increasing urban population and expanding economic activities.

The population projections developed for the National Water Resource Strategy (NWRS) preceded the Census 2001 information and needed to be revised. To this end, the DWAF has commissioned a parallel demographic study to update the country wide population scenarios. The detailed results from the parallel demographic study, with the main focus on the population in the Gauteng Province, are discussed in the water requirement and return flow report of this study (**DWAF, 2006a**). A brief description of the two population projections considered for this study is provided in **Part A** (**Sections A.5.5.2.1** and **A.5.5.2.2)** of this report.

In summary two population projections were considered for the Gauteng Province and these are referenced as follows:

- **Scenario A**: National Water Resource Strategy High Population Scenario
- **Scenario B**: August 2006 Population Projection Scenario

B.5.6.2 Rand Water supply area

The water requirements and return flows for the Rand Water supply area were determined with the Water Requirement and Return Flow database model which was developed for DWAF as part of the Crocodile (West) River Return Flow Assessment Study (**DWAF, 2004e**). The model uses Sewage Drainage Areas (SDAs) as modelling component where a sewer pipe network system collects the wastewater for treatment at the waste water treatment works before it is discharged into a river system. There were forty seven Sewage Drainage Areas (SDAs) identified in the Rand Water (Gauteng) supply area as illustrated graphically in **Figure A.5.2** of **Part A,** where the thick black line shows the catchment divide between the northern and southern areas. The wastewater returned in the northern SDAs contributes to the water resources of the Crocodile (West) River and those SDAs draining to the south contributes to the Vaal River System. The Sewage Drainage Areas located within each of the indicated municipal areas are listed in **Table A.5.13**.

For the purposes of this study, two basic water requirement and return flow projection scenarios, based on the two population projections mentioned in **Section B.5.6.1**, were compiled. The scenarios are, therefore, labelled **Scenario A** and **B** respectively, and these labels are used to identify and reference the scenarios in subsequent sections of this report. The methodology that was followed to compile these two sets of water requirement and return flow projections is described in the detailed water requirement and return flow report of this study (**DWAF, 2006a**). The results from these assessments were incorporated into a spreadsheet database to generate the data required by the Water Resource Planning Model (WRPM).

Based on the findings of the First Stage Strategy, the **Scenario B** projections were adopted for the development of the Second Stage Reconciliation Strategy. Therefore, since the **Scenario A** projections were only used as part of the First Stage analyses, a summary thereof can be found in **Table A.5.14** of **Part A.**

Table B. 5.20 summarises the **Scenario B** water requirement and return flow projections for the Rand Water supply area**,** showing the water requirements for the Northern and Southern municipalities and a remainder component called "Other".

Table B. 5.20: Water requirement and return flow projection scenario summary based on the August 2006 Population Projection Scenario (Scenario B)

Component Descriptions		Planning Years					
		2005	2010	2015	2020	2025	2030
Water Requirements (Supplied by Rand Water)	Northern Municipalities	542	575	617	644	681	721
	Southern Municipalities	564	619	669	714	747	782
	Other users	194	210	226	239	251	264
	Total	***1,300***	***1,403***	***1,512***	***1,596***	***1,679***	***1,766***
	Portion North	47.5%	49.0%	48.1%	48.0%	47.4%	47.7%
	Portion South	52.5%	51.0%	51.9%	52.0%	52.6%	52.3%
Return Flows (From all municipalities)	Northern Municipalities	266	324	362	394	423	444
	Southern Municipalities	289	329	362	392	418	438
	Total	***556***	***653***	***724***	***785***	***841***	***882***
	Portion North	47.9%	49.6%	50.0%	50.1%	50.3%	50.3%
	Portion South	52.1%	50.4%	50.0%	49.9%	49.7%	49.7%

Notes: (1) All volumetric values are given in million m^3/annum.

It should be noted that the “Other” component includes water requirements of individual users including mines, industries and other small municipalities supplied from Rand Water. The assumptions for the other users were that they would increase by the same ratio as the water requirements of the municipalities.

The **Scenario B** projections, presented in **Table B. 5.20** were also used for the 2007/2008 AOA of the IVRS. Comparisons between actual and projected water use, however, indicated that the actual water use for the planning year 2006/2007, amounting to approximately 1334 million m^3/annum, was higher than the projected value. Consequently, the **Scenario B** projections were adjusted over the period 2006 to 2010 by adopting the actual water use for 2006/2007 as starting point. The Rand Water projections adopted for both stages of this study, as well as the most recent projections provided by Rand Water in 2004, are shown graphically in **Figure L-6** of **Appendix L**.

The lines on the graph represent the following information:

- The thick black line starting in the year 1990 shows the actual water use up to the year 2006. The impact of water restrictions due to drought conditions is shown during 1995 and 1996.

- The dark blue line (**Sc A** (**Recon_2006**)) shows the water requirements for **Scenario A**.

- The red dotted line (**Sc B** (**Recon_2006**) shows the water requirements for **Scenario B**.

- The light blue line **RW (2004 incl AIDS)**, is a projection scenario produced by Rand Water in 2004 and included the impact of HIV AIDS.

- The light blue dotted line **RW (2004 Questionnaire)**, is a projection scenario produced by Rand Water in 2004 that was compiled from information they received through a questionnaire to all the users supplied by Rand Water.

- The black dotted line (**Sc C** (**Recon_2006**))represents the Water Conservation and Water Demand Management scenario described in **Section A.6.2.1.1**. **Scenario C** is the most optimistic WC/WDM scenario and includes a 5 year water loss programme as well as water use efficiency measures.

- The red line (**Sc D** (**Recon_2006**)) represents the WC/WDM scenario described in **Section A.6.2.1.2**. For **Scenario D** no water use efficiency measures were introduced, but it was assumed that water losses can be controlled within the next 5 years (2005 to 2010).

- The thin black line (**Sc E** (**Recon_2006**)) represents the Water Conservation and Water Demand Management scenario described in **Section A.6.2.1.3**. **Scenario E** is basically the same as **Scenario D**, but it was assumed that water losses can only be controlled within the next 10 years.

B.5.6.3Sedibeng Water

Sedibeng Water is the bulk service provider supply water to both urban and industrial (mining) water users. Sedibeng Water receives water from the Vaal River System from two abstraction locations. The first is Balkfontein on the Vaal River and, the second, from Allemanskraal Dam at their Virginia Works. Virginia Town, which falls within the Sedibeng Water supply area, has an allocation of 15.2 million m^3/a from Allemanskraal Dam. The water use in their supply area has decreased historically mainly due to the decreasing mining activity in the region. Sedibeng Water provided projections in April 2007 which indicated that their water requirement will increase from 44 million m^3/annum in 2007 to 49 million m^3/annum in 2030. The portion of their total water use to be supplied from their Virginia Works (Allemanskraal Dam) is constant over the planning period at 15.2 million m^3/annum which is equal to their allocation from the resource.

Since May 2004, however, Allemanskraal Dam has constantly been at alarmingly low storage levels and as a result severe restrictions have been imposed on users over the past three years. On 30 April 2007 storage within Allemanskraal Dam was at 16.8% of its live Full Supply Capacity and users have again been restricted to only 15% of their quota which must be used before December 2007. Consequently Sedibeng Water has made allowance for Virginia Town to be supplied from the Vaal River (via the Balkfontein abstractions) during 2007. This is reflected in the Sedibeng Water projections shown in **Figure L-7** of **Appendix L**. Supplying Virginia Town via Balkfontein has the implication of placing a higher demand directly on the Vaal River.

B.5.6.4MidVaal Water Company

Midvaal Water Co treats and supplies water to users in the Klerksdorp area and has experienced a decline in water use mainly due to the closing of several mining operations. Projections for Midvaal Water Co were received from them in May 2007 indicating that their water use will remain constant at 37 million m^3/annum over the planning period. This is about 2 million m^3/annum less than the projected water requirements adopted for the First Stage. The Midvaal projections and actual water use are shown in **Figure L-8** of **Appendix L**.

B.5.6.5 Other urban areas

The projections for all the other urban areas receiving water from the Vaal River System were determined using the growth rates from the National Water Resource Strategy. Where actual water use data was available the starting point (volume for the first year in the projection) was adjusted to match the actual value on which the future growths were applied. As part of the First Stage Strategy adjustments were made for Lekwa LM, Amersfoort, Msukaligwa LM (former Ermelo), Bethlehem and "Small Users" comprising of Jim Fouche, Oranjeville, Vaal Marina, etc. The resulting changes were also adopted for the Second Stage. The total water requirement in 2007 is projected to be 168 million m^3/annum for this group and increases to 190 million m^3/annum in the year 2030.

B.5.7 SCENARIO B_2: SUMMARY OF BASE WATER REQUIREMENT AND RETURN FLOW SCENARIO

In addition to the water requirements and return flows described in the above-mentioned sections, the WRPM configuration of the IVRS also makes provision for the modelling of different types of water losses (wetland losses, evaporation losses along river reaches, conveyance losses, operating losses, etc) from the river system. Allowance is also made for urban runoff (i.e. rainfall runoff from large paved areas typically found in urbanised areas) as well as flow resulting from mining activities. The Waterval River, Klip River, Suikerbosrant and Lower Barrage (Riet River) catchments have been identified as the only catchments with significant urbanisation. Projections regarding the increase in runoff due to growing urbanisation of the Waterval and Vaal Barrage catchments were also incorporated in the demand database of the WRPM. Although mine dewatering impacts on the runoff in the Upper Vaal and along the main stem of the Vaal River downstream of Vaal Barrage, it has the most significant influence on the water quantity and quality of the Vaal Barrage and Mooi River incremental catchments.

Combining all the water requirements and return flows of all the sectors from the information given in the previous sections and including other components such as losses and mine dewatering mentioned above, provides the summary as presented in **Table B.5.21** below. Since the August 2006 population scenario was applied for the Gauteng Province, the combined water requirements and return flows, as presented in **Section B.5.6.2**, is referenced as the **Scenario B_2** demand projection scenario.

Table B.5.21: Summary of water requirements and return flows (Scenario B_2)

Water users	Planning years					
	2007	2010	2015	2020	2025	2030
Water Requirements						
Rand Water	1339	1390	1498	1582	1665	1753
Mittal Steel	17	17	17	17	17	17
ESKOM (Including DWAF 3rd Party Users)	354	408	417	415	414	411
SASOL (Sasolburg)- Raw water	25	27	30	33	37	41
SASOL (Secunda)	91	95	107	115	123	130
Midvaal Water Company	37	37	37	37	37	37
Sedibeng Water (Balkfontein only)	44	45	46	47	48	49
Other towns and industries	183	185	188	189	189	190
Vaalharts/Lower Vaal irrigation	542	542	542	542	542	542
Other irrigation	751	593	494	494	494	494
Wetland / River Losses	325	326	327	329	330	331
Return Flows						
Southern Gauteng (Rand Water)	342	362	392	418	438	459
Midvaal Water Company	1	1	1	1	1	1
Sedibeng Water	2	2	2	2	2	2
Other towns and industries	63	65	69	73	77	81
Irrigation	68	52	43	43	43	43
Mine dewatering	116	109	126	128	126	126
Increased urban runoff	101	103	107	113	121	129
OVERALL GROSS SYSTEM DEMAND:	3708	3664	3704	3799	3895	3995
OVERALL NET SYSTEM DEMAND:	3015	2968	2966	3021	3088	3154

Notes: (1) All volumetric values are given in million m^3/annum.

When comparing the results of the **Scenario B_2** projections adopted for the Second Stage with that of the First Stage's **Scenario B** (presented in **Table A.5.17**), the following differences should be noted:

- Although the August 2006 population scenario was applied for the Rand Water supply area, adjustments were made over the period 2006 to 2010 to ensure that the projection's starting point is in line with the actual water use (refer to green line shown on **Figure L-6** of **Appendix L**);

- The revised April 2007 Base Scenario projections were included for Eskom;

- The most recent October 2007 projections were used for Sasol Secunda; and
- Updated projections (obtained in April 2007) were adopted for Sedibeng Water and Midvaal Water Company.

A more detailed summary of the individual water requirement projections incorporated in **Scenario B_2** are provided in **Table L-1** of **Appendix L**.

B.6 ALTERNATIVE WATER DEMAND SCENARIOS

B.6.1 BACKGROUND

As mentioned in **Sections B.5.5** and **B.5.6** the water requirement projections of large industrial users and bulk water suppliers are updated on a regular basis. Furthermore, previous analyses of the IVRS have shown that the impact of alternative water requirement projections on the date at which intervention is required, can be significant. Therefore, for the purposes of long-term water resource planning it is necessary to consider a range of alternative water requirement projection scenarios for the IVRS. It is important to note that these projections comprise of various combinations of the alternative water requirement projections of individual user groups.

The alternative IVRS water requirement projection scenarios evaluated as part of the Second Stage of this study are described in the subsequent sections.

B.6.2 SCENARIO D_2: REDUCTION IN WASTAGE OVER 5 YEARS

This demand scenario was based on **Scenario B_2** (refer to **Section B.5.7**) but includes changes to the water requirement projection adopted for the Rand Water supply area as discussed below.

During the development of the First Stage Strategy, three WC/WDM scenarios were compiled from the assessment of the potential for water conservation and water demand management in the Gauteng urban sector. The savings were applied to the water requirement of the First Stage **Scenario B** (see **Section A.5.5.3.2**) and were labelled **Scenarios C**, **D** and **E** respectively. The detail description and saving results from these scenarios are presented in **Section A.6** of this report. From the results of the First Stage Strategy it was decided to work towards the implementation of **Scenario D** for the Gauteng urban area.

In short, the basic assumptions in terms of water conservation and water demand management initiatives adopted for **Scenario D** are as follows:

- Water losses can be controlled within the next 5 years (2005 to 2010) and maintained afterwards (same as for **Scenario C**).
- No water use efficiency is introduced.

The IVRS **Scenario D_2** water requirement and return flow projection, which was adopted for most of the Second Stage scenario analyses, is summarised in **Table B.6.1**. A more detailed summary of the individual water requirement projections incorporated in **Scenario D_2** are provided in **Table L-2** of **Appendix L**.

Table B.6.1: Summary of water requirements and return flows (Scenario D_2)

Water users	Planning years					
	2007	2010	2015	2020	2025	2030
Water Requirements						
Rand Water	1255	1210	1307	1382	1452	1540
Mittal Steel	17	17	17	17	17	17
ESKOM (Including DWAF 3rd Party Users)	354	408	417	415	414	411
SASOL (Sasolburg)- Raw water	25	27	30	33	37	41
SASOL (Secunda)	91	95	107	115	123	130
Midvaal Water Company	37	37	37	37	37	37
Sedibeng Water (Balkfontein only)	44	45	46	47	48	49
Other towns and industries	183	185	188	189	189	190
Vaalharts/Lower Vaal irrigation	542	542	542	542	542	542
Other irrigation	751	593	494	494	494	494
Wetland / River Losses	325	326	327	329	330	331
Return Flows						
Southern Gauteng (Rand Water)	314	294	317	337	351	366
Midvaal Water Company	1	1	1	1	1	1
Sedibeng Water	2	2	2	2	2	2
Other towns and industries	63	65	69	73	77	81
Irrigation	68	52	43	43	43	43
Mine dewatering	116	109	126	128	126	126
Increased urban runoff	101	103	107	113	121	129
OVERALL GROSS SYSTEM DEMAND:	3624	3483	3513	3599	3682	3782
OVERALL NET SYSTEM DEMAND:	2959	2856	2849	2902	2962	3034

Notes: *(1) All volumetric values are given in million m^3/annum.*

B.6.3 SCENARIO H_2: ESKOM AND SASOL HIGH WATER REQUIREMENT PROJECTIONS

This scenario is based on **Scenario B_2** with the following changes:

- **Eskom**: The April 2007 high demand projections were adopted for Eskom's Power Stations.
- **Expansion of Coal To Liquid (CTL) Fuel Industry**: Allowance was made for the additional water requirements of Sasol's proposed Mafutha Project (details of which are provided below).

Sasol has announced their plans to implement a new CTL plant (Mafutha) to be sited in either the Northern Free State near Koppies or the Lephalale area. The proposed additional plants will be implemented in two phases (in 2015 and 2020) and the water requirements thereof are summarised in **Table B.6.2**.

Table B.6.2: Estimated water requirements of the Mafutha Project

Description	Phase 1: 2015 (million m^3/a)	Phase 2: 2020 (million m^3/a)
CTL facility	32	32
Mining facility (coal beneficiation)	3	3
Town (domestic use)	5	5
Total demand:	**40**	**40**

For the purposes of the IVRS annual operating analysis, Sasol recommended that the Mafutha water requirements be imposed as a demand on Vaal Dam. Consequently it was decided to also investigate the impact of this potential demand as part of the defined "high demand" scenario. Details of the water requirement and return flow projections included in **Scenario H_2** are provided in **Table L-3** of **Appendix L**.

B.6.4 SCENARIO I_2: HIGH WATER REQUIREMENT PROJECTIONS FOR RAND WATER

This scenario is based on **Scenario H_2** and includes the following changes:

- **Rand Water**: The water requirement projection adopted for Rand Water was based on the 2003 Questionnaire projection obtained from Rand Water in 2004.

The ratios between the Northern and Southern Gauteng demands and return flows resulting from the **Scenario B_2** RW projections were applied to the 2003 Questionnaire demand projection to determine the split between North and South and to also assess the demands and return flows to be associated with each of the five Demand Centres comprising the RW Southern Gauteng water use area. The **Scenario I_2** water requirement and return flow projections are summarised in **Table L-4** of **Appendix L**.

B.6.5 SCENARIO E_2: REDUCTION IN WASTAGE OVER 10 YEARS

Details of the water requirement and return flow projections used for this scenario are presented in **Table L-5** of **Appendix L**. **Scenario E_2** is based on **Scenario B_2**, but includes the following WC/WDM projection for the Rand Water supply area:

- **Rand Water**: The **Scenario E** projection which assumed that water losses can be controlled within the next 10 years (2005 to 2015) and maintained afterwards, was adopted. It should be noted that no water use efficiency measures were included in **Scenario E**.

B.6.6 SCENARIO J_2: TRADING OF IRRIGATION WATER RIGHTS

The water requirement and return flow projections of **Scenario B_2** were used for this scenario. However, the assumption was made that all the irrigation water rights upstream of Vaal Dam will be bought out over a period of three years. The total irrigation demand associated with the water rights upstream of Vaal Dam was estimated to be in the order of 95.4 million m^3/a with an associated return flow of 21.3 million m^3/a.

The trading of water rights were implemented over a three year period and the resulting water requirements and return flows are summarised in **Table L-6** of **Appendix L**.

B.6.7 SCENARIOS K_2 AND K_3: SLOW AND FAST DECOMMISSIONING PLANS OF ESKOM

Eskom provided information on their strategic planning for water supply to their Power Stations in Mpumalanga in September 2007. The information included projected water requirements associated with both a slow (Plan A) and a fast (Plan B) decommissioning plan. The associated reductions in the water requirements of the Eskom Power Stations situated within the VRESS and the impact of these reductions on the net water requirements of the IVRS are shown in **Table B.6.3** and **Table B.6.4** for Plan A and Plan B respectively.

Table B.6.3: Scenario K_2: Eskom's Plan A demand reductions and net demand projection

Description	Projections (million m^3/annum) for Planning Years							
	2007	2010	2015	2020	2025	2030	2035	2040
Reduction in Eskom water use	0	0	0	0	10	35	67	108
Net System Demand	3015	2968	2966	3021	3078	3119	3156	3185

It should be noted that the net demand projections were extrapolated to the year 2040 by applying the annual growth rate calculated over the period 2025 to 2030. For the slow decommissioning of Power Stations (Plan A) the reduction in water use was assumed to increase by 10% per annum over the period 2035 to 2040.

Table B.6.4: Scenario K_3: Eskom's Plan B demand reductions and net demand projection

Description	Projections (million m^3/annum) for Planning Years							
	2007	2010	2015	2020	2025	2030	2035	2040
Reduction in Eskom water use	0	0	0	0	80	162	162	162
Net System Demand	3015	2968	2966	3021	3008	2992	3061	3131

From **Table B.6.4** it can be seen that the reduction in water use for the year 2030 based on the fast decommissioning plan (Plan B) was assessed at 162 million m^3/annum and it was assumed that the reduction will remain constant over the period 2030 to 2040.

B.6.8 COMPARISON OF NET SYSTEM WATER REQUIREMENTS

The water requirement and return flow projection scenarios considered as part of the Second Stage of this study are summarised in **Table B.6.5**. It should be noted that references to the water requirement projections of users that are common to all the demand scenarios are not included in **Table B.6.5** (i.e. only the differences between the scenarios are highlighted). Detailed information on the WC/WDM scenarios and the recommendations made in terms thereof can be found in the relevant study report entitled "*Potential Savings through WC/WDM in the Upper and Middle Vaal Water Management Areas"* (**DWAF, 2006b**).

Table B.6.5: Summary of demand scenarios considered for the Second Stage

Scenario Reference	Scenario Description	Water requirement projections adopted for Individual Users		
		Rand Water	Eskom	Sasol Mafutha
B_2	Base Scenario (excluding WC/WDM)	Scenario B	April 2007 Base Scenario	Excluded
D_2	WC/WDM scenario with water loss management over 5 years	Scenario D	April 2007 Base Scenario	Excluded
H_2	Eskom and Sasol high demand scenario	Scenario B	April 2007 High Scenario	Excluded
I_2	RW high demand scenario	RW 2004: 2003 Questionnaire	April 2007 High Scenario	Included
E_2	WC/WDM scenario with water loss management over 10 years	Scenario E	April 2007 High Scenario	Included
J_2	Trading of irrigation water rights (Upstream of Vaal Dam)	Scenario B	April 2007 Base Scenario	Excluded
K_2	Eskom slow decommissioning plan (Plan A)	Scenario B	April 2007 Base Scenario with Plan A reduction	Excluded
K_3	Eskom fast decommissioning plan (Plan B)	Scenario B	April 2007 Base Scenario with Plan B reduction	Excluded

The total system's net water requirement projections associated with these scenarios are provided in **Table B.6.6** below and are compared graphically in **Figure B.6.1**.

Table B.6.6: Comparison of total system net water requirements

Scenario Reference	Scenario Description	Planning Years					
		2007	**2010**	**2015**	**2020**	**2025**	**2030**
B_2	Base Scenario (excluding WC/WDM)	3015	2968	2966	3021	3088	3154
D_2	WC/WDM scenario with water loss management over 5 years	2959	2856	2849	2902	2962	3034
H_2	High demand scenario	3015	2976	3016	3115	3182	3249
I_2	RW high demand scenario	3030	3040	3124	3284	3425	3577
E_2	WC/WDM scenario with water loss management over 10 years	2978	2903	2861	2906	2966	3037
J_2	Trading of irrigation water rights (Upstream of Vaal Dam)	3015	2894	2891	2947	3014	3080
K_2	Eskom slow decommissioning plan (Plan A)	3015	2968	2966	3021	3078	3119
K_3	Eskom fast decommissioning plan (Plan B)	3015	2968	2966	3021	3008	2992

Notes: (1) All volumetric values are given in million m^3/annum.

The impact of the initial growth and subsequent eradication of unlawful irrigation water use on the net water requirements of the IVRS is reflected in **Figure B.6.1**. The net water requirement projections of **Scenarios I_2** and **D_2** represent the upper and lower bounds respectively of the demand scenarios that were evaluated as part of the Second Stage of this study.

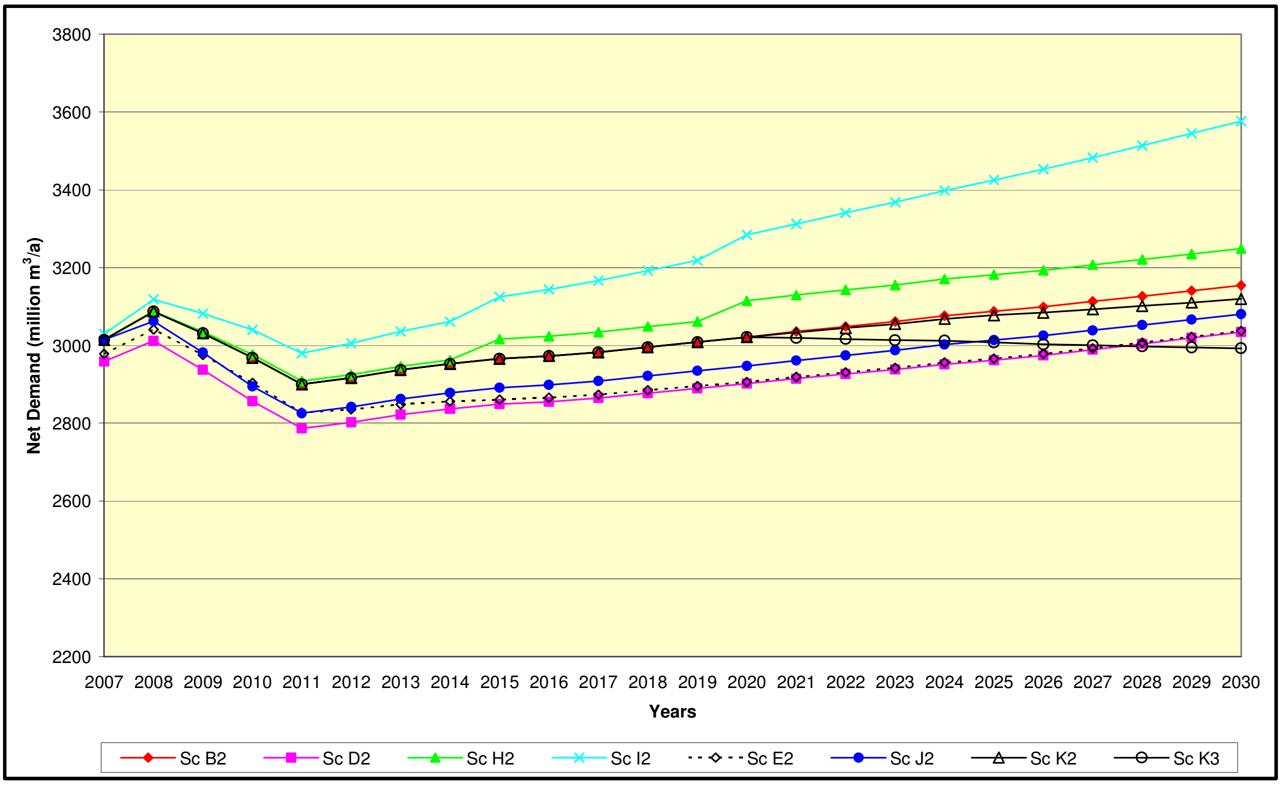


Figure B.6.1: Comparison of total system net water requirement projections

B.7 INFRASTRUCTURE INTERVENTION OPTIONS

As mentioned in **Part A**, the Vaal Augmentation Planning Study (VAPS), completed in 1996, concluded that either a further phase of the Lesotho Highlands Water Project or further water resource developments in the Thukela River System could be considered as alternatives for augmenting the water resources of the Vaal River System.

B.7.1 THUKELA WATER PROJECT (TWP)

Subsequent to the VAPS, DWAF undertook the Thukela Water Project Feasibility Study (TWPFS) to determine the most feasible scheme configuration for development in the Thukela River System. The study concluded that two proposed dams, one on the Bushman's River (Mielietuin Dam) and the other on the main stem of the Thukela River (Jana Dam), with transfer infrastructure, would be the most feasible scheme configuration to provide a nominal transferable yield of 15 m^3/s (473 million m^3/annum).

A further study, the "*Thukela Water Project Decision Support Phase (TWPDSP)*" study, was carried out to, among other things, undertake a Comprehensive Reserve Determination Study for the Thukela River System and compile an implementation programme for the TWP. The results from this study indicated that the first water could be delivered twelve years after the decision is taken to proceed with the development. The Historic Firm Yield of the TWP, incorporating the Ecological Water Requirements (EWR), for the largest dam sizes was determined to be 454 million m^3/annum.

For the reconciliation options discussed in the Second Stage Reconciliation Strategy Report of this study (**DWAF, 2007h**) a phased approach was adopted for the implementation of the two dams and their pumping conveyance conduits. The Historic Firm Yield (HFY) of 136 million m^3/annum was adopted for the Mielietuin Dam and its associated transfer link whereas the HFY for Jana Dam was taken as 318 million m^3/annum (10.1 m^3/s). It is important to note that the TWP was not physically included in the WRPM configuration that was used for the Second Stage scenario analyses.

B.7.2 LESOTHO HIGHLANDS FURTHER PHASES (LHFP)

A joint feasibility study by the South African and Lesotho governments were commissioned in 2005 with the purpose of identifying the most feasible further phases of the scheme. Results from the

LHPH Study were made available to the Reconciliation Study Team which indicated that the proposed Polihali Dam with transfer infrastructure was the preferred Phase 2 option. The implementation period required for the scheme was estimated to be ten years after the decision is taken to proceed with the scheme. (If the decision is taken today, however, a further three year preparation phase has to be added to the ten years. This is to complete the current feasibility study and to investigate funding options.) The Historical Firm Yield of the Polihali Dam options was determined to be 458 million m^3/annum.

The second phase of the LHFP Feasibility Study commenced in October 2006 and the reconciliation results presented in the First Stage Reconciliation Strategy Report of this study (**DWAF, 2006g**) were to be used to determine the optimal configuration during that study. Information on the optimal Polihali Dam and gravity conveyance infrastructure configuration was obtained from the LHFP Feasibility Study in August 2007 and was subsequently incorporated in the WRPM configuration (refer to **Section B.8.9**) that was used for the Second Stage assessments.

The incremental yield of the preferred Polihali option was found to be 541 million m^3/annum (17.1 m^3/s) with an associated reduction in yield of the Orange River System (ORS) of about 257 million m^3/annum.

B.8 UPDATING OF WRPM CONFIGURATION

B.8.1 OVERVIEW

The WRPM configuration resulting from the 2007-2008 Annual Operating Analysis of the IVRS was adopted as basis for the Second Stage Reconciliation Strategy analyses. This configuration included all the WRPM updates that were made as part of the First Stage (refer to **Section A.8** for details). Further refinements to the WRPM configuration were, however, required as described below.

The hydrology updates discussed in **Section B.3**, as well as the sub-system refinements of selected sub-catchments that are described in **Section B.4**, were included in the WRPM configuration. One of the major changes made to the WRPM configuration was the inclusion of irrigation modules (refer to **Section B.5.2**). Preliminary results prompted several changes to be made to the WRPM configuration to ensure realistic modelling of the water resources system (both in terms of volumes and quality) and its associated water requirements. The necessary changes made to the WRPM configuration is described in the following sections and the resulting schematic diagrams of the IVRS are provided in **Appendix J** (**Figures J-1** to **J-12**).

As shown in these schematic diagrams, the IVRS comprise of the following sub-systems:

- Komati Sub-system (**Figure J-12**);
- Usutu Sub-system (**Figure J-1**);
- Heyshope Sub-system (**Figure J-1**):
- Zaaihhoek and Upper Thukela Sub-systems (**Figure J-1**);
- Upper Vaal Sub-system (**Figure A-1**);
- Thukela Sub-system downstream of Spoienkop Dam (**Figure J-2**);
- Senqu and Upper Orange Sub-systems (**Figure J-3**);
- Vaal Barrage Sub-system (**Figure J-4**);
- Middle Vaal Sub-system (**Figure J-5**);

- Lower Vaal Sub-system which includes the Riet-Modder Sub-system (**Figure J-6**);
- Witbank Dam Sub-system in Upper Olifants River catchment(**Figure J-7**);
- Middleburg Dam Sub-system in Upper Olifants River catchment (**Figure J-8**);
- Loskop Dam Incremental Sub-system in Upper Olifants River catchment (**Figure J-9**);
- Lower Orange Sub-system (**Figure J-10**); and
- Fish River Sub-system in Namibia (**Figure J-11**).

B.8.2 RE-ASSESSMENT OF ADDITIONAL SALT LOADS FOR RW DEMAND CENTRES

As mentioned in **Section A.8.2**, the Southern Gauteng demand supplied from Rand Water (RW) was originally modelled by means of a single Demand Centre Module (DCM). The DCM simulates the water and salt mass balances in areas of concentrated industrial and commercial activity. The DCM has the functionality of modelling the consumptive volumetric water requirements and its associated salt loss as well as the volumetric return flow volume and its associated salt concentration.

The detailed level of information that was available for this study enabled modelling of the urban water requirements and return flows of the Rand Water supply area at a much more refined scale. Consequently the single DCM was replaced with five DCMs corresponding to five groups of Sewage Drainage Areas (SDAs) as shown in **Table B.8.1**. Details of the configuration of the five DCMs can be found in **Section A.8.2**.

Table B.8.1: Definition of Demand Centre Modules for Southern Gauteng SDAs

DCM Number	Description	Supply Channel Number	Consumptive Abstraction Channel Number	Return Flow Channel Number	Average Return Flow Factor for 2006
40	SDAs with effluent discharges being made to the Klip River (WRPM Node Number 46)	1023	69	864	0.602
293	SDAs with effluent discharges being made to the	1024	1017	865	0.603

DCM Number	Description	Supply Channel Number	Consumptive Abstraction Channel Number	Return Flow Channel Number	Average Return Flow Factor for 2006
	Suikerbosrand River (WRPM Node Number 261)				
294	SDAs with effluent discharges being made to the Upper Riet River (WRPM Node Number 267)	1025	1029	866	0.575
295	SDAs with effluent discharges being made to the Lower Riet River (WRPM Node Number 270)	1026	1047	867	0.352
296	SDAs with effluent discharges being made to the Mooi River (WRPM Node Number 252)	1027	1048	75	0.663

Note: For WRPM reference numbers refer to the schematic diagram provided in **Figure J-4** of **Appendix J**.

The average salt concentration of the water supplied to the DCM is determined by the salt concentrations of the relevant water resources. While a degree of consumptive water usage takes place in the DCM, the effluent flow is increased with an additional salt load. This additional salt load accounts for increases in the salt concentration of effluent water due to consumer/man made activities such as cleaning detergents used for household purposes and chemicals used in industries.

For the WRPM analyses it is necessary to project the TDS load that has to be added for each future month simulated by the WRPM. The additional salt load is specified as a monthly time series file in tonnes/month allowing for increased salt loads over time which is then added to the salt load originating from the water supply. In the past, the general assumption has been made that the added TDS load of the demand centre will grow in relation to its water demand projection.

The methodology originally adopted for determining the additional salt load files that were required for each of the DCMs listed in **Table B.8.1**, is described in **Section A.8.3**. The preliminary water quality results corresponding to the return flows from the five DCMs did not compare well with the observed TDS concentrations. It was, therefore, necessary to re-assess the additional salt loads associated with the five DCMs.

The methodology adopted for the re-assessment of the individual salt load files of the five DCMs was as follows:

- The average annual salt load factor (additional salt load/water use) or TDS concentration derived for the original Southern Gauteng DCM based on the historical water use and additional salt loads covering the period 1977 to 1994 was determined. The resulting TDS concentration was found to be in the order of 258.28 mg/l. It was found that this value corresponded well with observed TDS concentrations.

- The projected annual return flows (million m^3/annum) of the five DCMs, based on the RW demand projection **Scenario B,** were then multiplied with the average annual TDS concentration of 258.28 mg/l to obtain a projection of additional annual salt loads (tonnes/annum) for each of the DCMs.

- The average monthly demand distribution was determined based on the historic water use data and this distribution pattern, together with the projected future additional annual salt loads were used to create projected monthly additional salt loads for each of the demand centres.

The average monthly demand distribution used for the disaggregation of annual salt loads is shown in **Table B.8.2** and the annual results for each of the DCMs are summarised in **Table B.8.3**. The indicated additional salt load time series files were included in the WRPM configuration.

Table B.8.2: Monthly demand distribution based on Southern Gauteng historic water use

Historic Demand Distribution (% of annual demand)											
Oct	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
8.64	8.50	8.08	8.53	7.86	8.33	8.11	8.24	8.08	8.23	8.57	8.83

Table B.8.3: Projected additional annual salt loads for Rand Water DCMs

Year	Projected additional annual salt loads (tonnes/annum) for indicated DCMs (Associated file name)					Total projected additional annual salt load (million m^3/annum)
	DC40 (DC40.SLD)	DC293 (DC293.SLD)	DC294 (DC294.SLD)	DC295 (DC295.SLD)	DC296 (DC296.SLD)	
2005	57409	13432	8694	3807	1667	85007
2006	58572	13731	8795	3832	1706	86636

Year	Projected additional annual salt loads (tonnes/annum) for indicated DCMs (Associated file name)					Total projected additional annual salt load (million m^3/annum)
	DC40 (DC40.SLD)	DC293 (DC293.SLD)	DC294 (DC294.SLD)	DC295 (DC295.SLD)	DC296 (DC296.SLD)	
2007	59759	14037	8898	3858	1747	88298
2008	60970	14350	9002	3884	1788	89993
2009	62205	14669	9107	3910	1830	91722
2010	63466	14996	9213	3936	1874	93485
2011	64524	15269	9304	3959	1912	94968
2012	65601	15547	9396	3981	1951	96476
2013	66695	15829	9488	4004	1992	98008
2014	67807	16117	9582	4027	2033	99566
2015	68938	16410	9676	4050	2074	101149
2016	69892	16655	9757	4070	2111	102486
2017	70859	16904	9839	4090	2149	103841
2018	71840	17156	9921	4111	2188	105215
2019	72834	17412	10004	4131	2227	106608
2020	73841	17672	10088	4152	2267	108020
2021	74555	17854	10148	4167	2298	109023
2022	75276	18038	10209	4183	2330	110035
2023	76003	18224	10270	4199	2362	111058
2024	76738	18412	10331	4215	2394	112090
2025	77480	18602	10393	4231	2427	113132
2026	78229	18794	10455	4247	2460	114185
2027	78986	18988	10518	4263	2494	115248
2028	79750	19183	10581	4279	2528	116321
2029	80521	19381	10644	4295	2563	117405
2030	81300	19581	10708	4312	2598	118499

The additional annual salt loads of the individual Rand Water DCMs are shown in **Figure B.8.1**. From this graph it is clear that the largest portion of the total additional salt loads (DC40) is discharged into the Klip River.

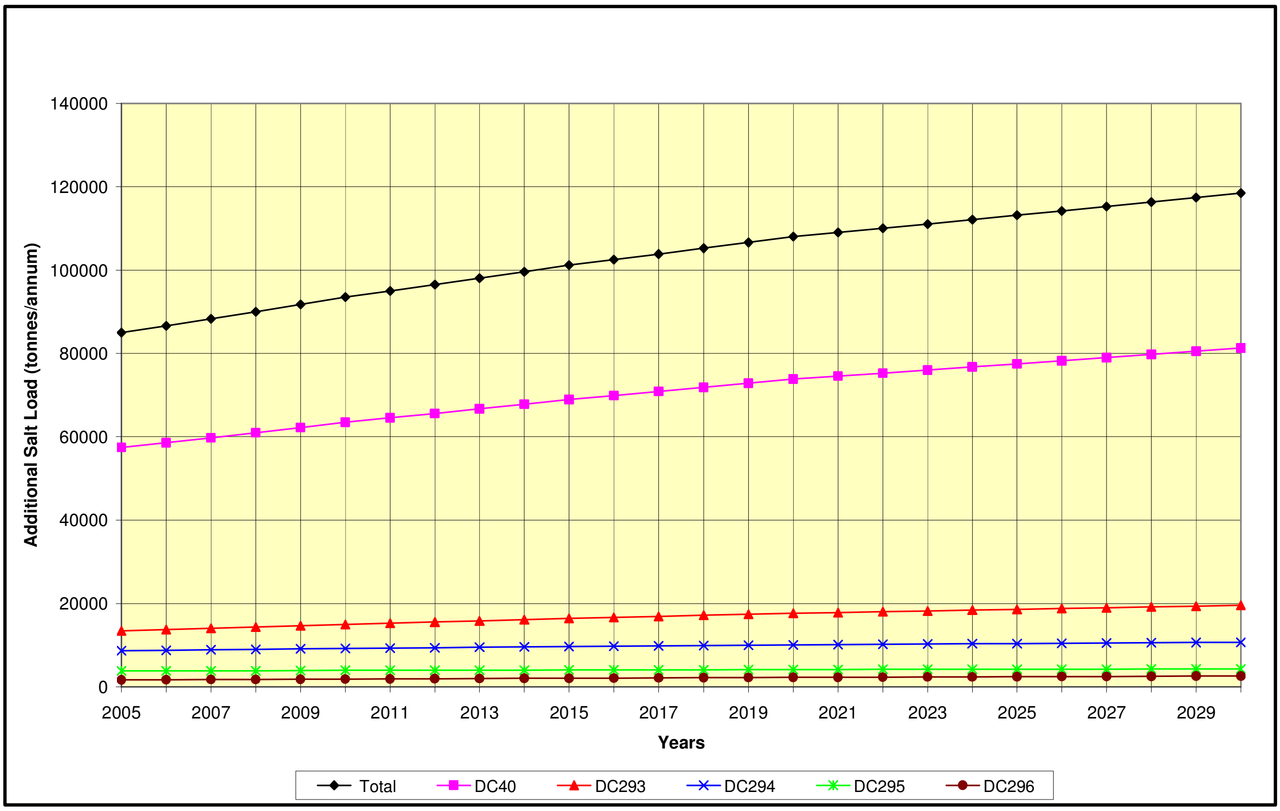


Figure B.8.1: Comparison of additional annual salt loads of Rand Water DCMs

B.8.3 RE-CONFIGURATION OF MIDVAAL WATER COMPANY DCM

Midvaal Water Company (WC) supplies water to a number of municipalities and mines located in the Middle Vaal Catchment. Midvaal WC abstracts water directly from the Vaal River just downstream of its confluence with the Renoster River and the abstractions and return flows are simulated within the WRPM by means of a DCM (DC84). For the purposes of the Vaal River System Annual Operating Analysis (AOA) it was acceptable to model a single return flow channel (WRPM channel 128) representing the total discharges from the Waste Water Treatment Works (WWTW) of all the relevant municipalities supplied by Midvaal WC.

However, since the detailed Schoonspruit Sub-system configuration (refer to **Section B.4.1**) has been included in the WRPM configuration, it was necessary to make some refinements in terms of the waste water discharges of the Klerksdorp WWTW. The water requirements of Klerksdorp Municipality are supplied by Midvaal Water Company (WC), but effluent from the Klerksdorp WWTW is discharged into the Schoonspruit River downstream of Johan Neser Dam. To ensure proper modelling of the water quality, it was therefore necessary to re-configure the Midvaal DCM to allow for two return flow routes. WRPM channel 1724 was included in the configuration of DC84 to represent the discharges of the Klerkskraal WWTW (refer to **Figure J-5** of **Appendix J**).

Since the projected water requirements of Midvaal WC was estimated at 37 million m^3/annum, and the return flows from the Klerkskraal WWTW and the remaining WWTW were estimated at 6.72 and 1.35 million m^3/annum respectively (i.e. a total of 8.07 million m^3/annum), the return flow factor was adjusted from 2.3% to 21.8%. Furthermore, the return flow ratios associated with the two discharge routes (channels 128 and 1724) were calculated based on the relative return flow volumes. Consequently it was assumed that 16.7% of the total return flow would be routed through Channel 128 and the remaining 83.3 % through channel 1724.

The projected additional salt loads were also re-assessed (file DC84.SLD). A TDS concentration of 250 mg/l was applied to the total return flow of 8.07 million m^3/annum and an additional salt load of 2018 tonnes/annum was calculated. A uniform monthly distribution was adopted to determine the monthly salt loads. The proportioning of the additional salt loads to be allocated to each of the return flow routes was based on the same ratios that were derived for the return flows.

B.8.4 RE-CONFIGURATION OF BLOEMHOF INCREMENTAL CATCHMENT

When the Middle Vaal catchment was configured for the WRPM as part of the VRSAU Study, the system network was set up to account for a proper water balance. The main tributaries were, however, not configured to enter the main stem of the Vaal River at the exact locations. The positions of where the Mooi and Schoonspruit rivers enter the Vaal River, therefore, needed to be updated in order to produce salinity simulation results at selected location in the Vaal River System. These water quality monitoring points were identified as part of the Integrated Water Quality Management Plan Study (**DWAF, 2007b**).

The following changes, which are shown on **Figure J-5** of **Appendix J**, were made to the WRPM configuration:

- The outflow from the Mooi River Sub-system (WRPM channel 109) was set to enter the Vaal River at node 1796 upstream of the Renoster River's confluence with the Vaal.

- The Schoonspruit River (WRPM channel 1734) was configured to enter the Vaal River at node 1797 upstream of the Vals River's confluence with the Vaal.

B.8.5 DETERMINATION OF NEW PARAMETER FILE

Owing to the hydrology updates of selected sub-systems as described in **Section B.3** and the re-assessment of the Bloemhof Dam Incremental hydrology (refer to **Section B.3.4**), it was necessary to create a new parameter file that would reflect the proper cross-correlations amongst the different hydrology sets. The new parameter file (PARAMK6.DAT) includes 197 hydrology sets and was incorporated in the WRPM configuration adopted for the Second Stage analyses.

B.8.6 MODELLING OF SMALL DAMS IN THE MIDDLE VAAL CATCHMENT

The WRPM configuration for the IVRS that was adopted for the First Stage Reconciliation Strategy did not include short-term yield reliability curves for Allemanskraal, Erfenis, Koppies, Klerkskraal, Boskop, Klipdrift, Rietspruit and Johan Neser dams. These dams supply water to users that do not have access to the main stem of the Vaal River and in most cases these dams operate independently. In the past these dams and the users supplied from them were included in the system network, however, no curtailment rules were available or had been applied as part of past AOA studies. With the new capability that had been built into the WRPM, it was possible to implement independent curtailment rules for sub-systems and dams such as these.

The development of short-term yield curves for Allemanskraal, Erfenis, Koppies, Klipdrift and the Mooi River Sub-system (comprising of Klerkskraal, Boskop and Lakeside dams) were undertaken as part of the 2007/2008 AOA. The short-term yield curves and the necessary refinements to the individual sub-systems were, therefore, incorporated in the WRPM configuration. These changes included the definition of allocation rules for each of the sub-systems. The updated system configurations are shown in **Figure J-5** of **Appendix J** and detailed information on the modelling of these small dams can be found in the 2007/2008 AOA report (**DWAF, 2008**).

It is important to note that the short-term yield curves could not be developed for the Schoonspruit dams (Rietspruit and Johan Neser) as the functionality to model the outflows from the Schoonspruit eye stochastically was not available at the time.

B.8.7 ADJUSTMENT OF SALINITY PARAMETERS OF VAALHARTS IRRIGATION MODULES

Comparisons between observed and simulated TDS concentrations in the Harts River System showed that the simulated TDS concentrations associated with inflows to Spitskop Dam were significantly higher than the observed values which were in the order of 800 mg/l. Since the irrigation return flows of the Vaalharts Irrigation Scheme, which enter the Harts River upstream of Spitskop Dam, were the only sources of additional salt loads, the salinity results of the revised irrigation modules (RR370, RR379 and RR383) were compared against the salinity results of the original irrigation modules which were calibrated as part of the VRSAU Study. The simulated salinity results of the irrigation modules that were revised as part of the Feasibility Study for the Utilisation of Taung Dam (**DWAF, 2007c**) proved to be significantly higher. In order to obtain realistic results it was, therefore, necessary to adjust the calibrated salinity parameters values. Consequently, the values of the parameters "proportion of salt loss to deep storage" and "initial salt storage in the lower zone" were adjusted to obtain the desired impact. An iterative approach was adopted for the adjustment of these parameter values within the three Vaalharts irrigation modules. The original and final revised parameter values are shown in **Table B.8.4**.

Table B.8.4: Original and adjusted salinity parameter values (Vaalharts Irrigation Scheme)

Irrigation Module No.	Original salinity parameter values		Revised salinity parameter values	
	RRPSL [(1)] (factor)	RRSSLI [(2)] (mg/l)	RRPSL [(1)] (factor)	RRSSLI [(2)] (mg/l)
RR370	0.028	4200	0.14	1400
RR379	0.028	4200	0.14	1400
RR383	0.028	4200	0.14	1400

Note: [(1)] RRPSL: Proportion of salt loss to deep storage

[(2)] RRSSLI: Initial salt storage in the lower zone

B.8.8 ADJUSTMENT OF SALINITY PARAMETERS OF VALS RIVER IRRIGATION MODULES

Irrigation activities within the Vals River catchment were originally (as part of the VRSAU Study) modelled by means of irrigation modules. When the irrigation water requirements were updated based on the results of Vaal River Irrigation Study (DWAF, 1999) all the irrigation modules upstream of Bloemhof Dam were deactivated and the net irrigation demands were imposed on the water resources of the system. Irrigation modules were again created as part of the Second Stage of this study to replace the net irrigation demands. As shown in **Section B.5.2.6**, two irrigation modules, RR332 and RR334, representing irrigation supplied from farm dams and irrigation supplied from direct river abstractions respectively, were created for the Vals River catchment. Since the simulated salinity results corresponding to the outflow of the Vals River were significantly higher than the observed salinity values, it was necessary to adjust the values of the salinity parameters of the two irrigation modules.

For the dummy dam irrigation, Irrigation Module RR332, adjustments were only made to the value of the parameter "proportion of salt loss to deep storage". However, for the mainstream irrigation (Irrigation Module RR334) which represents the largest irrigation area in the Vals River catchment, the values of the parameters "proportion of salt loss to deep storage", "initial salt storage in the upper zone" and "initial salt storage in the lower zone" were adjusted to obtain the desired TDS concentration of approximately 450 mg/l. An iterative approach was again adopted for the adjustment of these parameter values. The original and final parameter values are shown in **Table** B.8.5.

Table B.8.5: Original and adjusted salinity parameter values (Vals River Irrigation)

Irrigation Module No.	Original salinity parameter values			Revised salinity parameter values		
	RRPSL [(1)] (factor)	RRSSUI [(2)] (mg/l)	RRSSLI [(3)] (mg/l)	RRPSL [(1)] (factor)	RRSSUI [(2)] (mg/l)	RRSSLI [(3)] (mg/l)
RR332	0.006	674.75	1319.14	0.015	674.75	1319.14
RR334	0.003	1032.82	2154.29	0.010	900.0	900.0

Note: [(1)] RRPSL: Proportion of salt loss to deep storage

[(2)] RRSSUI: Initial salt storage in the upper zone

[(2)] RRSSLI: Initial salt storage in the lower zone

B.8.9 VAAL RIVER EASTERN SUB-SYSTEM AUGMENTATION PROJECT (VRESAP)

The configuration of the WRPM that was adopted as basis for the Second Stage of this study included the modelling of the infrastructure and operating rules related to the Vaal River Eastern Sub-system Augmentation Project (VRESAP) pipeline. The VRESAP pipeline and pump station is currently under construction and since the commissioning of the VRESAP several problems were experienced due to unforeseen circumstances.

Due to construction delays in terms of the permanent pump station at Vaal Dam, it was requested that the following revised information be considered as part of the 2007/2008 AOA:

- **Commissioning Date**: 1 October 2008 (note that 1 November 2007 was adopted for the 2006/2007 AOA and the First Stage of this study);

- **Maximum transfer capacity:** The design capacity of the pipeline was given as 5.4 m^3/s (467 Ml/d) or 170 million m^3/a by the VRESAP Consultants (W le Roux). It was, however, confirmed with DWAF (P Pyke and W van der Westhuizen) that a maximum transfer capacity of 160 million m^3/a (5.07 m^3/s) should be adopted for the 2007/2008 AOA.

- **Vaal Dam minimum operating level**: The VRESAP Consultants requested that a minimum operating level of 67% (1481.5 masl) be maintained in Vaal Dam to allow pumping from a temporary floating pump station until such time as construction of the permanent pump station is completed. It is anticipated that this Minimum Operating Level (MOL) would be required for a 12 to 24 month period starting from 1 October 2008 onwards. The maximum release capacity of 70 m^3/s (i.e. 187.5 million m^3/month) from Sterkfontein Dam was identified as a potential constraint and it was realised that timely releases from Sterkfontein would have to be made to ensure that Vaal Dam is at the required MOL on 1 October 2008. Through preliminary calculations and subsequent scenario analysis it was determined that the 67% storage level in Vaal Dam should be set as a MOL from 1 April 2008 (i.e. six months prior to the VRESAP commissioning date).

The above-mentioned information was included in the WRPM configuration used for the planning scenario analyses of the Second Stage.

B.8.10 AUGMENTATION OF KOMATI SUB-SYSTEM CONVEYANCE INFRASTRUCTURE

Eskom commissioned a study in 2005 to analyse and evaluate alternative options to increase the supply capability of the existing conveyance infrastructure of the Komati Sub-system. The analysis required detail modelling of the Komati Sub-system. The detail Komati Sub-system configuration based on the infrastructure augmentation option (Option 2a) recommended by Eskom was, included in the 2006/2007 AOA . Option 2a assumed the supply of 1m^3/s from the Vaal into the Olifants using the river as a conveyance route to supplement Duvha's water requirements via Witbank Dam and Naauwpoort Pump Station. This option included the construction of a desalination plant at Naauwpoort. It was assumed that the desalination plant would be active in May 2008.

However, a study recently undertaken by Africon indicated that the construction of a pipeline from Rietfontein to Duvha (with maximum transfer capacity of 1m^3/s) would be a more cost effective alternative option. The commissioning date of the recommended pipeline was assumed to be January 2010. Furthermore, Eskom also provided a monthly demand distribution pattern to be used for the Eskom Power Stations as shown in **Figure B. 8.2**. This updated information was included in the WRPM configuration of the Second Stage.

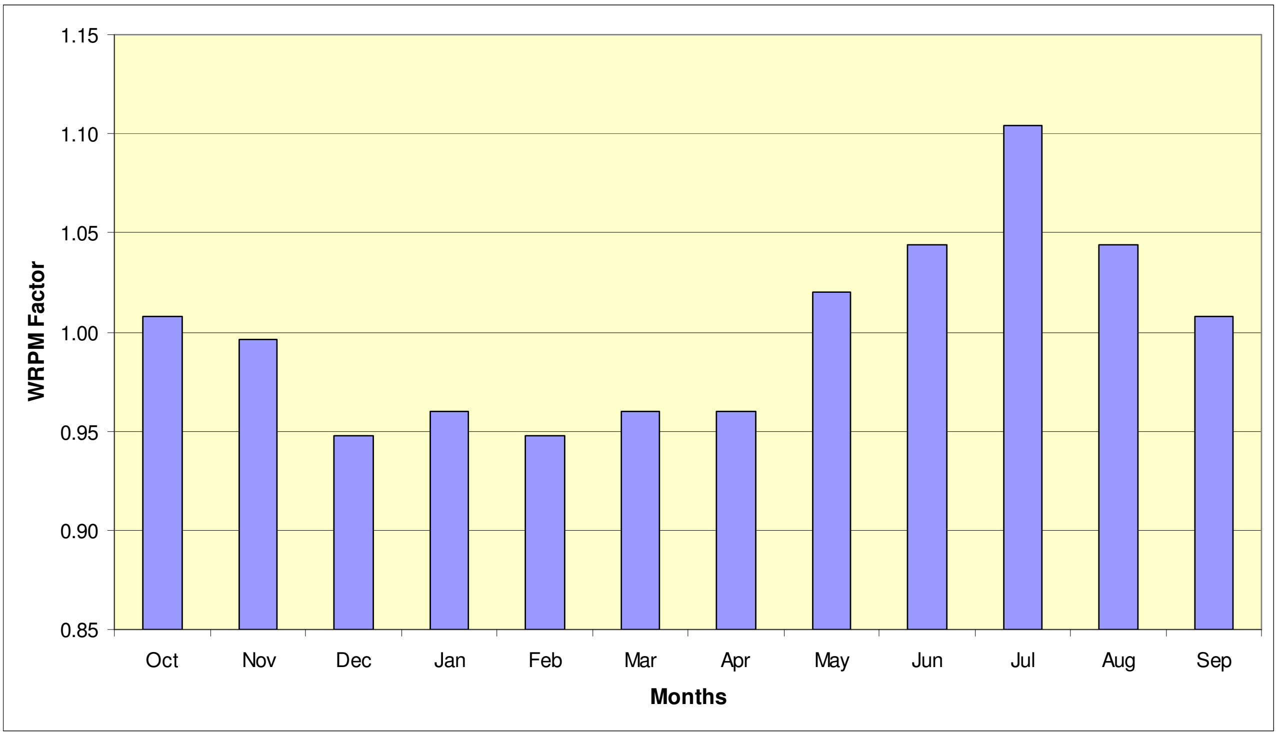


Figure B. 8.2: Monthly demand distribution for Eskom Power Stations

B.8.11 CONFIGURATION OF THE POLIHALI AUGMENTATION OPTION

As mentioned in **Section B.7.2**, the first phase of the Lesotho Highlands Further Phases (LHFP) Feasibility Study indicated that the Polihali Dam with transfer infrastructure was the preferred LHFP option. It was decided to undertake detailed planning analysis only for the Polihali Dam option. The information on the Polihali Dam option obtained from the LHPH Feasibility Study was subsequently incorporated in the WRPM configuration as shown in **Figure K-4** of **Appendix K**. It is important to note that the Polihali Dam option as shown in **Figure K-4** was only included in the analyses of selected scenarios.

The agreed VRSAU Study hydrology + 1% of the Mean Annual Runoff (MAR) was used for the LHFP Feasibility Study. It was, therefore, necessary to increase the VRSAU Study hydrology that has been included in the WRPM database with 1%.

The area-capacity characteristics of Polihali Dam is summarised in **Table B.8.6**. It was assumed that Polihali Dam with a Full Supply Capacity (FSC) of 1857.24 million m^3 will be commissioned in May 2018.

Table B.8.6: Area-capacity characteristics of Polihali Dam

Elevation (masl)	Capacity (million m^3)	Surface Area (km^2)	Comments
1920.00	0.00	0.00	Bottom
1950.00	27.22	2.00	
1970.00	89.09	4.37	
1990.00	212.98	8.27	
1995.00	257.56	9.53	
2000.00	308.22	10.82	
2009.00	417.85	13.29	Minimum Operating Level (MOL)
2010.00	430.03	13.56	
2020.00	581.17	16.72	
2030.00	768.11	20.81	
2040.00	1002.80	25.87	
2045.00	1140.89	29.25	
2055.00	1465.76	35.73	
2060.00	1652.79	39.13	
2065.00	1857.24	42.67	Full Supply Level (FSL)
2075.00	2322.19	50.42	

The Polihali-Katse transfer tunnel is modelled by means of WRPM channel number 1394. It was assumed that this tunnel will be commissioned in **May 2019**. A hydraulic relationship of the future Polihali-Katse transfer tunnel was used to determine the water to be transferred by gravity from Polihali to Katse. The rate of flow between Polihali and Katse dams depends on the relative levels of storage in these dams. The relationship between the difference in head and the rate of transfer as obtained from the LHFP Study is given in **Table B.8.7** and was incorporated in the WRPM configuration.

Table B.8.7: Polihali Dam to Katse Dam transfer relationship

Head difference (m)	**0.00**	**1.70**	**2.90**	**4.60**	**5.70**	**8.90**	**11.60**	**18.10**	**26.00**	**35.30**
Transfer (m^3/s)	0.00	7.50	10.00	12.50	14.00	17.50	20.00	25.00	30.00	35.00

An environmental release of 15% of the MAR had to be released from Polihali Dam. The environmental releases were simulated in the WRPM using a channel (WRPM channel number 1395) that routes the environmental water requirements from an inflow node upstream of Polihali Dam (Node 365) to a node just downstream of the dam (Node 122). This was done to ensure that the environmental releases have first priority compared to transfers made to Katse Dam.

B.8.12 CONFIGURATION FOR PRELIMINARY ECOLOGICAL RESERVE ASSESSMENT

The Comprehensive Reserve Determination Study for the Integrated Vaal River System was commissioned by the DWAF (Chief Directorate Resource Directed Measures) in February 2007. Since the study is being undertaken over a period of 3 years, it was anticipated that the final Ecological Reserve (ER) results would not be available for this study.

Consequently, it was decided to assess the impact of implementing the preliminary Ecological Water Requirements (EWR). The EWR information obtained from the Chief Directorate Resource Directed Measures for the preliminary assessment was mainly determined through low confidence determination methods. The scenario results based on this information, therefore, only serve as a preliminary indication of what the reconciliation situation would be if the EWRs are implemented.

Similar to the First Stage analyses, EWR sites were identified downstream of al the major dams within the IVRS and a total of 28 sites were included in the WRPM configuration. **Table B.8.8** lists all the major dams for which EWR sites were defined, as well as the associated WRPM channels through which the EWR releases are being made. It is important to note that the actual release capabilities of the individual dams were not taken into account. It was thus assumed that it would be possible to release the EWRs through the existing outlet works of all the dams without any constraints.

Table B.8.8: List of major dams and their corresponding EWR release channels

Dam/Weir Name	WRPM Channel No.
Gladdespruit Weir	1052
Nooitgedacht Dam	1059
Morgenstond Dam	1046
Westoe Dam	1038
Jericho Dam	1039
Heyshope Dam	1040
Zaaihoek Dam	1041
Woodstock Dam	1042
Sterkfontein Dam	1043
Grootdraai Dam	247
Vaal Dam	248
Boskop Dam	249
Klipdrift Dam	291
Koppies Dam	293
Allemanskraal Dam	294
Erfenis Dam	295
Johan Neser Dam	292
Bloemhof Dam	645
Vaalharts Weir	297
Wentzel Dam	1033
Taung Dam	1034
Spitskop Dam	1035
Douglas Weir	1036
Rustfontein Dam	1057
Krugersdrift Dam	1037
Tierpoort Dam	1055
Kalkfontein Dam	1056
Lillydale	1054

B.9 FUTURE INTERVENTION REQUIREMENTS

B.9.1 OVERVIEW

The following intervention options were considered for the Integrated Vaal River System (IVRS):

- Alternative WC/WDM initiatives;
- The LHFP augmentation option (Polihali Dam and gravity conveyance infrastructure);
- The Thukela Water Project (TWP) augmentation option (Jana and Mielietuin dams with their pumping conveyance infrastructure).

Given the base water requirement and return flow scenario provided in **Chapter B.5** and the alternative demand scenarios presented in **Chapter B.6**, the need for intervention (when further WC/WDM measures and/or the development of an augmentation scheme is required) can be determined by assessing the water reconciliation (water balance) situation over the planning period. This was undertaken by firstly defining the planning scenarios and, secondly, carrying out scheduling analysis to determine the date at which further intervention would be required.

Since the water balance of the Orange River System (ORS) is affected by the operating rules and intervention options considered for the Vaal River System, it was necessary to undertake a combined assessment of the Vaal and Orange River systems. Previous analyses indicated that dilution options result in surplus water that becomes available in Bloemhof Dam. The surplus water in Bloemhof Dam can, in turn, be utilised to meet the water requirements of the Lower Orange River System. The Lower Orange River Management Study (LORMS) indicated that the ORS requires augmentation in 2015. Furthermore, as mentioned in **Section B.7.2** the implementation of the Polihali Dam option, will cause a reduction in the ORS yield. The WRPM configuration of the IVRS that was used for the planning scenario analyses includes the ORS.

In summary the purpose of the WRPM analyses was as follows:

- To assess the timing of interventions;
- To determine the surplus water available in Bloemhof Dam that can be used to support the water requirements of the Lower Orange System;
- To assess the impact of different possible intervention options (as listed above);

- To assess the impact of alternative water quality scenarios; and
- To assess the impact of implementing the preliminary Ecological Water Requirements (EWR) in the IVRS.

To this end, a number of planning scenarios were defined. The selected planning scenarios comprised of the following main components:

- Alternative water requirement scenarios;
- Identified WC/WDM interventions;
- Possible infrastructure augmentation options; and
- Identified water quality management options.

It is important to note that a comprehensive list of planning scenarios was compiled to assess the impact of a range of feasible alternative management options in terms of both water quantity and quality. Not all of the identified scenarios were, however, analysed with the WRPM. The strategy was to identify and analyse a base scenario and to use the base scenario results as benchmark for the selection of alternative scenarios to be analysed with the WRPM.

The planning scenarios are described in **Section B.9.2,** the basic assumptions adopted for all the scenarios are summarised in **Section B.9.3** and the results of the planning analyses are presented in **Section B.9.4**. It should be noted that the WRPM run labels given in brackets are for reference purposes only and identify the computer file names for each of the scenarios analysed with the WRPM.

B.9.2 DESCRIPTION OF PLANNING SCENARIOS

Although twenty planning scenarios were formulated for analysis and/or evaluation, only seven were analysed with the WRPM. The seven scenarios selected for analysis covered a range of possible future conditions and interventions as described in the following sections.

B.9.2.1 Scenario 1a (V07R1ABP): Demand Scenario D_2 and current management practice

The purpose of this scenario was to assess the current management practices within the IVRS and included the following assumptions:

- **Urban water requirements and return flows**: The **Scenario D_2** demand and return flow projections presented in **Table L-2** of **Appendix L** were adopted for this planning scenario.
- **Irrigation Scenario 1**: Curtailment of unlawful irrigation water use was applied (see **Section B.5.4** for details).
- **Intervention option**: The recommended Polihali Dam and conveyance infrastructure option (refer to Section **B.8.11**) was included in the WRPM configuration used for this scenario.
- **TDS treatment scenario:** No treatment of mine and industrial effluent discharges was considered.
- **Rand Water's source of supply:** It was assumed that Rand Water is supplied directly from Vaal Dam.
- **Dilution option:** Releases have to be made from Vaal Dam to maintain a TDS concentration of 600 mg/l downstream of the Vaal Barrage.

Based on the dilution option mentioned above, it was expected that an increasing trend in the projected storage volumes would occur within Bloemhof Dam. It was assumed that the excess water available in Bloemhof Dam could be used to augment the water supply to the Lower Orange River System.

The following stepwise approach was adopted for the assessment of the impact of different assumptions of **Scenario 1a:**

- Analyse the IVRS by using the WRPM configuration that excludes the Polihali Dam option. The results from this initial analysis would then indicate the date at which the recommended LHFP option would be required.
- Determine the excess water that can be supplied from Bloemhof Dam to the Lower Orange River System.

- Assess the impact on the IVRS when incorporating the Polihali Dam option and supplying the Bloemhof Dam's excess water to the Lower Orange System.

B.9.2.2Scenario 1b (VT07R1B): Alternative dilution option (450 mg/l)

The purpose of this scenario was to assess the impact of maintaining a TDS concentration of 450 mg/l downstream of Vaal Barrage. With the exception of the Polihali Dam option (which was not included for this scenario) and the alternative dilution option, the remainder of the assumptions that were adopted for **Scenario 1b** is identical to that of **Scenario 1a**. Similar to **Scenario 1a** Bloemhof Dam's excess water supply to the Lower Orange River was also determined for this scenario.

B.9.2.3Scenario 1c (VT07R1C): Treatment of mine and industrial discharges

The purpose of **Scenario 1c** was to evaluate the impact of direct reuse of mine and industrial discharges and the subsequent removal of salinity in the relevant catchments.

The basic assumptions adopted for **Scenario 1c** are similar to that of **Scenario 1b** with the following exception:

- **TDS treatment scenario:** The treatment of mine and industrial effluent discharges as indicated in **Table B. 9.1** was included in the WRPM configuration.

Table B. 9.1: Summary of treated mine and industrial discharges

Description of source	WRPM File name	WRPM Channel No.	Catchment	Recipient of treated effluent
Mines in Western Basin	Westm.Q/TDS	890	Klip	Rand Water
Mines in Central Basin	Centm.Q/TDS	848	Klip	Rand Water
Mines in Eastern Basin	Eastm1.Q/TDS	832	Suikerbosrand	Rand Water
Mines in Eastern Basin	Eastm2.Q/TDS	1028	Suikerbosrand	Rand Water
Mines in Far-Western Basin	Fwestm.Q/TDS	850	Upper Riet	Rand Water
Mines in Wonderfonteinspruit	Bosmdw.Q/TDS	786	Mooi	Rand Water

Description of source	WRPM File name	WRPM Channel No.	Catchment	Recipient of treated effluent
Mines in Middle Vaal	Minew.Q/TDS	167	Middle Vaal	Rand Water
Sasol Secunda	Sasol.Q/TDS-	1357	Waterval	Sasol Secunda Complex
Sasol Sasolburg	-	77	Vaal Barrage	Sasol Sasolburg Complex
Seepage in Waterval catchment	Seepwa.Q/TDS		Waterval	Seepage was set to zero

The treated mine discharges ranged from 107 million m^3/annum in 2007 to about 119 million m^3/annum from the year 2014 onwards. Based on observed data the Sasol Secunda effluent was estimated to be in the order of 4.2 million m^3/annum. The abstraction and industrial effluent of the Sasol Sasolburg Complex is modeled by means of a Demand Centre Module (refer to DC84 shown in **Figure J-4** of **Appendix J**). The resulting treated effluent considered for reuse by Sasol Sasolburg was in the order of 17.2 million m^3/annum in 2007 and increased to about 21.9 million m^3/annum in 2018 after which it was assumed to remain constant. A TDS concentration 200 mg/l was used for all the treated effluent.

B.9.2.4Scenario 1c1 (VT07R1C1): Treatment of selected mine discharges

The purpose of **Scenario 1c1** is to evaluate the impact of partial reuse of mine discharges. To this end, **Scenario 1c1** was based on **Scenario 1c**, but only the discharges of selected mines listed in **Table B.9.2** were treated and reused by Rand Water.

Table B.9.2: Summary of mine discharges selected for partial reuse option

Description of source	WRPM File name	WRPM Channel No.	Catchment	Recipient of treated effluent
Mines in Central Basin	Centm.Q/TDS	848	Klip	Rand Water
Mines in Eastern Basin	Eastm1.Q/TDS	832	Suikerbosrand	Rand Water
Mines in Eastern Basin	Eastm2.Q/TDS	1028	Suikerbosrand	Rand Water

The treated mine discharges ranged from 23.8 million m^3/annum in 2007 to about 37.2 million m^3/annum from the year 2014 onwards (i.e. a reuse of almost 69% less compared to **Scenario 1c**). A TDS concentration of 200 mg/l was used for all the treated effluent. The surplus water available in Bloemhof Dam to support the water requirements of the Lower Orange System was also assessed for this scenario

B.9.2.5Scenario 2a (VT07R2A): Demand Scenario B2 and current management practice

Scenario 2a is an alternative to **Scenario 1a** in terms of the demand projection scenario that was used for the assessment. Therefore, with the exception of the following changes, the assumptions adopted for **Scenario 2a** is identical to that of **Scenario 1a:**

- **Urban water requirements and return flows**: The **Scenario B_2** demand and return flow projections presented in **Table L-1** of **Appendix L** were adopted for this planning scenario.
- **Intervention option**: The recommended Polihali Dam and conveyance infrastructure option (refer to Section **B.8.11**) was not included in the WRPM configuration used for this scenario.

The Bloemhof excess support to the Lower Orange System was also determined for this scenario. A planning period of 19 years was considered and 1000 stochastic sequences were analysed.

B.9.2.6Scenario 3 (VT07R03): Rand Water supplied from Vaal Barrage (Blending Option)

Scenario 3 is another alternative to **Scenario 1a** with the purpose of assessing the impact of supplying Rand Water from the Vaal Barrage and to allow for blending with water from Vaal Dam to maintain a TDS concentration of 300 mg/l. The assessment was based on 100 stochastic sequences and a planning period of 19 years.

B.9.2.7Scenario 8a (VT07R08): No water quality management

This scenario was based on **Scenario 3**. In essence, the no water quality management option adopted for **Scenario 8a** incorporated the following changes in terms of the WRPM configuration:

- **Rand Water's source of supply:** It was assumed that Rand Water is supplied from Vaal Barrage and no blending is made with releases from Vaal Dam (i.e. the TDS concentration of the water that was supplied to Rand Water was not controlled).

- **Dilution option:** No releases were made from Vaal Dam to maintain a specified TDS concentration downstream of the Vaal Barrage.

Scenario 8a assumptions allow for the maximum utilization of mine and urban discharges in the Vaal Barrage catchment. A planning period of 24 years and 1000 stochastic sequences were analysed for this scenario.

B.9.2.8 Summary of planning scenarios

The planning scenarios described in **Sections B.9.2.1** to **B.9.2.7**, as well as the scenarios identified for the reconciliation assessments, are summarised in **Table B.9.3**.

Table B.9.3: Summary of planning scenarios

Planning Scenario No.	WRPM Run Reference	Water Use Scenario	Intervention Option Included	Water Quality Scenario	Purpose
1a	V07R1ABP	D_2	LHFP (Polihali Dam)	• No TDS treatment • Rand Water supplied from Vaal Dam • Dilution to 600 mg/l in Vaal Barrage	Assessment of: • Current management practices • Augmentation from Polihali Dam option • Supply of excess water in Bloemhof Dam to ORS
1b	VT07R1B	D_2	None	• No TDS treatment • Rand Water supplied from Vaal Dam • Dilution to 450 mg/l in Vaal Barrage	Assessment of: alternative dilution rule
1c	VT07R1C	D_2	Reuse of mine and industrial discharges	• Treatment of mine and industrial discharges • Rand Water supplied from Vaal Dam • Dilution to 450 mg/l in Vaal Barrage	Evaluate impact of direct reuse of water and the removal of salinity.
1c1	VT07R1C1	D_2	Partial reuse of mine discharges	• Treatment of selected mine discharges • Rand Water supplied from Vaal Dam • Dilution to 450 mg/l	Evaluate direct partial reuse of water and the removal of salinity.

Planning Scenario No.	WRPM Run Reference	Water Use Scenario	Intervention Option Included	Water Quality Scenario	Purpose
				in Vaal Barrage	
1d (#)	-	D_2	• LHFP • Orange (Vioolsdrift Dam)	• Treatment of mine and industrial discharges • Rand Water supplied from Vaal Dam • Dilution to 450 mg/l in Vaal Barrage • Implement additional releases from Vaal Dam for nutrient management	This scenario included the reuse of mine and industrial discharges and was only necessary if Scenario 1c did not prove sufficient mixing for nutrient management.
2a	VT07R2A	B_2	None	• No TDS treatment • Rand Water supplied from Vaal Dam • Dilution to 600 mg/l in Vaal Barrage	Assessment of alternative water requirement and return flow scenario (Alternative to Scenario 1a).
2b (#)	-	B_2	• TWP • Orange (Vioolsdrift Dam)	• No TDS treatment • Rand Water supplied from Vaal Dam • Dilution to 600 mg/l in Vaal Barrage	Assessment of alternative reconciliation strategy (Alternative to Scenario 2a).
3	VT07R03	D_2	None	• No TDS treatment • Rand Water supplied from Vaal Barrage • Blend RW supply to 300 mg/l with water from Vaal Dam • Dilution to 600 mg/l in Vaal Barrage	Assessment of alternative source of supply for Rand Water (Alternative to Scenario 1a).
4 (#)	-	D_2	• LHFP • Orange (Vioolsdrift Dam)	• Best strategy from scenarios 1 to 3	Assess the situation if the EWR is implemented.
5 (#)	-	J_2	• LHFP • Orange (Vioolsdrift Dam)	• Best strategy from scenarios 1 to 3	Purchase of irrigation water rights (trading) – based on water use scenario B_2.
6 (#)	-	D_2	• TWP • Orange (Vioolsdrift Dam)	• Best strategy from scenarios 1 to 3	Evaluate TWP as alternative to LHFP for water use scenario D_2
7 (#)	-		• Taung Dam • TWP/Orange (Vioolsdrift Dam)	• Best strategy from scenarios 1 to 3	Options relating to the utilisation of Taung Dam.

Planning Scenario No.	WRPM Run Reference	Water Use Scenario	Intervention Option Included	Water Quality Scenario	Purpose
8a	VT07R08	D_2	None	• No water quality management • Rand Water supplied from Vaal Barrage	Alternative base scenario excluding the EWR.
8b (#)	VT07R08A	D_2	None	• No water quality management • Rand Water supplied from Vaal Barrage	Alternative base scenario including the EWR.
9 (#)	-	H_2	• LHFP and/or • TWP • Orange (Vioolsdrift Dam)	• As for Scenario 1a	Based on high demand scenario for Eskom. Assess projected net system balance.
10a (#)	-	I_2	• LHFP • TWP • Orange (Vioolsdrift Dam)	• As for Scenario 1a	Apply water use scenario H_2 with Rand Water's questionnaire scenario compiled in 2004.
10b (#)	-	I_2 plus WC/WDM	• LHFP • TWP • Orange (Vioolsdrift Dam)	• As for Scenario 1a	Same as for Scenario 10a with water use scenario C_2 (WC/DM).
11a (#)	-	K_2	• LHFP • Orange (Vioolsdrift Dam)	• As for Scenario 1a	Based on water use scenario B_2 and Eskom's slow program for the decommissioning of Power Stations.
11b (#)	-	K_2	• TWP • Orange (Vioolsdrift Dam)	• As for Scenario 1a	Based on water use scenario B_2 and Eskom's slow program for the decommissioning of Power Stations.
12 (#)	-	D_2	Availability due to global warming	• As for Scenario 1a	Perspective on global warming.

Note:	(#)	These scenarios were not analysed with the WRPM. Reconciliation strategies for these scenarios were inferred based on the results of the WRPM analyses.

B.9.3 BASIC ASSUMPTIONS FOR PLANNING SCENARIOS

The operating scenario (VT07H01) of the 2007-2008 Annual Operating Analysis (AOA) of the IVRS was adopted as basis for the analysis undertaken as part of the Second Stage of this study.

Analyses were undertaken for 100 and/or 1000 stochastic sequences. The basic assumptions that were common to all the scenarios described in **Section B.9.2** are listed below. It should be noted that some of the operating levels selected for the dams situated in the Vaal River Eastern Sub-system are linked to the commissioning date of the Vaal River Eastern Sub-system Augmentation Project (VRESAP).

The basic assumptions were as follows:

- **Starting conditions:** The actual dam storages and TDS concentrations as recorded on 1 May 2007 were adopted as the starting conditions for the WRPM analysis. The total Vaal River System storage trajectory over the past seven planning years is shown in **Figure** B.9.1. The total system storage is based on the actual storage of major dams within the Integrated Vaal River System (IVRS). Although impoundment at Mohale Dam commenced in November 2002, storage within the dam was only reflected in the total system storage since May 2004. **Figure** B.9.1 illustrates the fact that the starting storage condition for the 2006/2007 planning year represented the highest system storage state ever recorded for the IVRS. The actual dam storages adopted as starting conditions for the 2007/2008 AOA (and for the Second Stage analyses) are 14% (i.e. about 1654 million m^3) less than that of the 2006/2007 planning year.

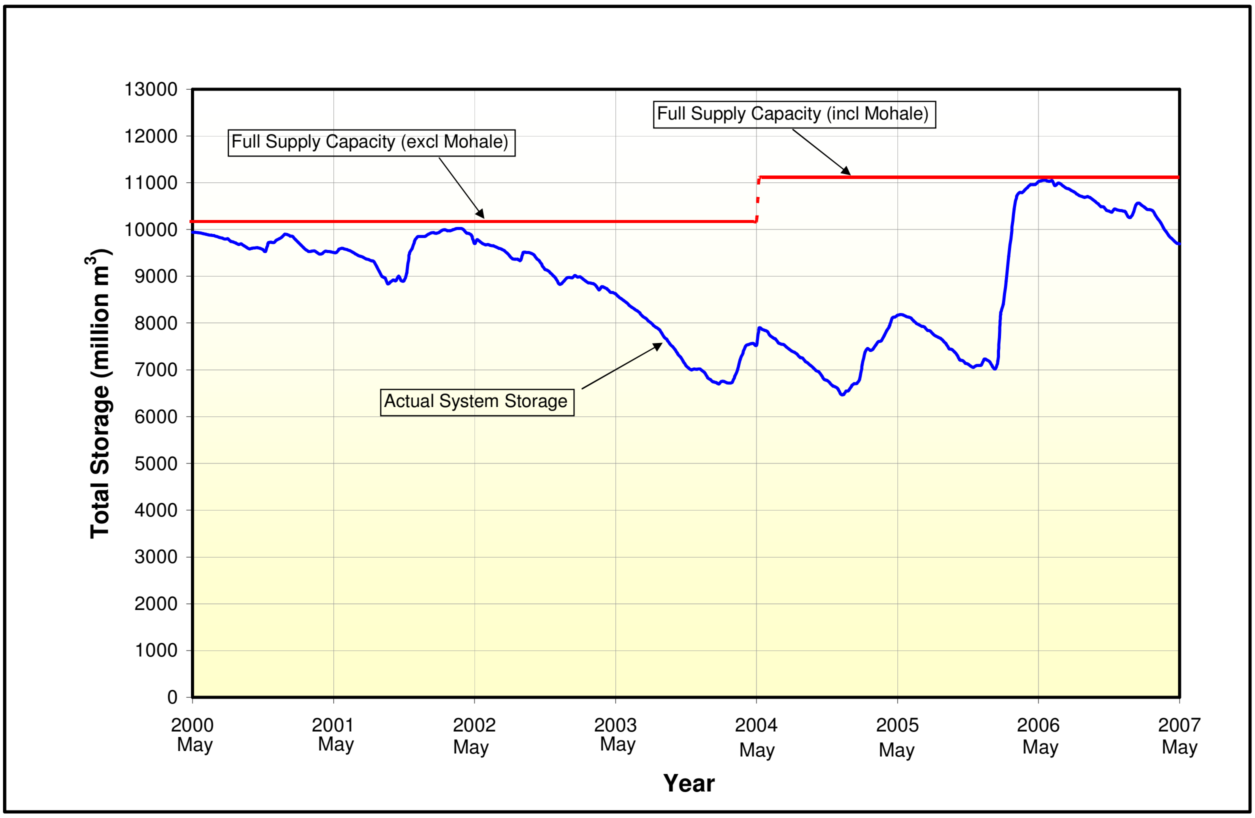


Figure B.9.1: Total Vaal River System Storage (from May 2000 to April 2006)

- **Thukela-Vaal transfer**: No pumping from the Thukela (Woodstock Dam) to Sterkfontein Dam until end of February 2008. Full pumping at 20 m^3/s from 1 March 2008 onwards..
- **Heyshope-Zaaihoek-Grootdraai transfer**: The 90% rule was adopted for the entire period of analysis (i.e. transfer from Heyshope and Zaaihoek dams to Grootdraai Dam when storage within Grootdraai Dam is below the 90% level).
- **Morgenstond-Jericho transfer:** The new pipeline and pump station (commissioned during 2004) is fully operational. A revised transfer relationship was subsequently derived for the total transfer from Morgenstond Dam to Jericho Dam based on information obtained from Mr P Jacobs at Jericho Dam. This revised relationship with a maximum transfer capacity of 3.182 m^3/s (100.4 million m^3/a) was adopted for the analysis. Transfers are regulated by the Usutu inter-reservoir operating rule as revised in 2006 with a maximum transfer capacity of 3.182 m^3/s.
- **Revised Usutu inter-reservoir operating rules**: The most recent inter-reservoir operating rules derived in 2006 were used for the analysis (Draw down sequence: Westoe-Jericho-Morgenstond; Draw down levels: 50%-70%-21%). The inter-reservoir operating rule is illustrated in **Figure B.9.2**.

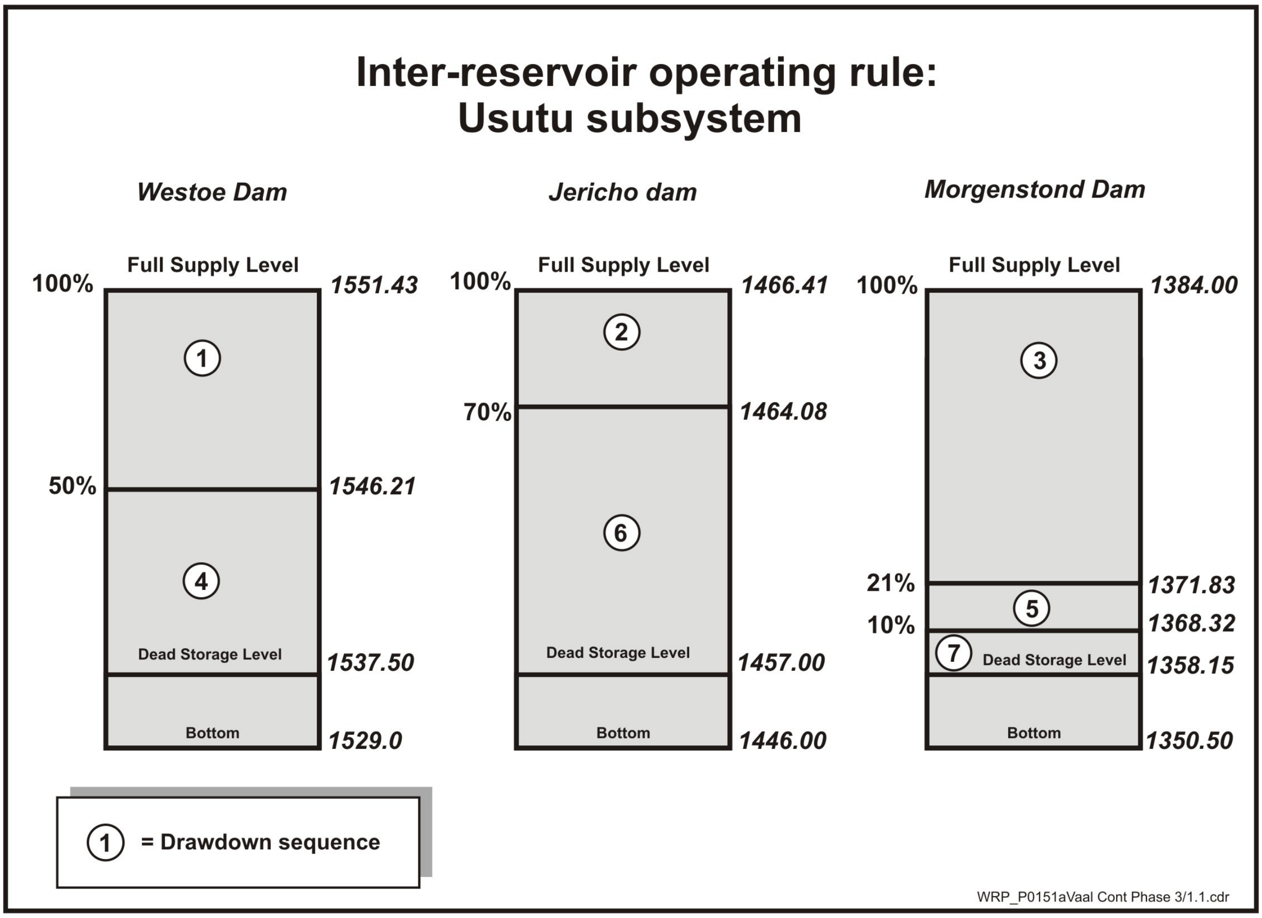


Figure B.9.2: Usutu Sub-system Inter-reservoir Operating Rules

As shown in **Figure B.9.2**, a new minimum operating level (1368.32m with associated storage of 10.763 million m^3) was included for Morgenstond Dam representing the last water to be used in the Usutu Sub-system.

- **Revised short-term curves for Usutu Sub-system**: The short-term yield reliability curves based on the inter-reservoir operating rules derived in 2006 (refer to **Figure B.9.2**) were incorporated in the WRPM configuration.
- **Vaal River Eastern Sub-system Augmentation Project (VRESAP):**
  - **Commissioning date**: 1 October 2008.
  - **Maximum transfer capacity of Vaal pipeline**: 160 million m^3/annum.
  - **Vaal Dam minimum operating level**: Maintain level in Vaal Dam at 1481.5m (67%) for a period of 18 months, i.e. from 1 April 2008 to 1 October 2009. The additional 6 months prior to the VRESAP commissioning date are required to accommodate the maximum release capacity of 70 m^3/s (i.e. 187.5 million m^3/month) from Sterkfontein Dam.
- **Heyshope-Morgenstond transfer:**
  - May 2006 to October 2008: Transfer when Morgenstond Dam is below 35 million m^3 (level of 1375.0 m).
  - October 2008 onwards: Transfer when Morgenstond Dam is below 80 million m^3 (level of 1381.34 m).
- **Heyshope buffer storage:**
  - May 2006 to October 2008: Reserve no water for transfer to the Usutu.
  - October 2008 to May 2018: Reserve storage below 150 million m^3 (level of 1294.54 m).for transfer to the Usutu.
  - May 2018 to end of analysis period: Reserve storage below 58 million m^3 (level of 1289.63 m) for transfer to the Usutu.
- **Grootdaai Dam buffer storage:** Reserve storage below 90% from October 2008 onwards (i.e. from VRESAP commissioning date onwards).
- **Special releases from Westoe:** Allowance was made for three bulk releases, each amounting to 2 million m^3, during August, September and October 2007 to augment the water supply of Sappi's plant in Swaziland.
- **Region B Users**: Modelled within Olifants sub-systems with no support from Vaal system for the full period of analysis.

- **Dilution rule**: Rand Water supplied directly from Vaal Dam with releases from Vaal Dam to limit the TDS concentration to 600 mg/l downstream of Vaal Barrage (based on the dilution functionality incorporated in the WRPM).
- **Senqu sub-system:** Incorporated revised short term curves based on the Mohale-Katse transfer tunnel operating rule and Ecological Reserve water requirements adopted by the LHDA (new functionalities incorporated in the WRPM).
- **LHWP scheduled transfers**: The monthly scheduled transfers amounting to an annual total of 780 million m^3/a for the year 2007 were obtained from the LHDA in January 2007 and were incorporated in the analysis.
- **Compensation releases**:
  - Vygeboom Dam: Release 0.65 m^3/s during the full period of analysis.
  - Nooitgedacht Dam: Release 0.15 m^3/s for full period.
  - Grootdraai Dam: Releases based on normal flow (20 million m^3/a)
  - Zaaihoek Dam: Releases based on normal flow (11.4 million m^3/a)
  - Releases from Katse and Mohale dams modelled by means of the revised IFR structure based on the updated Ecological Reserve requirements.
- **Komati Sub-system conveyance infrastructure**: Eskom indicated that the supply capability of the existing conveyance infrastructure will be increased by means of the following augmentation option:
  - **A new pipeline**: Transferring water from Rietfontein to Duvha Power Station;
  - **Capacity of new pipeline**: 1.0 m^3/s (31.56 million m^3/a);
  - **Anticipated commissioning date**: 1 January 2010.
- **Jericho South line refurbishment:** Maximum transfer capacity of 1.54 m^3/s adopted for transfers from Jericho to Onverwacht during the period 1 May 2007 to 31 August 2007.
- **Operating rules for small dams in Middle Vaal catchment:**
  - Allemanskraal, Erfenis, Koppies and Klipdrift dams were operated as individual sub-systems.
  - Klerkskraal, Boskop and Lakeside dams were modelled as a single sub-system.
  - Short-term yield reliability curves were included for these sub-systems.
- **Bloemhof Dam**: Minimum operating level at 6% (Level of 1219.32m with associated storage of 74.55 million m^3).
- **Vaalharts Weir**: Operate at 90% level (level of 1189.67m).

- **Allemanskraal Dam**: Irrigation users restricted to 15% of their quota which must be used before December 2007.
- **Erfenis Dam**: No restrictions were imposed on users due to the high storage state of the dam.

B.9.4 PLANNING SCENARIO RESULTS

B.9.4.1 General

The behaviour of selected system components (e.g. projected reservoir storages and simulated flows through transfer routes) is presented as probabilistic distribution plots (box plots). A typical box plot indicating the various lines that depict specified exceedance probabilities of a probability distribution is provided in **Figure B.9.3**.

The graphical results of the seven scenario analyses undertaken with the WRPM are given in **Appendices M** through to **S** and the most significant results are highlighted in the sections below.

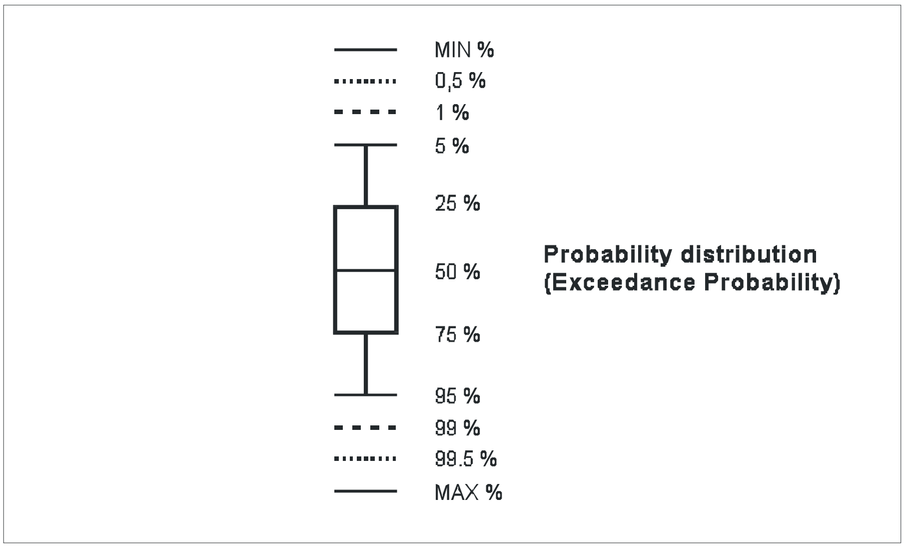


Figure B.9.3: Graphical depiction of a probability distribution or box plot.

It is important to note that the associated water quality results of all the planning scenarios analysed with the WRPM are not presented in this report. The Resource Water Quality Objectives (WRQOs), the approach to the assessing of the water quality results of all the WRPM scenarios, the economic impact of changes in the water quality on water users and the proposed strategies for the management of water quality in the Vaal River System are discussed in a separate report (**DWAF, 2007b**).

B.9.4.2Scenario 1a (VT07R1ABP): Demand scenario D_2 and current management practice

As mentioned in **Section B.9.2.1** the different components of this scenario was analysed in a stepwise approach. The initial analysis of this scenario, which excluded the Polihali Dam option, was based on 100 stochastic sequences and indicated that there was excess water available in Bloemhof Dam (refer to **Figure M-1** of **Appendix M**). This was due to the implementation of the 600 mg/l dilution option whereby releases were made from Vaal Dam to maintain the desired TDS concentration. An assessment was made of the excess water that can be abstracted from Bloemhof Dam in support of the Lower Orange System. The Bloemhof excess support is summarized in **Table B.9.4** and was included in the WRPM configuration used for the next step of the **Scenario 1a** analysis.

Table B.9.4: Bloemhof excess support to Lower Orange System for Scenario 1a

Years	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Excess Support (million m^3/a)	100.0	111.6	124.6	139.0	155.2	173.2	193.3	215.8	240.8	268.8	300.0

A scenario analysis based on 1000 sequences was subsequently undertaken to assess the date at which intervention is required, as well as the impact on Bloemhof Dam when providing the indicated excess support to the Lower Orange System. The curtailment results of this run are shown in **Figure M-2** and indicate that the adopted reliability criteria were violated in the year 2019 (i.e. intervention is needed by 2019). **Figure M-3** shows the corresponding projected storage trajectories of Bloemhof Dam which reflect the draw down of the dam resulting from the excess support to the Lower Orange System.

The Polihali Dam and associated conveyance infrastructure were subsequently included in the WRPM configuration used for the final **Scenario 1a** analysis. A planning period of 19 years was considered for this scenario and the graphical results based on 100 stochastic sequences are also shown in **Appendix M**. The demand-supply and annual total system storage trajectories are shown in **Figures M-4** and **M-5** respectively. The top line on the demand-supply graph (refer to

Figure M-4) shows the demand whereas the projected supply resulting from the curtailments imposed by the allocation procedure of the WRPM is depicted by the box and whiskers appearing below this demand line. **Figure M-5** indicates that the lowest projected system storage for the worst sequence results occurred in the year 2017 and amounted to about 4290 million m^3.

Projected storage trajectories for the major dams in the Vaal River and Senqu sub-systems are shown in **Figures M-6** to **M-12**. The projected response of the proposed Polihali Dam, commissioned in May 2018, is shown in **Figure M-14**.

B.9.4.3 Scenario 1b (VT07R1B): Alternative dilution option (450 mg/l)

The graphical results for this scenario are shown in **Appendix N**. Compared to **Scenario 1a**, it was expected that the 450 mg/l dilution rule adopted for this scenario would cause increased releases to be made from Vaal Dam. As shown in **Figure N-2** storage in Vaal Dam was depleted at the 99.5% probability level from 2011 onwards. Sterkfontein Dam (refer to **Figure N-1**) was also drawn down to relatively low storage levels from 2017 onwards. From the Bloemhof Dam storage trajectories provided in **Figure N-3** it is clear that the 450 mg/l dilution rule is causing Bloemhof Dam to spill frequently. Since the dilution rule applied for this scenario caused a wastage of water in terms of the Vaal River System, it was not rendered as a feasible option to be considered as part of further analyses.

B.9.4.4 Scenario 1c (VT07R1C): Treatment of mine and industrial discharges

This scenario evaluated the impact of direct reuse of water and the removal of salinity as described in **Section B.9.2.3**. The graphical results for Bloemhof Dam are shown in **Figure O-1** of **Appendix O**. Comparison with the results of **Scenario 1b** shows that the reuse of the treated mine and effluent discharges is causing the storage trajectories within Bloemhof Dam to be at much lower levels for **Scenario 1c**. Furthermore, the reuse results in lower TDS concentrations downstream of Vaal Barrage and, therefore, the releases required from Vaal Dam for dilution purposes were less for this scenario. The feasibility of this intervention option will, however, depend on the financial implications associated with the treatment of water at potable standards.

B.9.4.5Scenario 1c1 (VT07R1C1): Treatment of selected mine discharges

This scenario was analysed as an alternative to **Scenario 1c** and evaluated the partial reuse of water as discussed in **Section B.9.4.5**. The graphical storage trajectories for Bloemhof Dam are shown in **Figure P-1** of **Appendix P**. **Figure P-1** shows that there is surplus water available Bloemhof Dam for **Scenario 1c1**. The excess water from Bloemhof Dam was found to be the same as that of **Scenario 1a** (refer to **Table 9.4**). It was, therefore, concluded that the date at which intervention is required date, would be the same as that of **Scenario 1a** (i.e. the year 2019).

B.9.4.6Scenario 2a (VT07R2A): Demand Scenario B_2 and current management practice

This scenario is an alternative to **Scenario 1a** and merely incorporated a higher water demand and return flow projection for the Rand Water supply area (refer to demand **Scenario B_2** discussed in **Section B.5.7**). The graphical results for **Scenario 2a**, which were based on the analysis of 1000 stochastic sequences, are shown in **Appendix Q**.

From the curtailment results presented in **Figure Q-1**, it can be seen that the first violation of the adopted reliability criteria occurs in the year 2016. The higher demand **Scenario B_2** therefore causes the date at which intervention is required to move forward by three years. The higher system demand/supply is shown in **Figure Q-2**. With reference to the total system storage, it is shown in **Figure Q-3** that the lowest projected system storage for the 99.5% exceedance probability occurred in the year 2025 and amounted to about 3000 million m^3.

The storage trajectories of the Komati and Usutu sub-system are presented in **Figures Q-4** and **Q -5** respectively. No failures occurred in the Komati Sub-system, i.e. the sub-system was not depleted at the 99.5% exceedance probability level. In the Usutu Sub-system the first violation of the reliability criteria occurred in the year 2020. The storage trajectories of selected major dams are shown in **Figures Q-6** to **Q-13**.

B.9.4.7Scenario 3 (VT07R03): Rand Water supplied from Vaal Barrage (Blending Option)

The graphical results of this scenario, which was based on the analysis of 100 stochastic sequences covering a planning period of 19 years, are included in **Appendix R**. This scenario evaluated the alternative source of supply for Rand Water and the results can be compared against that of **Scenario 1a**. Comparison of the Sterkfontein Dam (**Figure R-1** versus **Figure M-7)** and the Vaal Dam (**Figure R-2** versus **Figure M-8**) storage levels show that these two dams are at higher storage levels for **Scenario 3.** This is due to the reuse of the discharges that are made in the Vaal Barrage catchment which in turn causes less water to be released from Vaal Dam in order to meet the required TDS concentration of 600 mg/l downstream of Vaal Barrage. Consequently, for **Scenario 3** the inflows into Bloemhof Dam are lower relative to that of **Scenario 1a**, resulting in correspondingly lower storage levels for Bloemhof Dam as shown in **Figure R-3**.

B.9.4.8Scenario 8a (VT07R08): No water quality management

Scenario 8a is another alternative to **Scenario 1a** and was primarily analysed as a reference scenario for water quality management purposes. Since Rand Water was supplied from Vaal Barrage with no blending from Vaal Dam and no additional releases were made from Vaal Dam for dilution of the TDS concentration downstream of Vaal Barrage, it was expected that Vaal Dam and Bloemhof Dam would be operated at higher and lower levels respectively when compared to the results of **Scenario 1a**. Analysis undertaken for **Scenario 8a** was based on a planning period of 24 years and 1000 stochastic sequences were considered. The graphical results for this scenario are included in **Appendix S**.

The curtailment results presented in **Figure S-1** show that although the first violation of the adopted reliability criteria occurs in 2026, there is no violation in 2027. Since the adopted reliability criteria are continuously violated from the year 2028 onwards, it was assumed that intervention is required in 2028. The total system storage is shown in **Figure S-2** and the projected storage trajectories of Sterkfontein, Vaal and Bloemhof dams are included in **Figures S-3**, **S-4** and **S-5** respectively.

As mentioned, the analysis of **Scenario 8a** was mainly required for water quality management purposes and for reference purposes only.

B.9.5 SCHEDULING ANALYSIS RESULTS

Projection analyses were carried out with the Water Resource Planning Model (WRPM) for the scenarios and based on the assessment of the risk of curtailments (refer to the scenario results presented in **Section B.9.4**) the supply capability of the system was determined to be 2877 million m^3/annum (i.e. the net system demand in 2018 for **Scenario 1a**). **Figure B.9.4** shows the net water requirements of **Scenario B_2** to **K_2** in relation to the system supply capability.

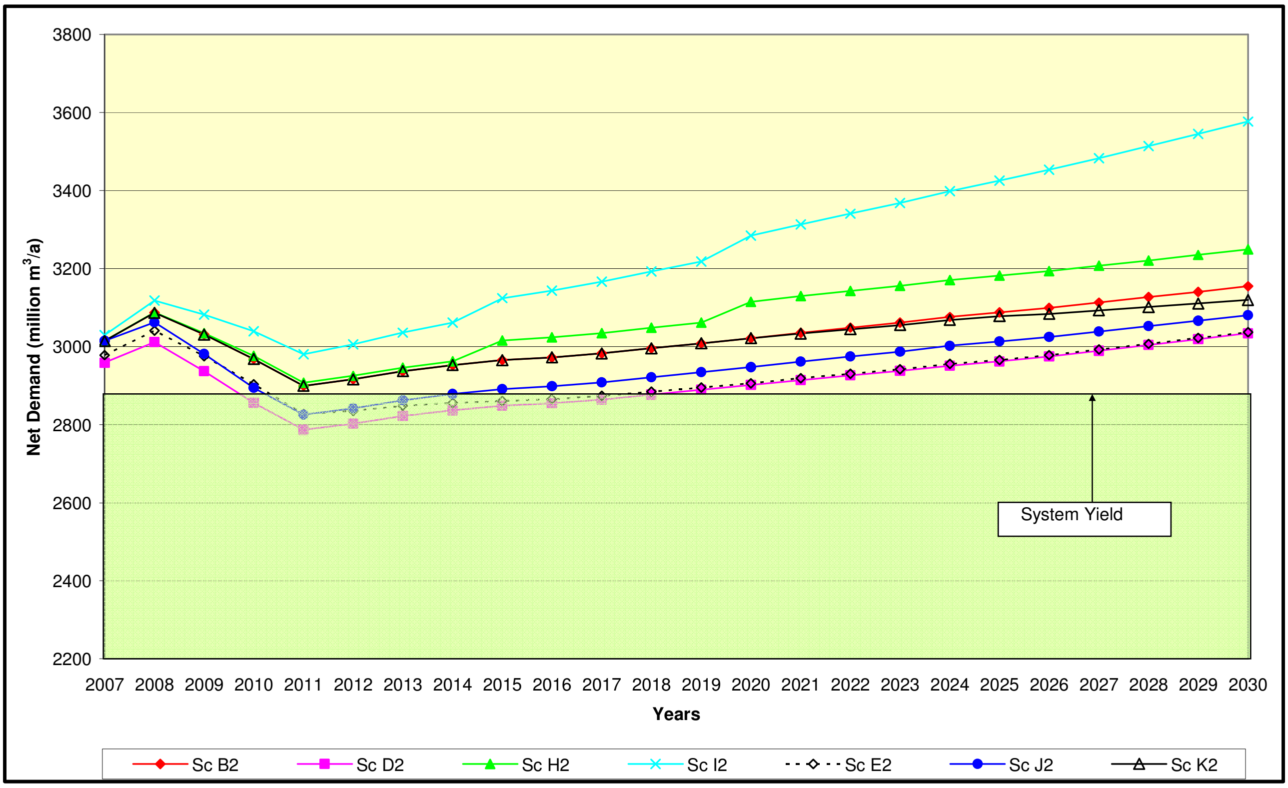


Figure B.9.4: Net system demand and system supply capability

The following observations can be made from **Figure B.9.4**:

- The unlawful water use in the irrigation sector results in the system being in a deficit situation from 2007 to 2009 for all the scenarios. This illustrates the importance of curbing the unlawful irrigation water use in order to maintain a positive water balance in the system and prevent excessive curtailments during drought periods.

- Based on the projected balance situation for **Scenarios B_2**, **K_2**, **H_2** and **I_2** it is shown that the system is in deficit over the entire planning period.

- If the potential savings through WC/WDM of **Scenarios D_2** and **E_2** (reduction in wastage over 5 and 10 years respectively) is achieved, further intervention is required in 2019.

- The balance situation for **Scenario J_2,** shows that by trading the irrigation water rights in the Vaal River catchment upstream of Vaal Dam, further intervention is only required in the year 2015.

B.9.6 RECONCILIATION OPTIONS

Several reconciliation options were formulated based on the scenarios described in **Section B.9.2** and the augmentation options presented in **Section B.7**. These options are presented and discussed in the study report entitled "Second Stage Reconciliation Strategy" (**DWAF, 2006h**).

B.9.7 WATER QUALITY MANAGEMENT

Water quality management is being investigated in detail as part of the parallel "*Integrated Water Quality Management Plan*" (IWQMP) study and will be reported on in a separate series of reports. At the time of writing this report, the IWQMP study was still in progress but the results were available for consideration in the Second Stage Reconciliation Strategy. A perspective on water quality management is provided in the report "Second Stage Reconciliation Strategy" (**DWAF, 2006h**).

B.10 CONCLUSIONS

Given the planning scenario results as presented in the previous chapters the following main conclusions can be drawn:

- Assuming that curtailment of unlawful irrigation water use (as described for **Irrigation Scenario 1**) materialises, it was found that a deficit situation occurred over the medium term (from 2007 to 2009) for all the scenarios analysed.

- The **Scenario 1a** results indicated that intervention is required in the year 2019. This means that, with WC/WDM the decision to proceed with an infrastructural intervention measure has to be taken immediately as the recommended LHFP option (Polihali Dam and conveyance infrastructure) can only be commissioned in May 2019.

- The scheduling analysis results for **Scenarios $\mathbf{B_2}$**, $\mathbf{K_2}$, $\mathbf{H_2}$ and $\mathbf{I_2}$ showed that the system is in deficit over the entire planning period. Therefore, saving water through the reduction of wastage by means of water conservation and demand management measures in the urban sector is essential as the earliest augmentation scheme (LHFP) can only be implemented in ten year's time.

- The Comprehensive Reserve Determination Study (commissioned by the DWAF Directorate Resource Directed Measures (RDM) in August 2006) will produce Ecological Water Requirement Scenarios and the implication thereof on the reconciliation options will have to be determined and evaluated.

B.11 RECOMMENDATIONS

Based on the results and conclusions presented in this report, it is recommended that the following aspects be considered:

- The curtailment of unlawful irrigation water use in the Upper Vaal WMA is essential and the necessary measures to enforce these curtailments should be implemented as a matter of urgency.

- Since the implementation of waste water management measures as assumed for demand **Scenario D_2** will ensure that the assurance of supply in the IVRS is not jeopardized prior to the commissioning of the preferred LHFP option (Polihali Dam), it is recommended that these WC/WDM initiatives be imposed immediately and that the resulting water saving achievements be monitored on a continuous basis.

- Re-evaluate the system balance once the validation studies and the comprehensive reserve determination study produce information.

- The water quality simulation of the irrigation modules in the Vaalharts, Mooi, Schoonspruit, Sand, Vet and Renoster catchments had to be adjusted to represent actual TDS concentrations. These adjustments were undertaken by increasing the deep percolation of salts to the lower soil zone. It is recommended that further alternative adjustment methods be considered. This will require refinement of the calibrations carried out for the indicated irrigation modules.

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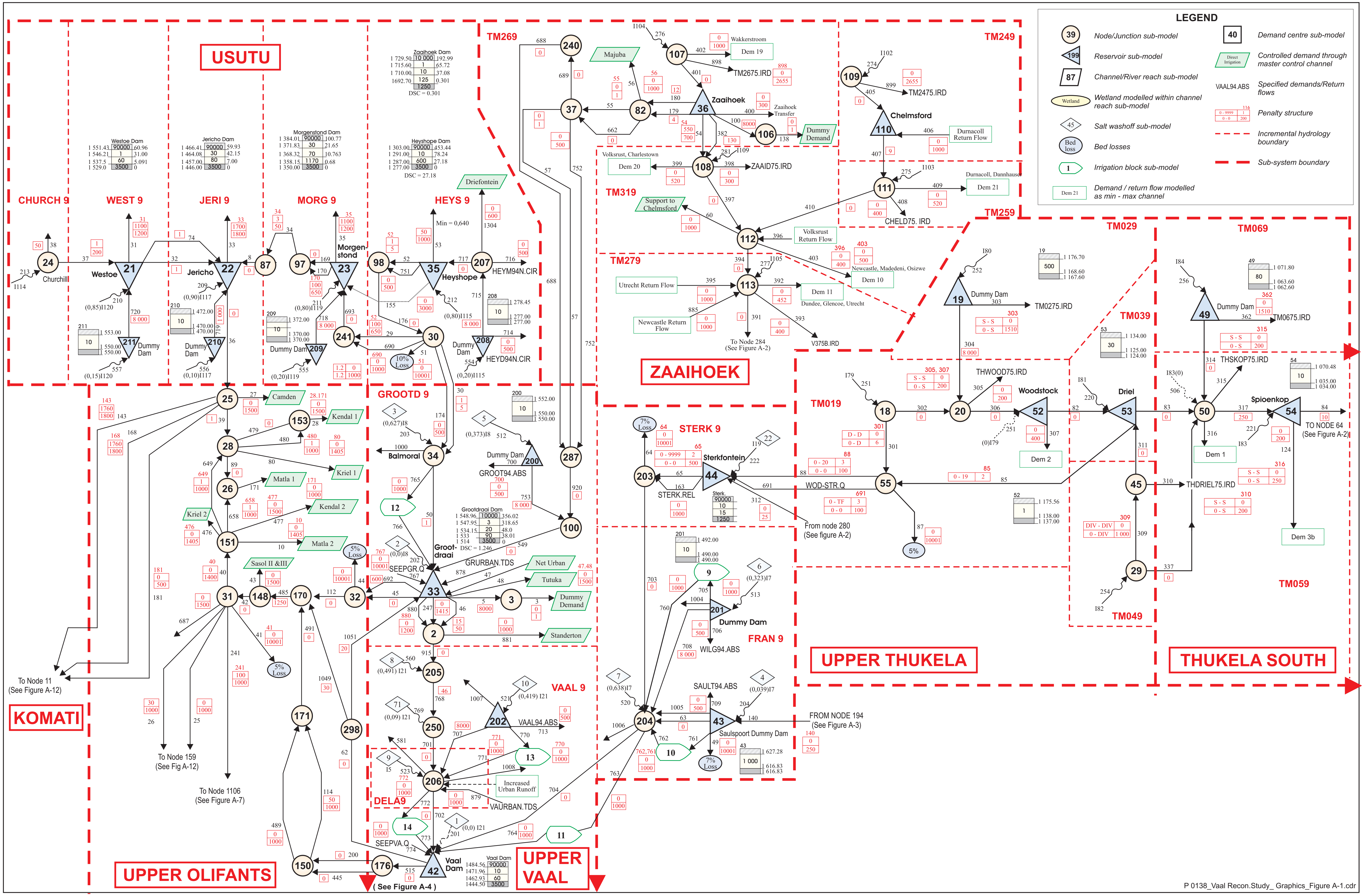
Author: C Talanda, HG Maré.

Appendix A

WRPM Schematic Diagrams of IVRS: Part A

No:	Description
A-1	Upper Vaal, Usutu, Thukela North, Upper and Thukela South Sub-systems
A-2	Thukela Sub-system
A-3	Senqu, Caledon and Upper Orange Sub-system
A-4	Vaal Dam to Vaal Barrage
A-5	Middle Vaal Sub-system
A-6	Lower Vaal and Riet/Modder Sub-systems
A-7	Witbank Dam Sub-system
A-8	Middelburg Dam Sub-system
A-9	Loskop Dam Incremental Sub-system
A-10	Lower Orange Sub-system
A-11	Fish River Sub-system Namibia
A-12	Komati Sub-system



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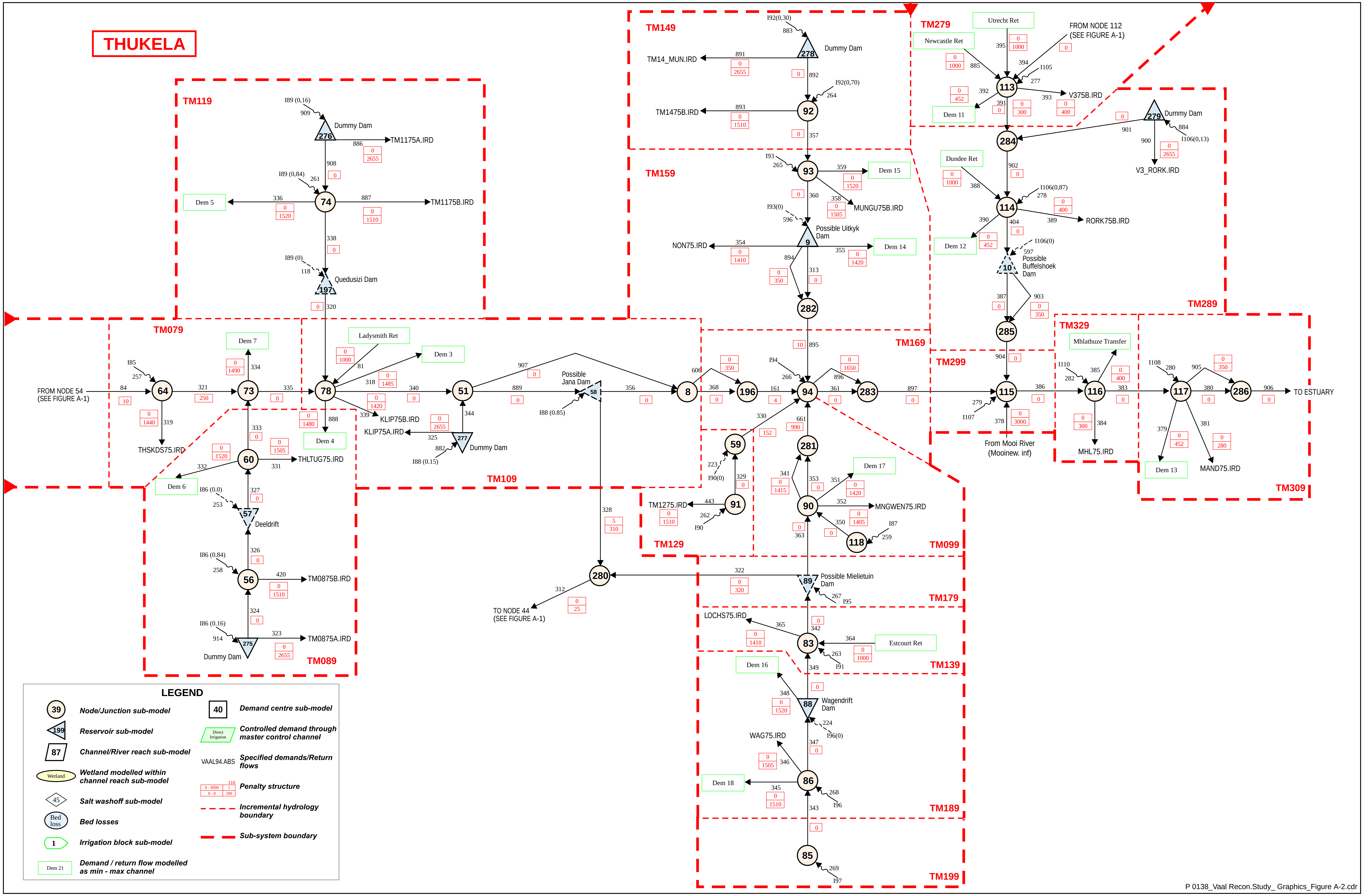
VAAL

VAAL RIVER SYSTEM: LARGE BULK WATER SUPPLY RECONCILIATION STRATEGIES AND WATER CONSERVATION AND DEMAND MANAGEMENT

WRPM Schematic Diagram: Upper Vaal, Usutu, Thukela North, Upper Thukela and Thukela South Sub-systems

A-1



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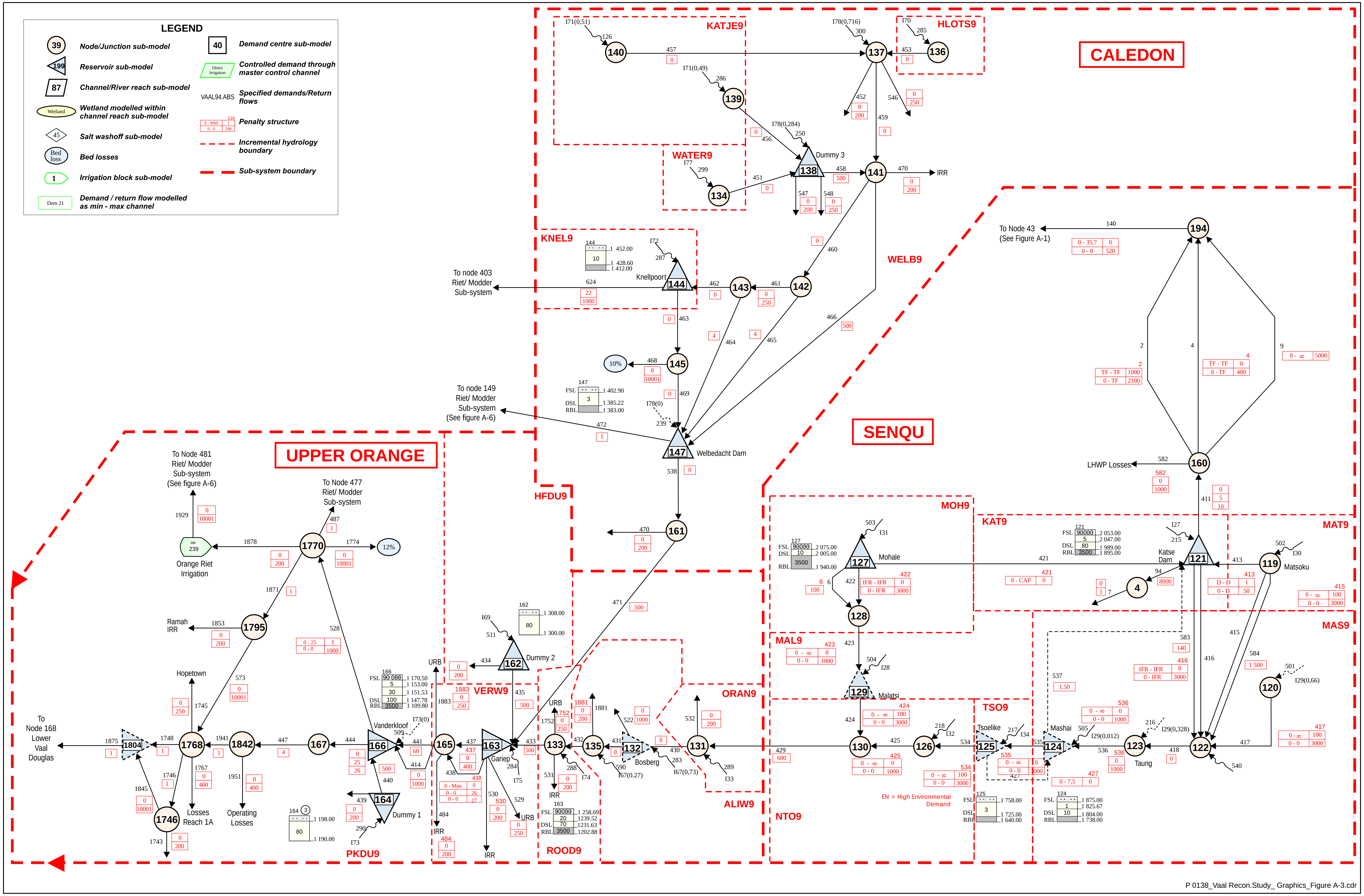
VAAL RIVER SYSTEM: LARGE BULK WATER SUPPLY RECONCILIATION STRATEGIES AND WATER CONSERVATION AND DEMAND MANAGEMENT

WRPM Schematic Diagram: Thukela Sub-system

A-2



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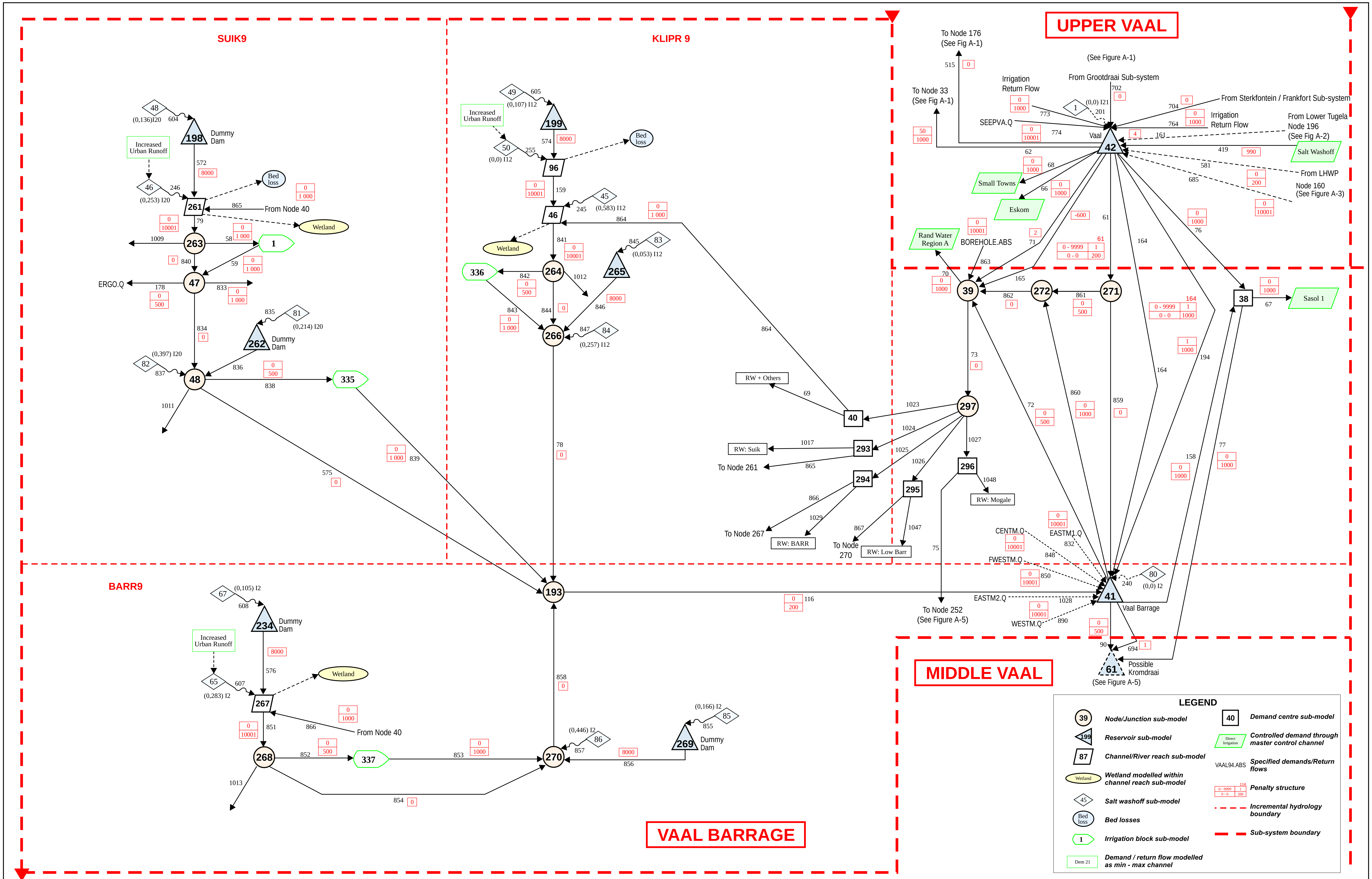
VAAL RIVER SYSTEM: LARGE BULK WATER SUPPLY RECONCILIATION STRATEGIES AND WATER CONSERVATION AND DEMAND MANAGEMENT

WRPM Schematic Diagram: Senqu, Caledon and Upper Orange Sub-system

A-3



P 0138_Vaal Recon.Study_ Graphics_Figure A-4.cdr

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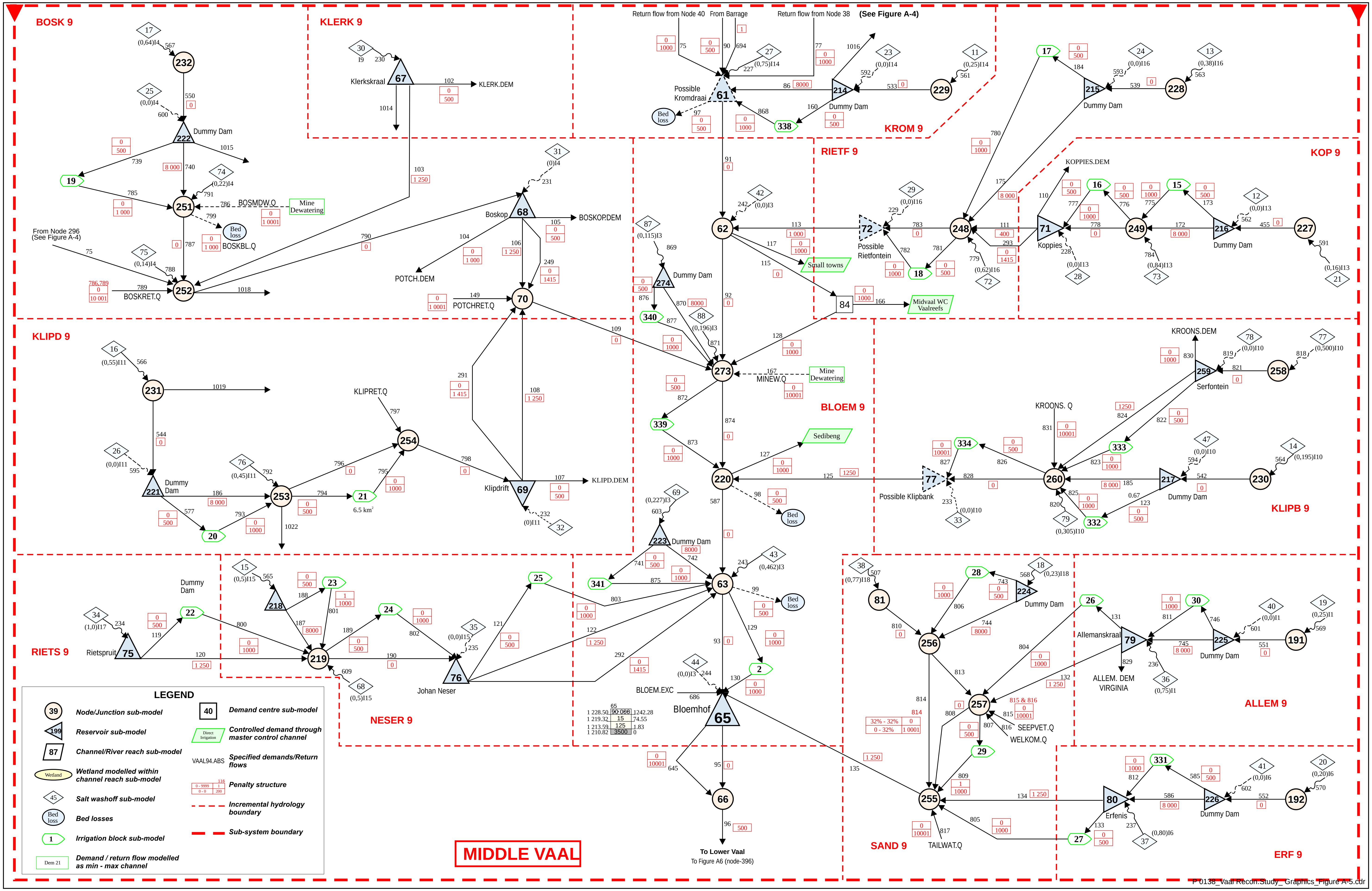
VAAL RIVER SYSTEM: LARGE BULK WATER SUPPLY RECONCILIATION STRATEGIES AND WATER CONSERVATION AND DEMAND MANAGEMENT

WRPM Schematic Diagram: Vaal Dam to Vaal Barrage

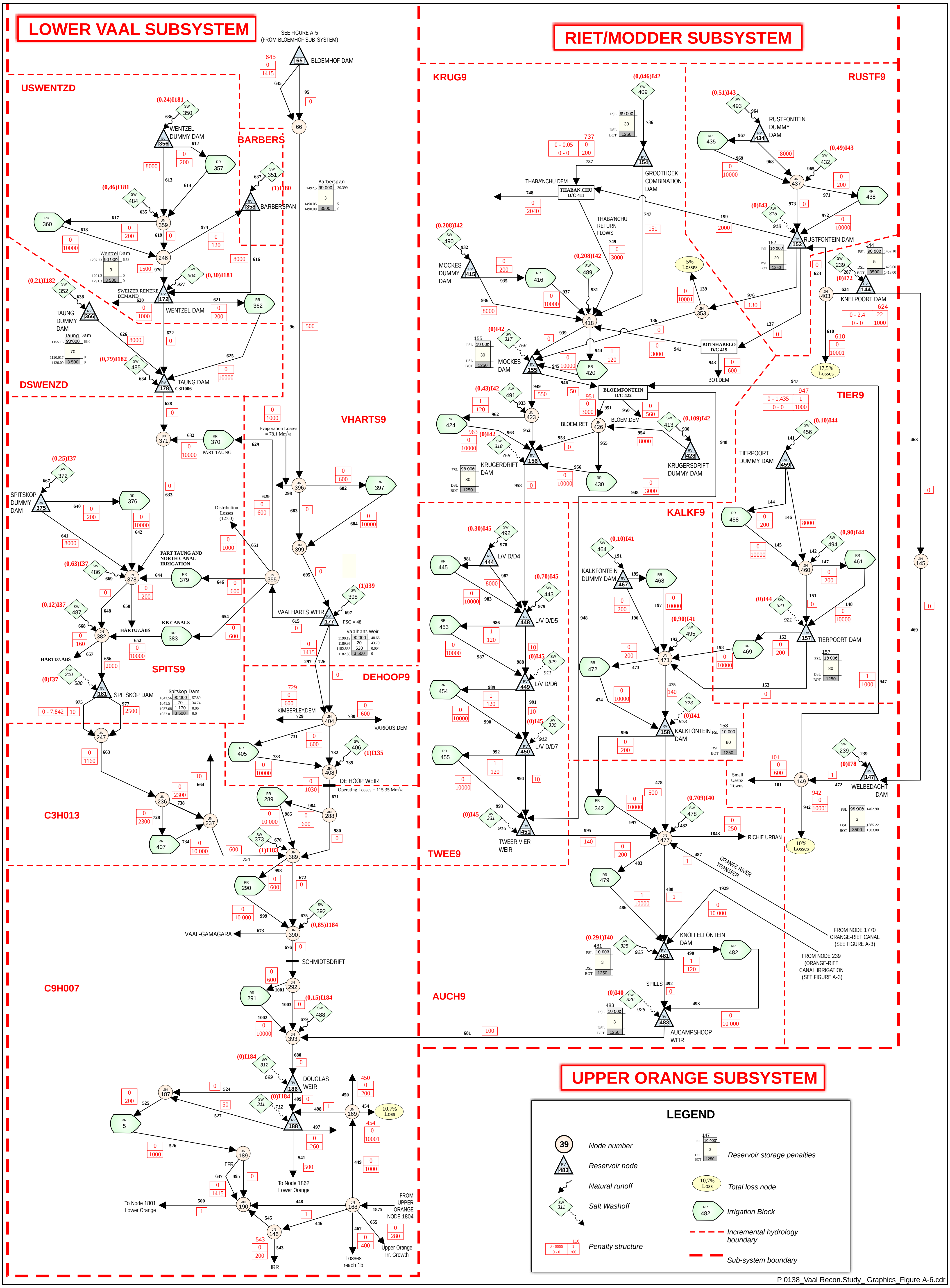
A-4



VAAL RIVER SYSTEM: LARGE BULK WATER SUPPLY RECONCILIATION STRATEGIES AND WATER CONSERVATION AND DEMAND MANAGEMENT

WRPM Schematic diagram: Middle Vaal Sub-system

A-5



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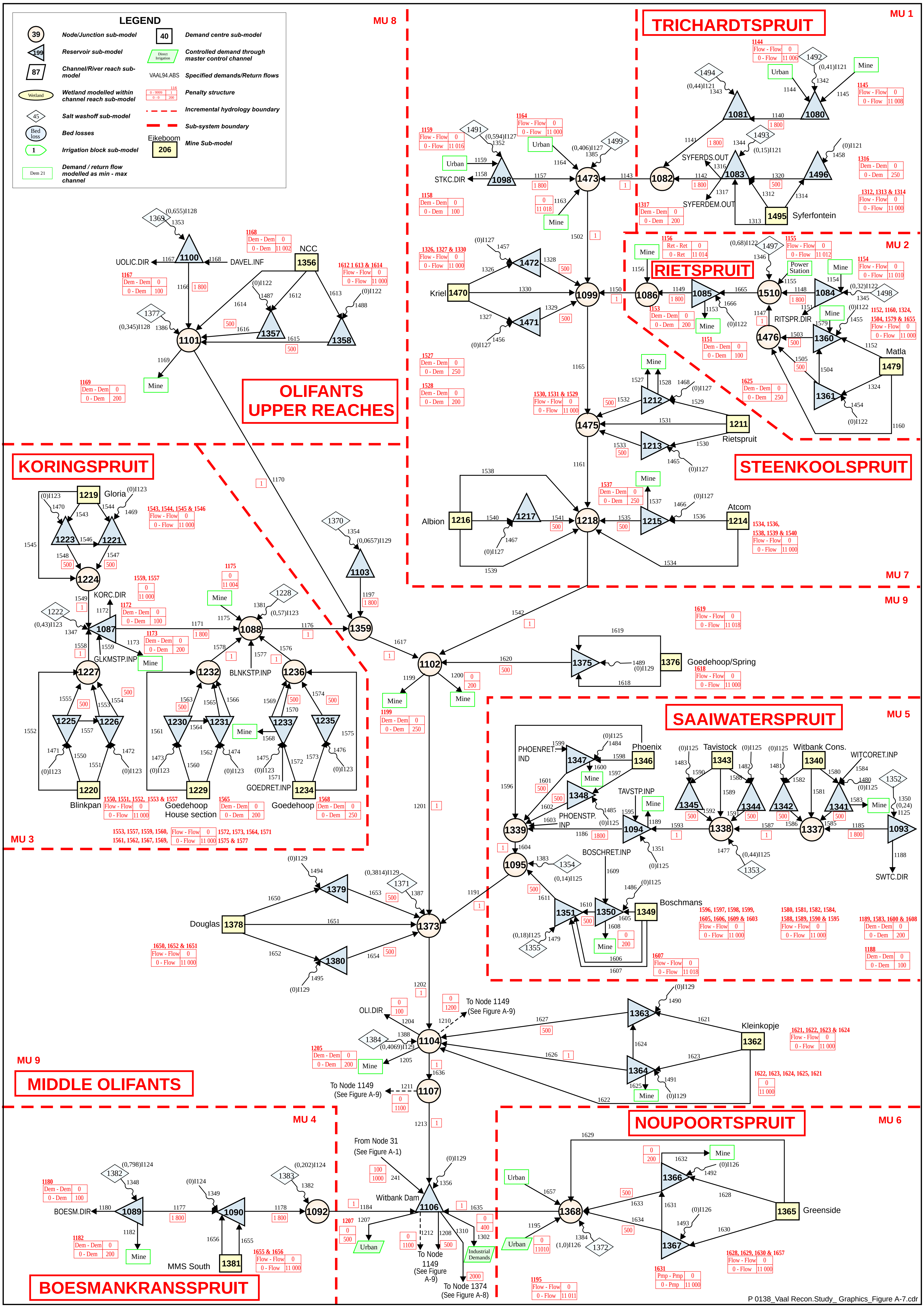
VAAL

VAAL RIVER SYSTEM: LARGE BULK WATER
SUPPLY RECONCILIATION STRATEGIES AND
WATER CONSERVATION AND DEMAND MANAGEMENT

WRPM Schematic Diagram: Lower Vaal & Riet/ Modder Sub-systems

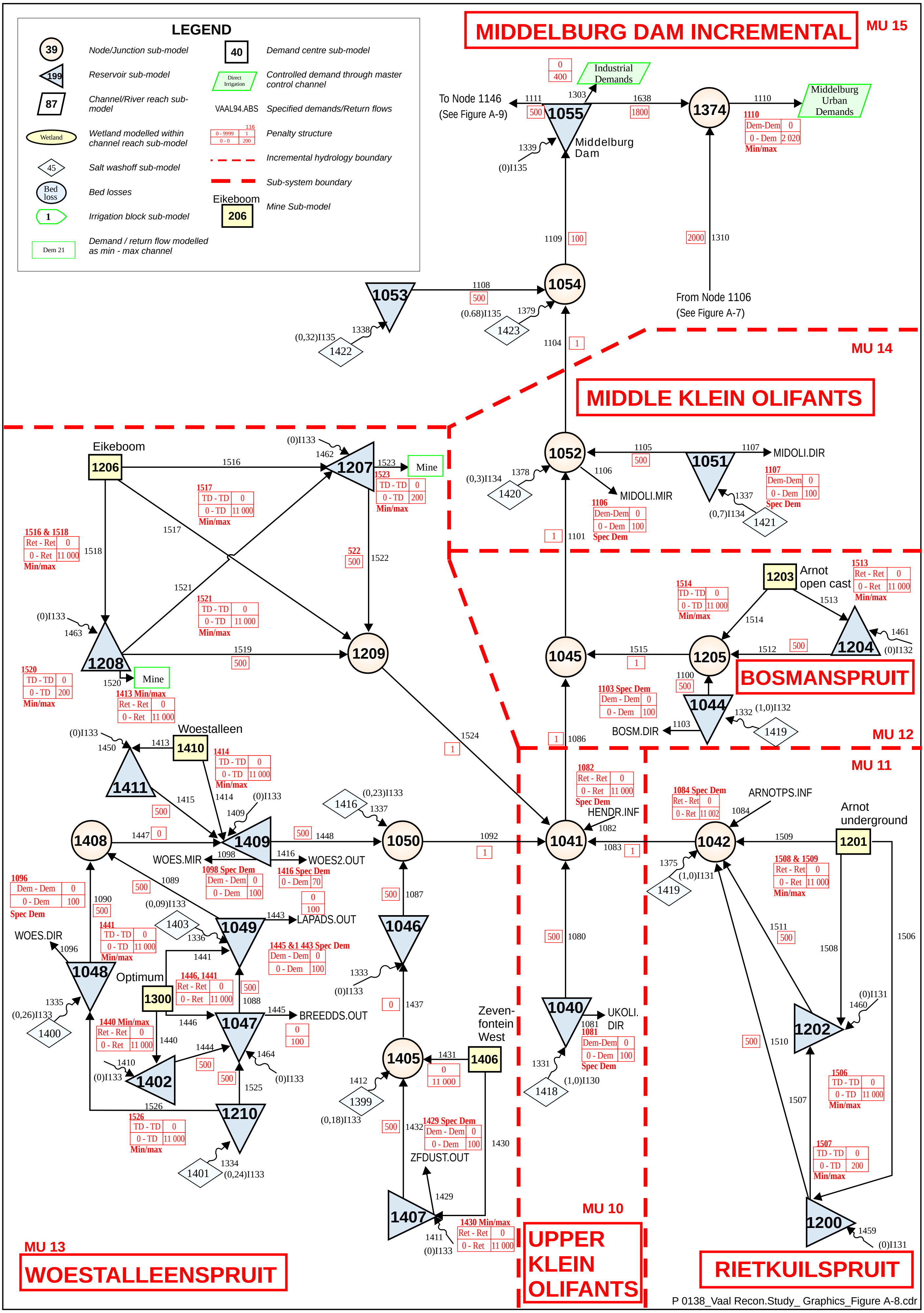
A-6



VAAL RIVER SYSTEM: LARGE BULK WATER SUPPLY RECONCILIATION STRATEGIES AND WATER CONSERVATION AND DEMAND MANAGEMENT

WRPM Schematic Diagram:
Witbank Dam Sub-system with Penalty Structure

A-7



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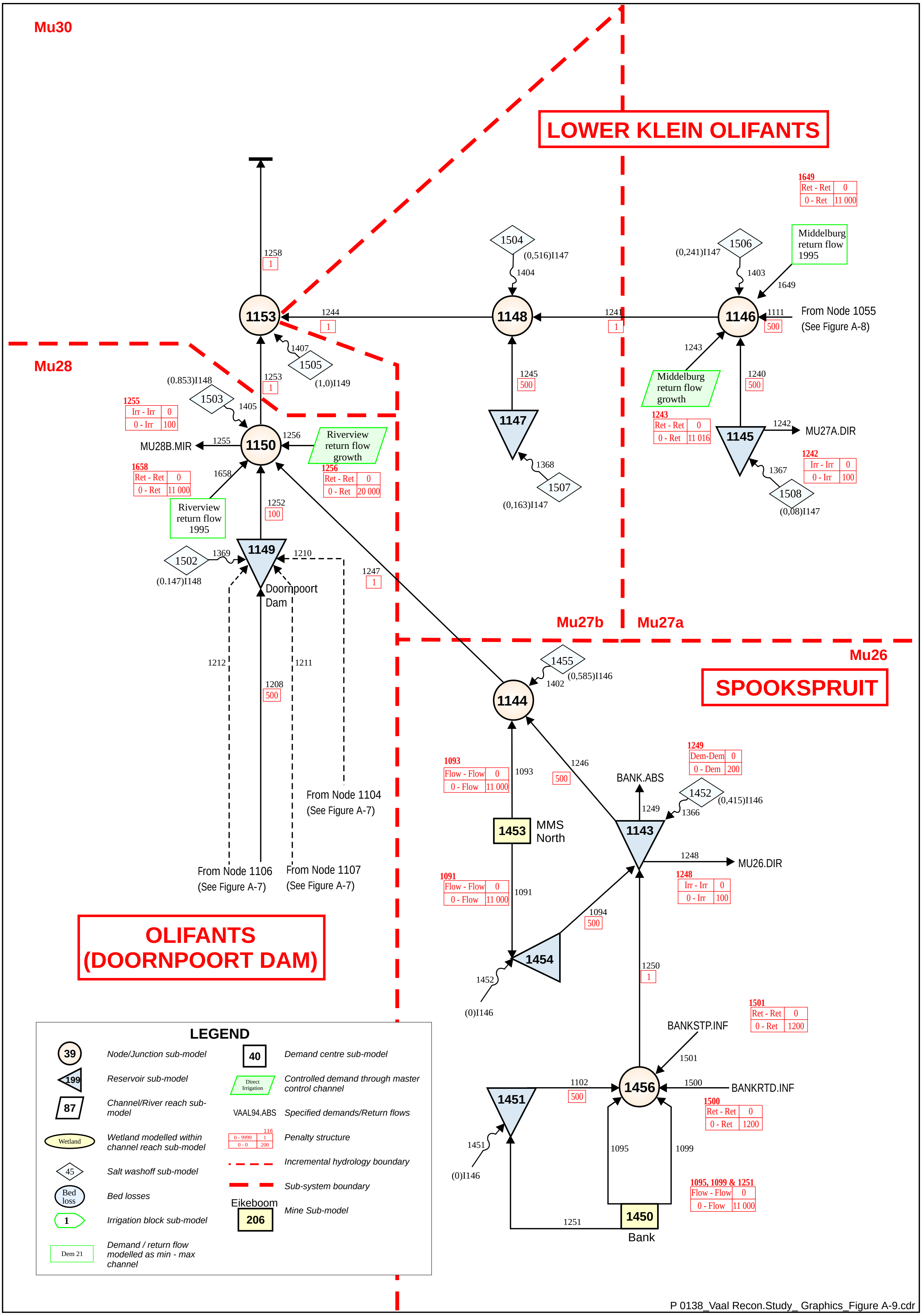
VAAL RIVER SYSTEM: LARGE BULK WATER SUPPLY RECONCILIATION STRATEGIES AND WATER CONSERVATION AND DEMAND MANAGEMENT

WRPM Schematic Diagram: Middelburg Dam Sub-system With Penalty Structures

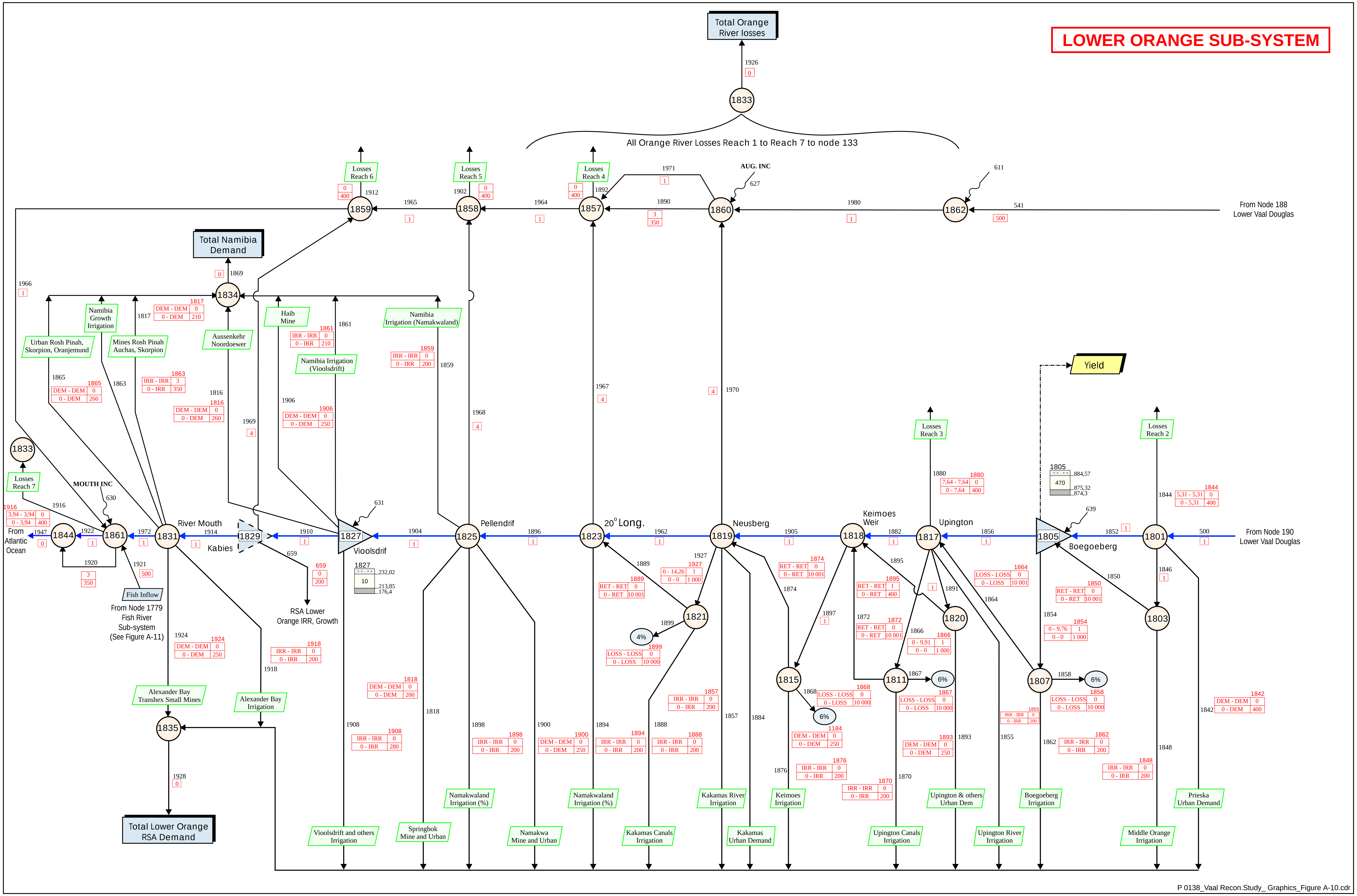
A-8



VAAL RIVER SYSTEM: LARGE BULK WATER SUPPLY RECONCILIATION STRATEGIES AND WATER CONSERVATION AND DEMAND MANAGEMENT

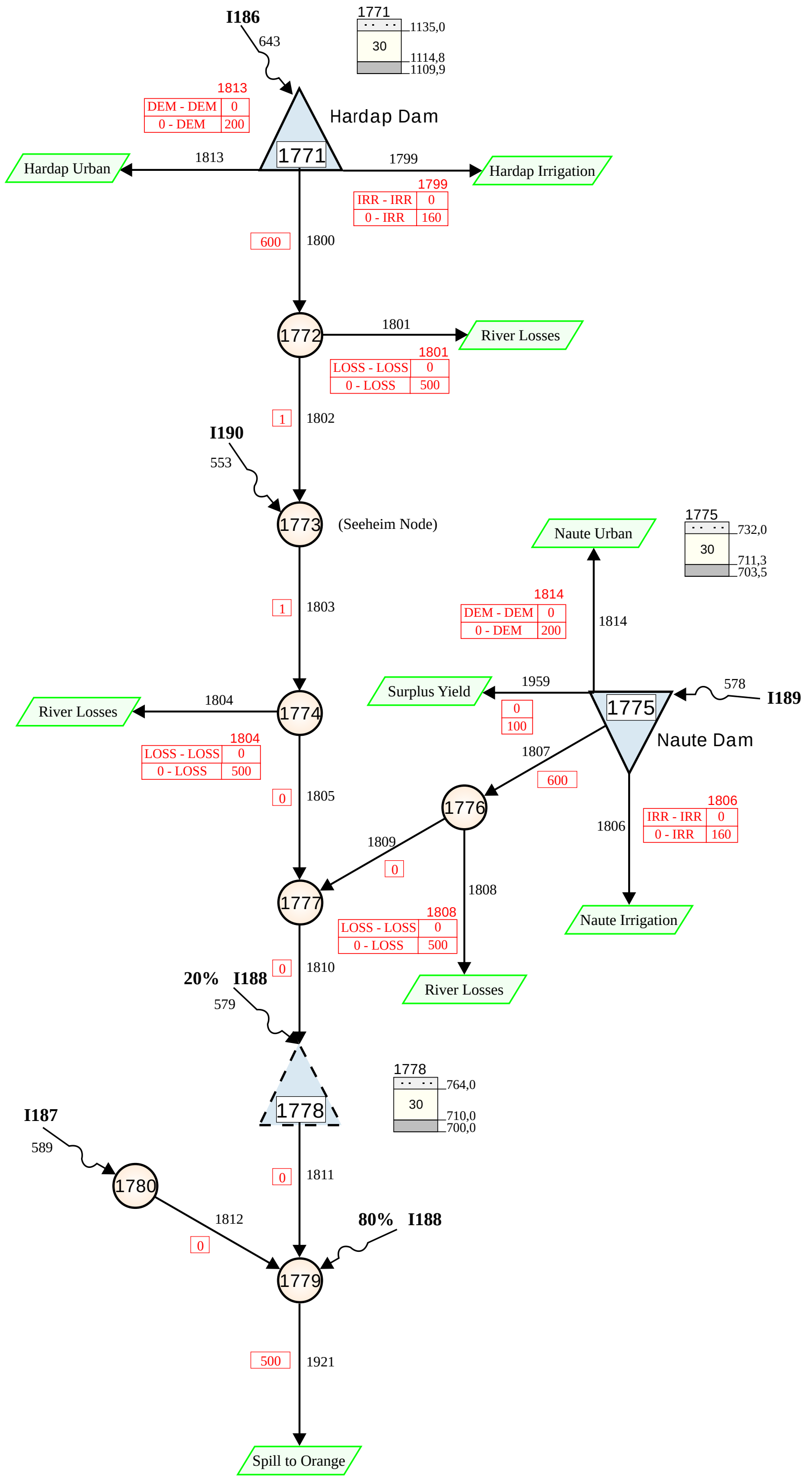
WRPM Schematic Diagram: Loskop Dam Incremental Sub-system With Penalty Structures

A-9



P 0138_Vaal Recon.Study_ Graphics_Figure A-10.cdr

NAMIBIA: FISH RIVER SUB-SUSTEM



To Node 1861
(See Figure A-10)

P 0138_Vaal Recon.Study_ Graphics_Figure A-11.cdr

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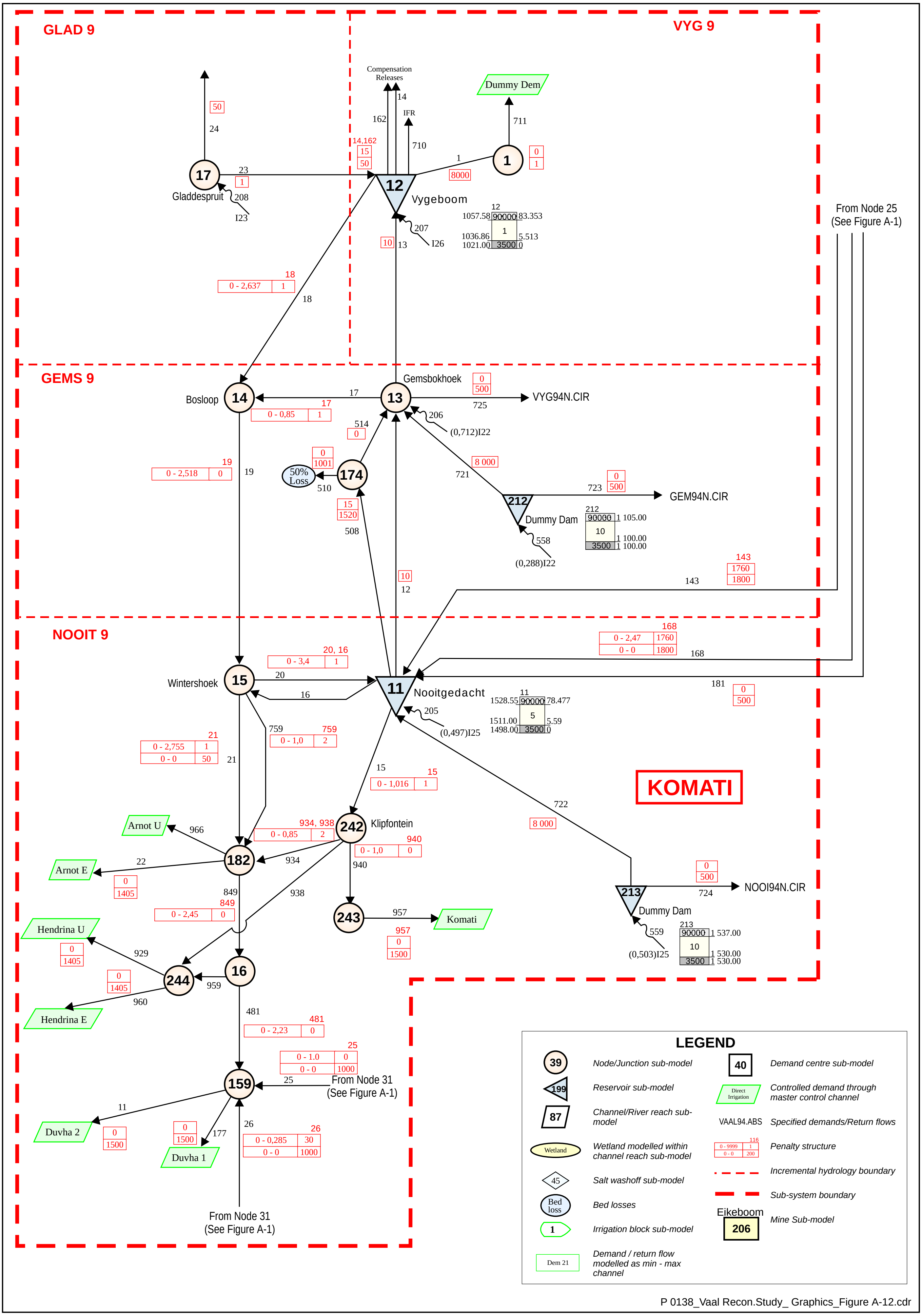
VAAL

VAAL RIVER SYSTEM: LARGE BULK WATER
SUPPLY RECONCILIATION STRATEGIES AND
WATER CONSERVATION AND DEMAND MANAGEMENT

WRPM Schematic Diagram:
Fish River Sub-system Namibia

A-11



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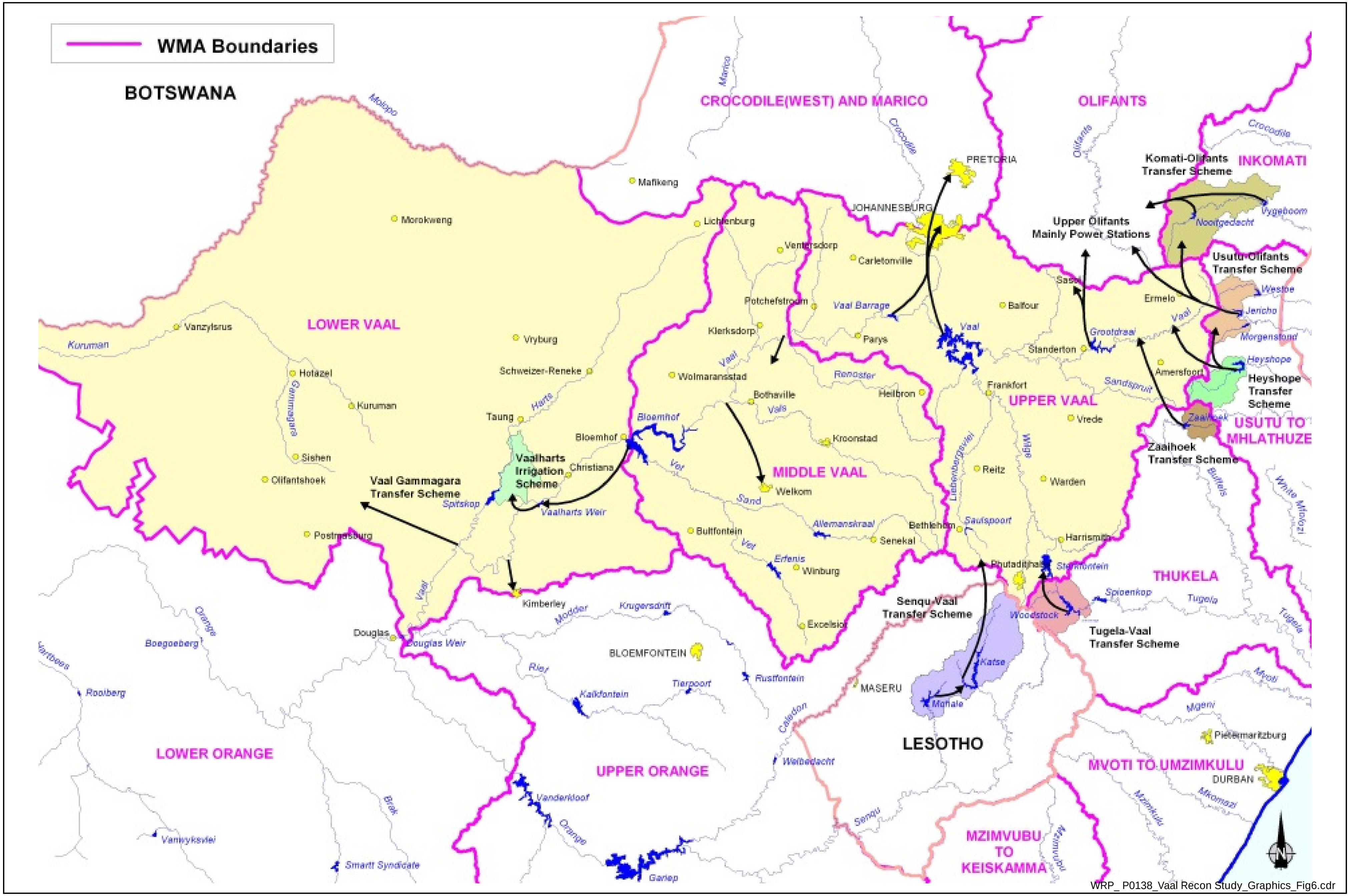
VAAL RIVER SYSTEM: LARGE BULK WATER SUPPLY RECONCILIATION STRATEGIES AND WATER CONSERVATION AND DEMAND MANAGEMENT

WRPM Schematic Diagram: Komati Sub-system

A-12

Appendix B

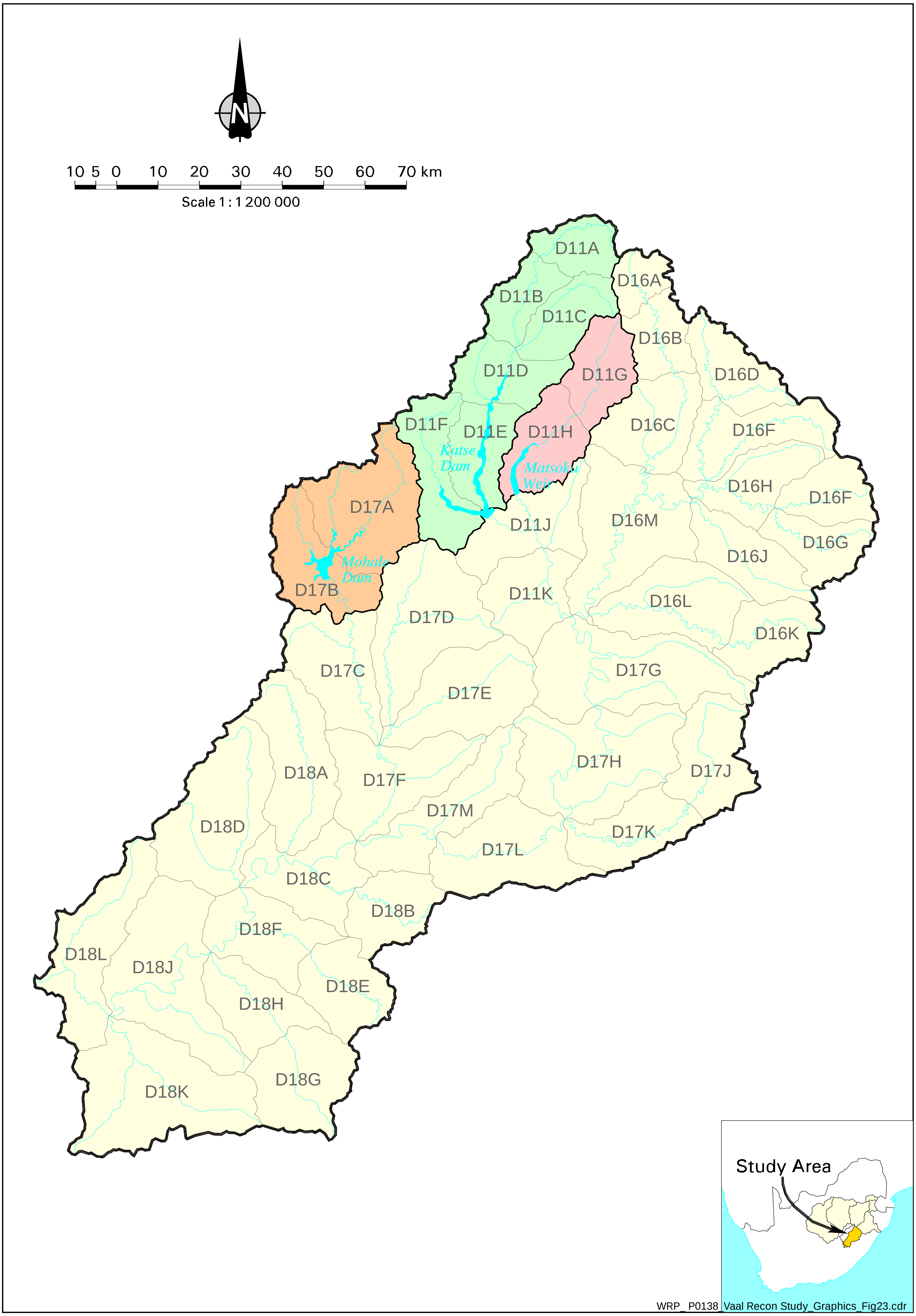
Figures



VAAL RIVER SYSTEM: LARGE BULK WATER SUPPLY RECONCILIATION STRATEGIES AND WATER CONSERVATION AND DEMAND MANAGEMENT

Study Area

B-1



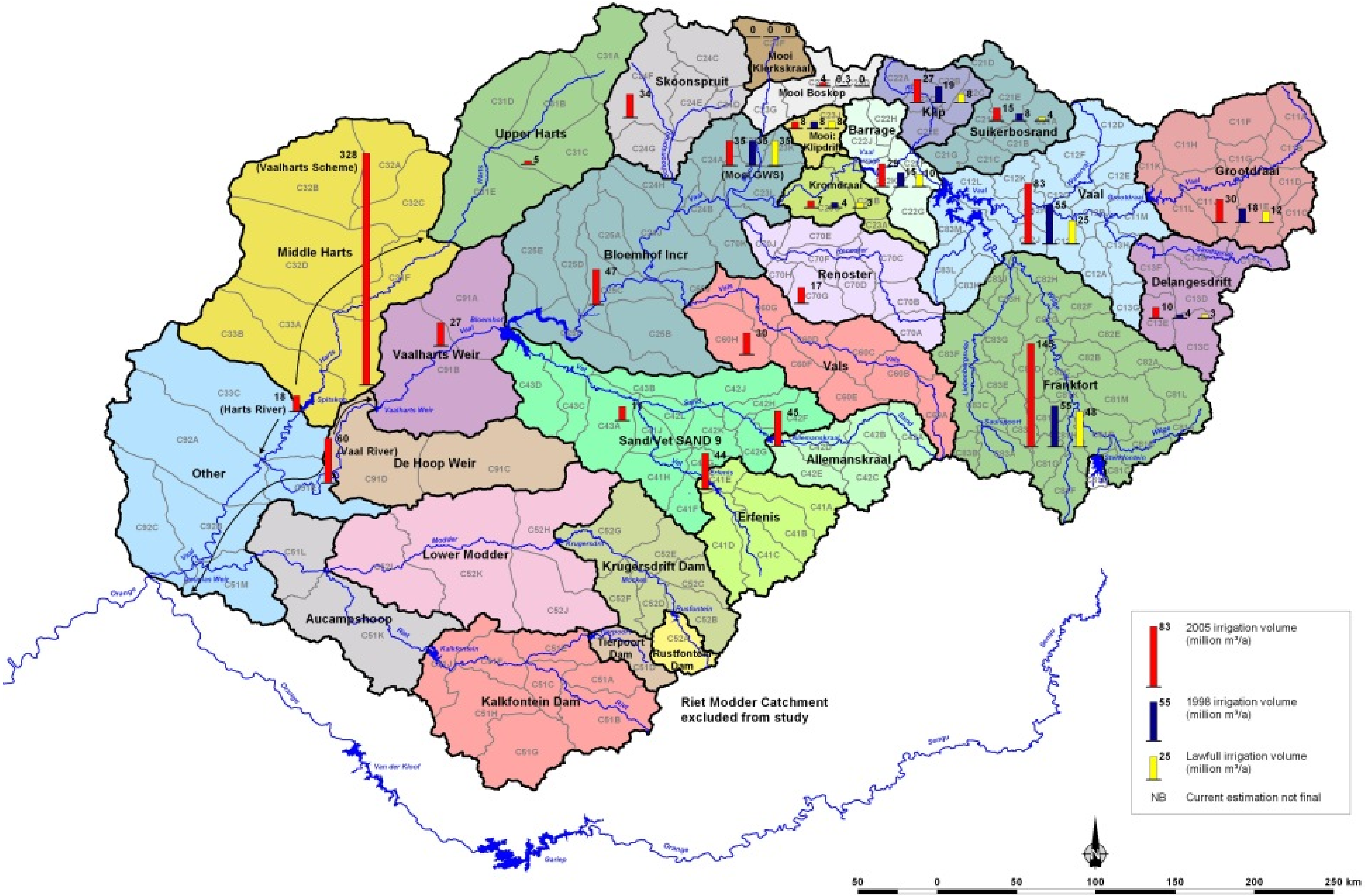
WRP_ P0138 Vaal Recon Study_Graphics_Fig23.cdr

VAAL

VAAL RIVER SYSTEM: LARGE BULK WATER SUPPLY RECONCILIATION STRATEGIES AND WATER CONSERVATION AND DEMAND MANAGEMENT

Senqu Catchment (Lesotho)

B-2



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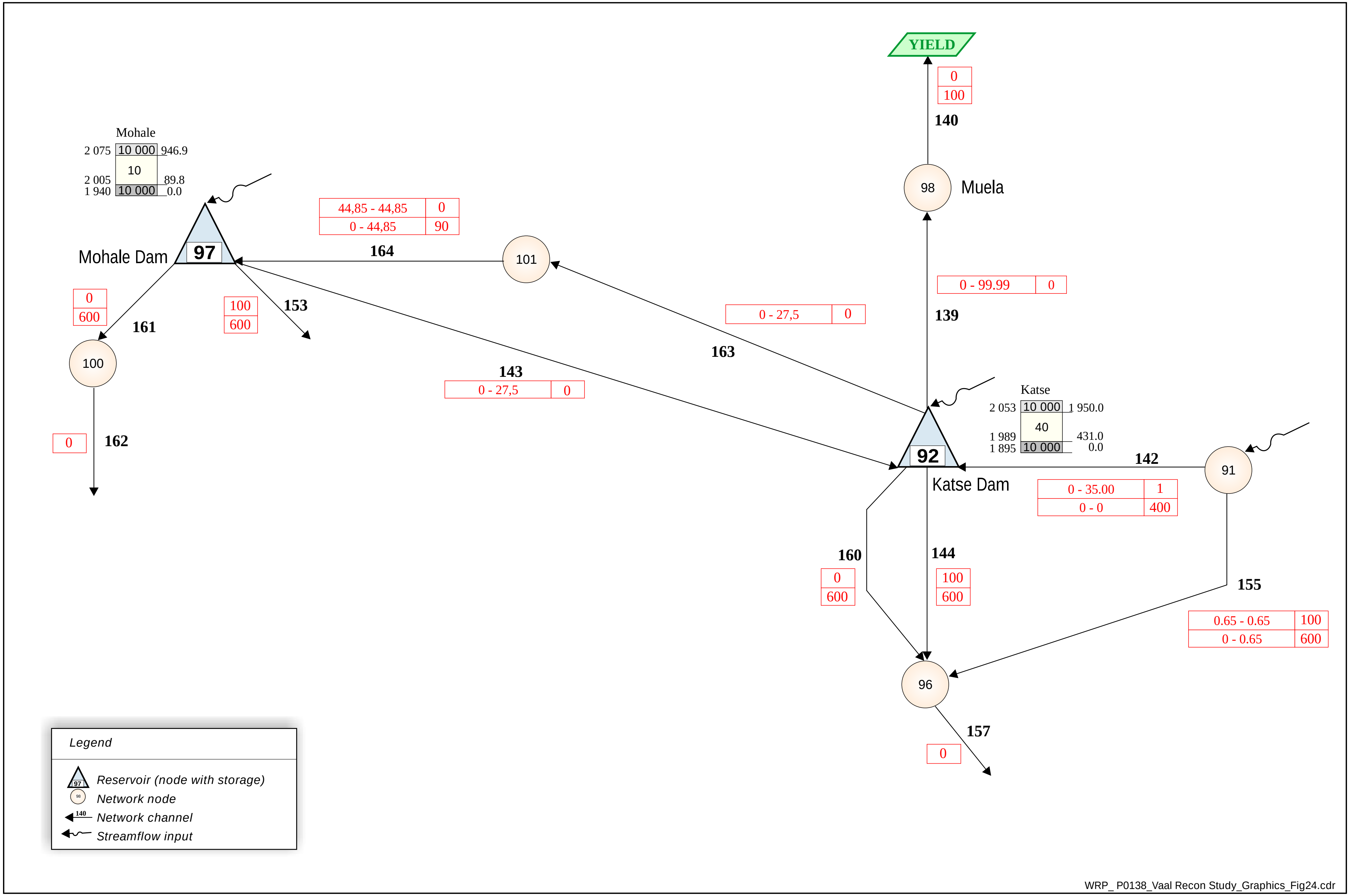
Appendix C

Senqu and Bloemhof Short Term Curves

No:	Description
C-1	WRYM Schematic Diagram: Senqu Sub-system
C-2	Short-term yield reliability characteristics: 10% net FSC: Senqu Sub-system
C-3	Short-term yield reliability characteristics: 20% net FSC: Senqu Subsystem
C-4	Short-term yield reliability characteristics: 40% net FSC: Senqu Sub-system
C-5	Short-term yield reliability characteristics: 60% net FCS: Senqu Sub-system
C-6	Short-term yield reliability characteristics: 80% net FSC: Senqu Sub-system
C-7	Short-term yield reliability characteristics: 100% net FSC: Senqu Sub-system
C-8	Senqu Sub-system: Short-term firm yield lines
C-9	Senqu Sub-system: Coefficient data files for short-term stochastic curves
C-10	Short-term yield reliability characteristics: 10% net FSC: Bloemhof Sub-system
C-11	Short-term yield reliability characteristics: 20% net FSC: Bloemhof Sub-system
C-12	Short-term yield reliability characteristics: 40% net FSC: Bloemhof Sub-system
C-13	Short-term yield reliability characteristics: 60% net FSC: Bloemhof Sub-system
C-14	Short-term yield reliability characteristics: 80% net FSC: Bloemhof Sub-system
C-15	Short-term yield reliability characteristics: 100% net FSC: Bloemhof Sub-system
C-16	Schematic diagram of the Upper Thukela

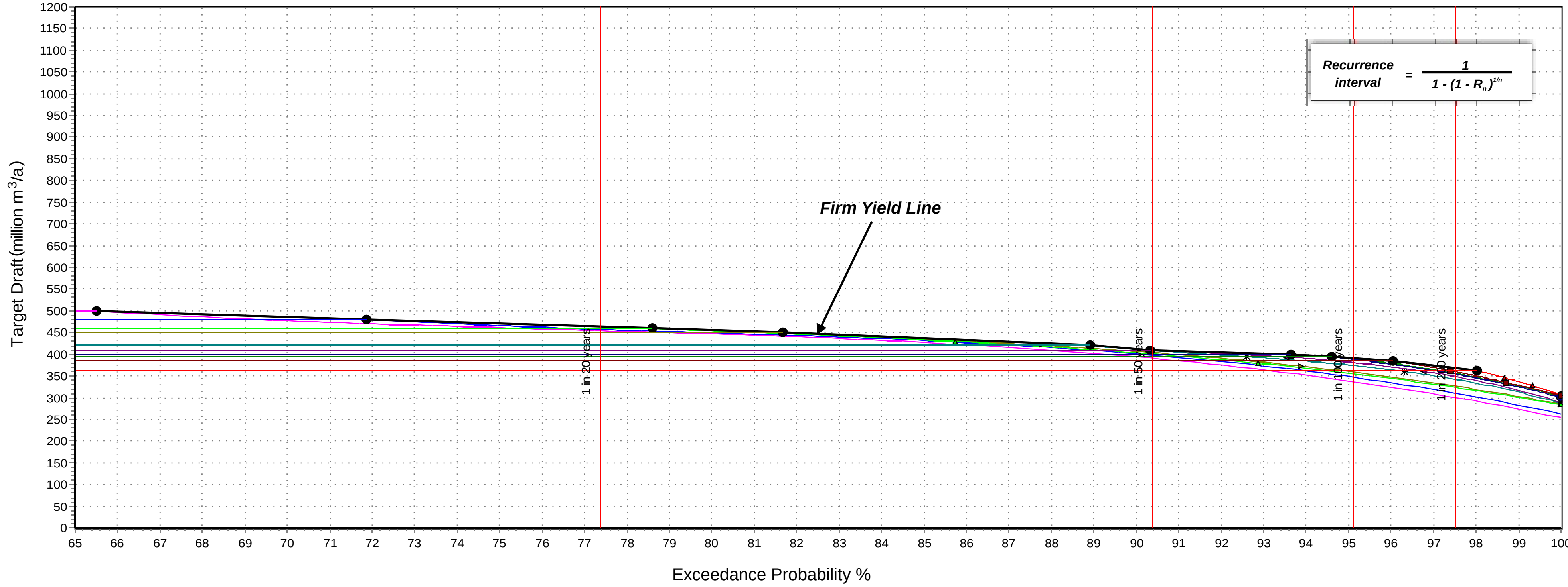


VAAL RIVER SYSTEM: LARGE BULK WATER SUPPLY RECONCILIATION STRATEGIES AND WATER CONSERVATION AND DEMAND MANAGEMENT

WRYM Schematic Diagram: Senqu Sub-system with Penalty Structures

C-1

Reliability of base yield derived from 501 5-year generated sequences



Mohale Net FSC = 857,1 million m^3
Katse Net FSC = 1518,6 million m^3
Total contributing FSC = 2375,7 million m^3

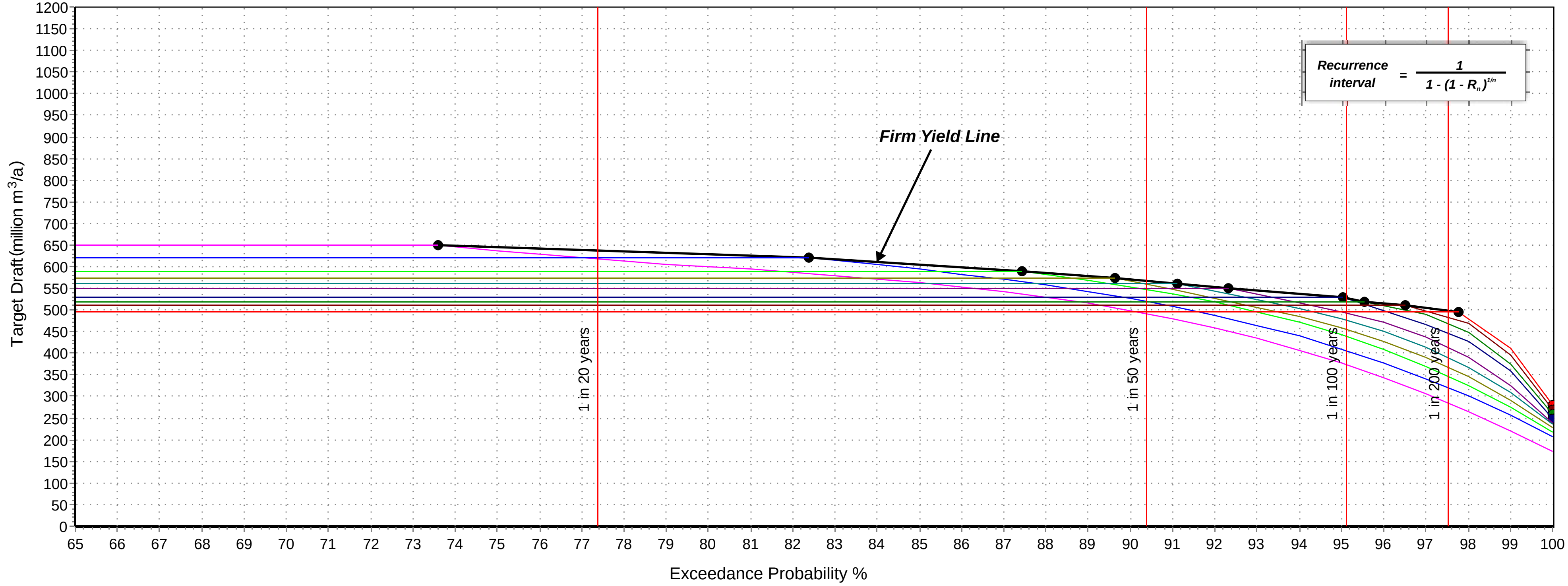
WRP_ P0138_Vaal Recon Study_Graphics_Fig25.cdr

VAAL RIVER SYSTEM: LARGE BULK WATER SUPPLY RECONCILIATION STRATEGIES AND WATER CONSERVATION AND DEMAND MANAGEMENT

Short-term yield-reliability characteristics: 10% net FSC: Senqu Sub-system

C-2

Reliability of base yield derived from 501 5-year generated sequences



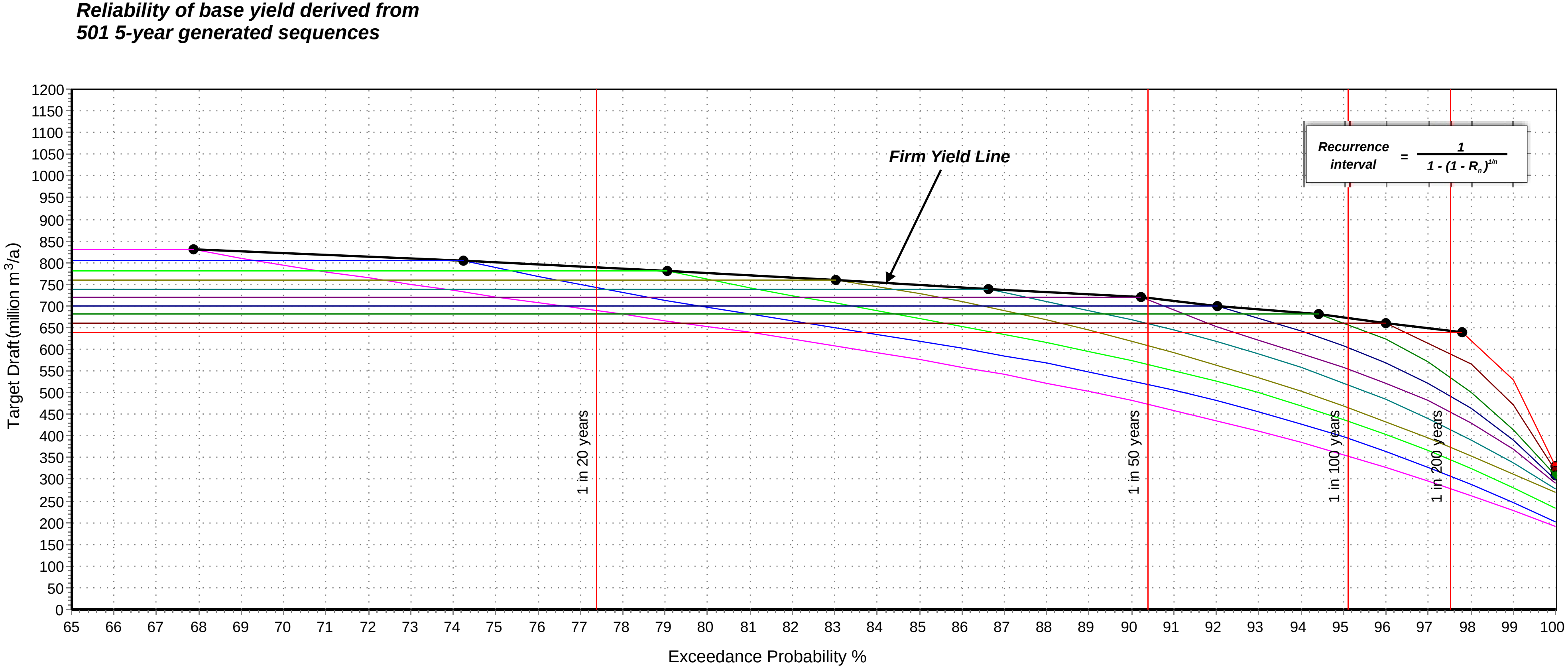
Mohale Net FSC = 857,1 million m^3
Katse Net FSC = 1518,6 million m^3
Total contributing FSC = 2375,7 million m^3

WRP_ P0138_Vaal Recon Study_Graphics_Fig25.cdr

VAAL RIVER SYSTEM: LARGE BULK WATER SUPPLY RECONCILIATION STRATEGIES AND WATER CONSERVATION AND DEMAND MANAGEMENT

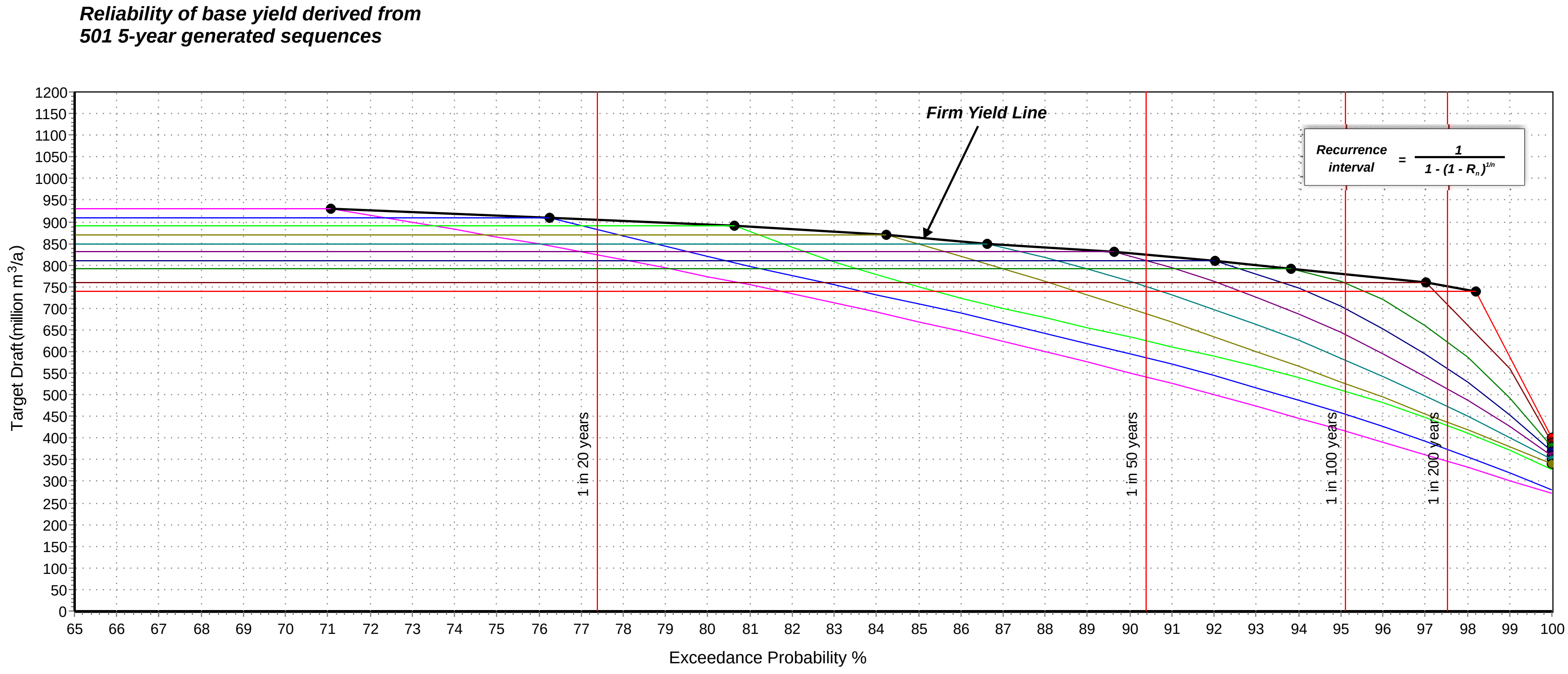
Short-term yield-reliability characteristics: 20% net FSC: Senqu Sub-system

C-3



Mohale Net FSC = 857,1 million m^3
Katse Net FSC = 1518,6 million m^3
Total contributing FSC = 2375,7 million m^3

WRP_ P0138_Vaal Recon Study_Graphics_Fig25.cdr

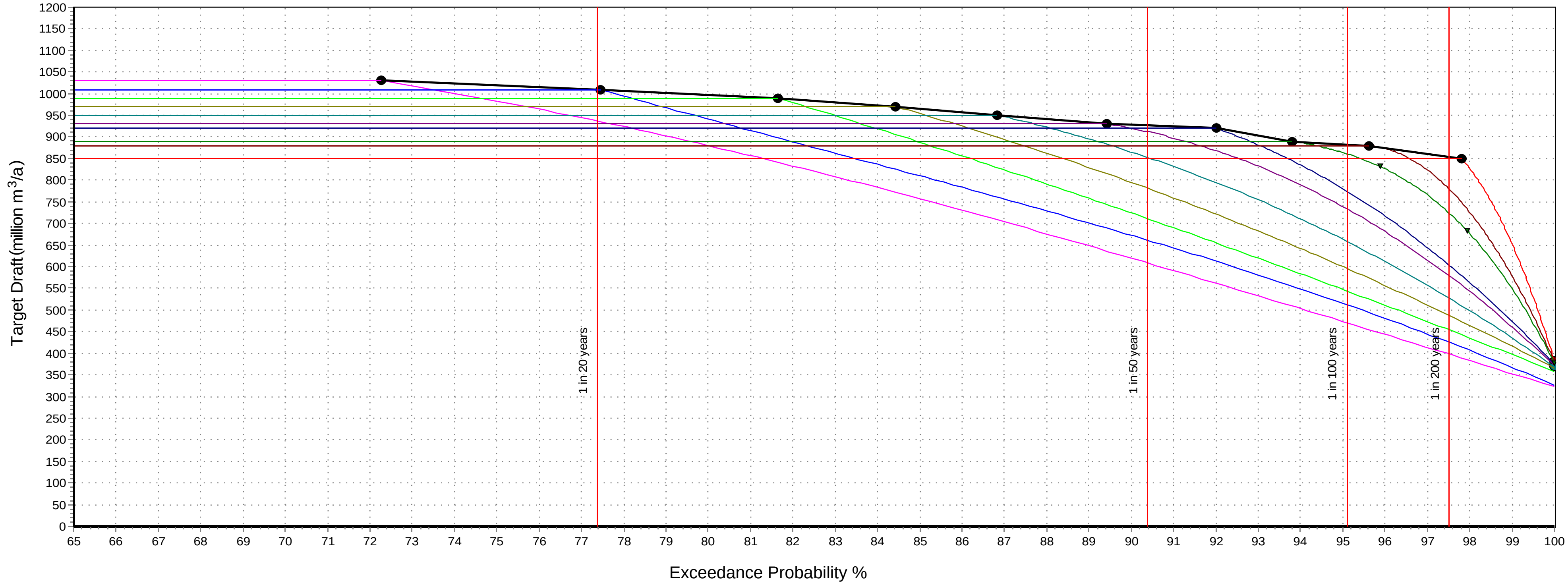


Mohale Net FSC = 857,1 million m^3
Katse Net FSC = 1518,6 million m^3
Total contributing FSC = 2375,7 million m^3

WRP_ P0138_Vaal Recon Study_Graphics_Fig25.cdr

Firm Yield Line

Reliability of base yield derived from 501 5-year generated sequences



Mohale Net FSC = 857,1 million m^3
Katse Net FSC = 1518,6 million m^3
Total contributing FSC = 2375,7 million m^3

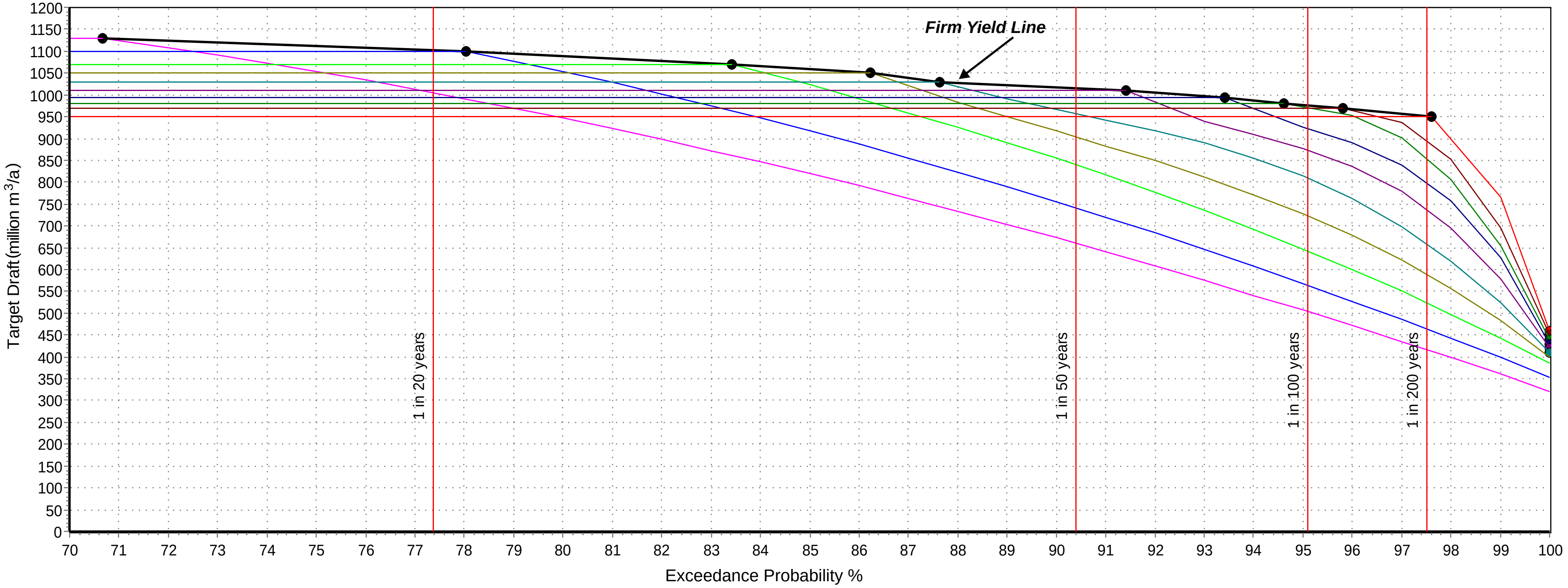
WRP_ P0138_Vaal Recon Study_Graphics_Fig25.cdr

VAAL RIVER SYSTEM: LARGE BULK WATER SUPPLY RECONCILIATION STRATEGIES AND WATER CONSERVATION AND DEMAND MANAGEMENT

Short-term yield-reliability characteristics: 80% net FSC: Senqu Sub-system

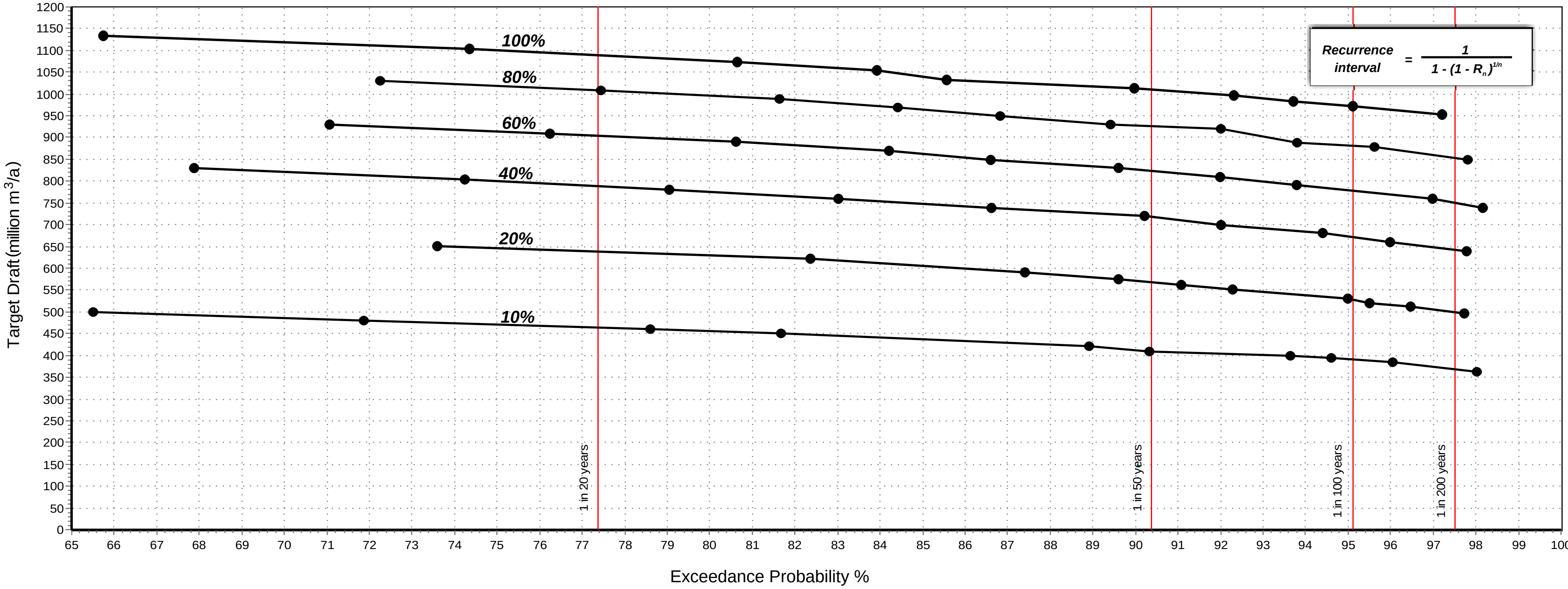
C-6

Reliability of base yield derived from 501 5-year generated sequences



Mohale Net FSC = 857,1 million m^3
Katse Net FSC = 1518,6 million m^3
Total contributing FSC = 2375,7 million m^3

Reliability of base yield derived from 501 5-year generated sequences



Mohale Net FSC = 857,1 million m^3
Katse Net FSC = 1518,6 million m^3
Total contributing FSC = 2375,7 million m^3

WRP_ P0138_Vaal Recon Study_Graphics_Fig25.cdr

SENQU SUB-SYSTEM C-9

System start at 100% net full supply volume

950.000000 0.515789 -1.162230 1.141134 -0.494693 0.023952
970.000000 0.536082 -1.283076 0.984127 -0.237133 0.041916
980.000000 0.551020 -1.388924 1.153105 -0.315202 0.053892
995.000000 0.567839 -1.559400 1.814041 -0.822480 0.065868
1010.000000 0.584158 -1.549114 1.835015 -0.870059 0.085828
1030.000000 0.601942 -1.497213 1.573070 -0.677799 0.123752
1050.000000 0.620789 -1.170079 1.008405 -0.459115 0.137725
1070.000000 0.680055 -1.347326 1.351050 -0.683780 0.165669
1100.000000 0.683222 -0.959238 0.347527 -0.071512 0.219561
1130.000000 0.715216 -1.007665 0.279830 0.012619 0.293413
1.000000 0.000000 0.000000 0.000000 0.000000 0.000000

System start at 80% net full supply volume

850.000000 0.549412 -0.477747 -0.849536 0.777872 0.021956
880.000000 0.567045 -1.023953 0.293565 0.163342 0.043912
890.000000 0.575281 -1.362531 1.114766 -0.327516 0.061876
920.000000 0.592391 -1.226353 1.309566 -0.675604 0.079840
930.000000 0.600000 -1.143740 0.743374 -0.199634 0.105788
950.000000 0.611579 -1.098389 0.810168 -0.323357 0.131737
970.000000 0.674265 -1.374815 1.475036 -0.774486 0.155689
990.000000 0.687897 -1.258710 1.287460 -0.716646 0.183633
1010.000000 0.678520 -0.954400 0.497017 -0.221137 0.225549
1030.000000 0.686189 -0.808385 -0.025464 0.147660 0.277445
1.000000 0.000000 0.000000 0.000000 0.000000 0.000000

System start at 60% net full supply volume

740.000000 0.459459 -0.455150 -0.096054 0.091745 0.017964
760.000000 0.486842 -0.875897 0.726835 -0.337780 0.029940
790.000000 0.518987 -0.797828 -0.003105 0.281946 0.061876
810.000000 0.543210 -0.923846 0.522250 -0.141614 0.079840
830.000000 0.566265 -0.854409 0.313810 -0.025666 0.103792
850.000000 0.588235 -0.938962 0.572421 -0.221694 0.133733
870.000000 0.609195 -0.996956 0.932920 -0.545160 0.157685
890.000000 0.631682 -1.014862 0.989822 -0.606642 0.193613
910.000000 0.692385 -1.064874 0.721698 -0.349209 0.237525
930.000000 0.708125 -0.962490 0.277611 -0.023246 0.289421
1.000000 0.000000 0.000000 0.000000 0.000000 0.000000

SENQU SUB-SYSTEM C-9 (Cont)

System start at 40% net full supply volume

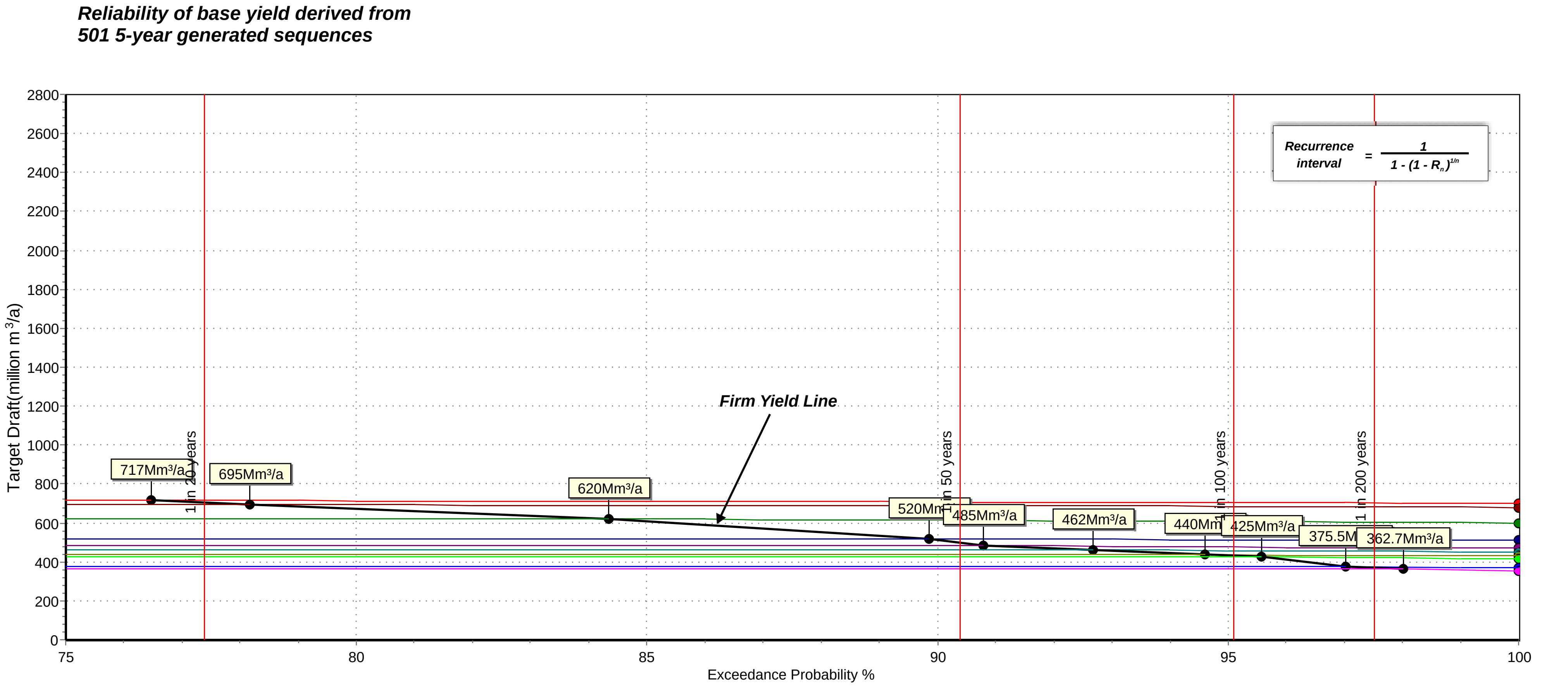
640.000000 0.484375 -1.045070 0.975274 -0.414580 0.021956
660.000000 0.515152 -1.118127 0.885420 -0.282444 0.039920
680.000000 0.544118 -1.020643 0.703401 -0.226876 0.055888
700.000000 0.573833 -1.151651 0.930493 -0.352675 0.079840
720.000000 0.594718 -1.145140 1.113569 -0.563147 0.097804
740.000000 0.626215 -1.149740 0.800629 -0.277104 0.133733
760.000000 0.681937 -1.390211 1.280821 -0.572546 0.169661
780.000000 0.708371 -1.416651 1.290790 -0.582510 0.209581
805.000000 0.750867 -1.524913 1.521266 -0.747220 0.257485
830.000000 0.770636 -1.478822 1.320077 -0.611891 0.321357
1.000000 0.000000 0.000000 0.000000 0.000000 0.000000

System start at 20% net full supply volume

495.000000 0.434343 -0.845899 0.661997 -0.250441 0.022404
510.000000 0.470588 -1.061440 0.761382 -0.170530 0.034807
520.000000 0.500000 -1.212072 1.053866 -0.341794 0.044707
530.000000 0.528302 -1.258965 1.312493 -0.581829 0.049649
550.000000 0.564162 -1.374956 1.392830 -0.582036 0.076738
560.000000 0.576708 -1.278473 1.156234 -0.454469 0.088999
575.000000 0.605026 -1.275474 1.141693 -0.471245 0.103668
590.000000 0.632166 -1.309720 1.013421 -0.335867 0.125583
620.000000 0.664834 -1.453584 1.188663 -0.399913 0.176290
650.000000 0.735492 -2.081694 2.392482 -1.046281 0.264114
1.000000 0.000000 0.000000 0.000000 0.000000 0.000000

System start at 10% net full supply volume

362.000000 0.151934 -0.177048 0.025110 0.000005 0.019841
385.000000 0.207792 -0.249264 0.028876 0.012596 0.039443
395.000000 0.232911 -0.049717 -0.763612 0.580417 0.053990
400.000000 0.247500 -0.240739 -0.323542 0.316781 0.063613
410.000000 0.295122 -0.727957 0.698146 -0.265311 0.096832
420.000000 0.316667 -0.743075 0.771792 -0.345384 0.110849
450.000000 0.366667 -0.760900 0.599442 -0.205210 0.183398
460.000000 0.382609 -0.813657 0.662315 -0.231267 0.213979
480.000000 0.453723 -1.249081 1.452652 -0.657293 0.281268
500.000000 0.492359 -1.409531 1.782689 -0.865516 0.344977
1.000000 0.000000 0.000000 0.000000 0.000000 0.000000



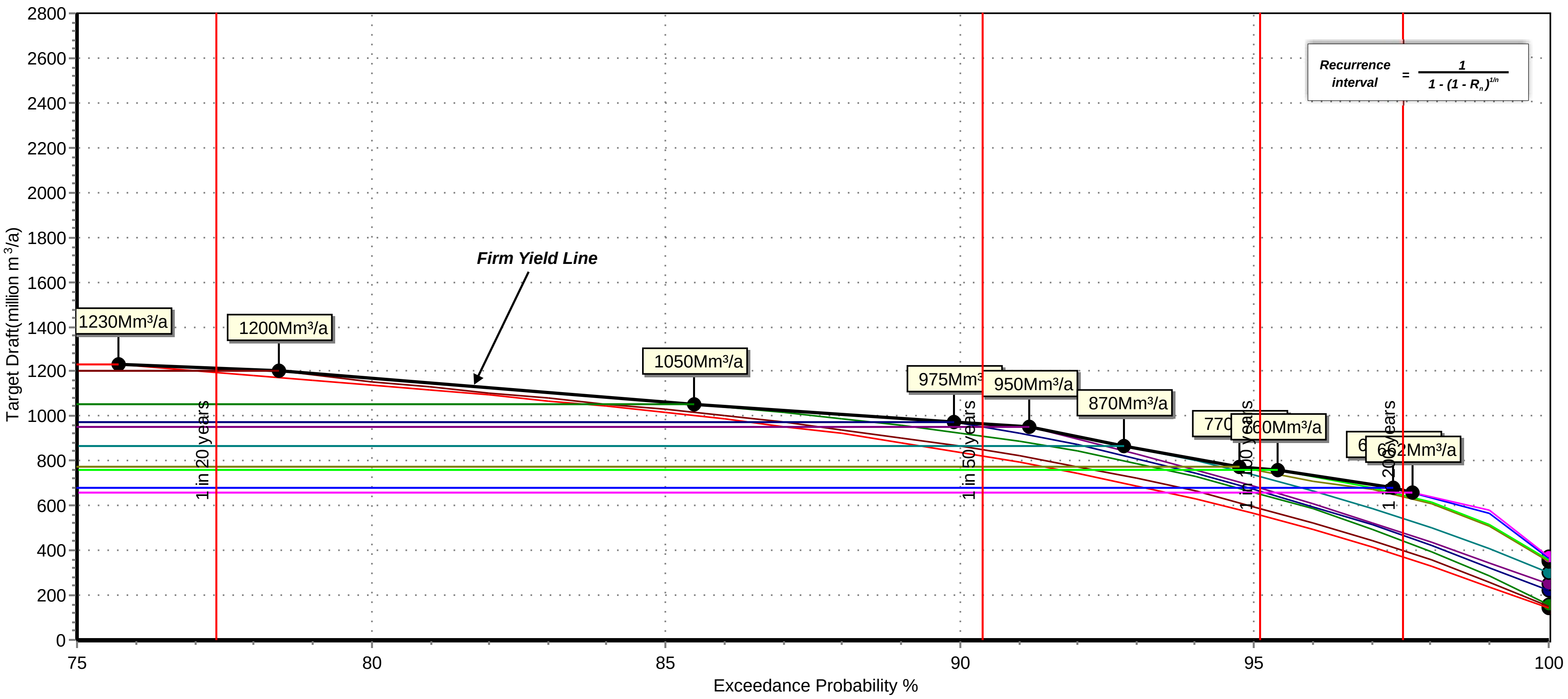
WRP_ P0138_Vaal Recon Study_Graphics_Fig33.cdr

VAAL RIVER SYSTEM: LARGE BULK WATER
SUPPLY RECONCILIATION STRATEGIES AND
WATER CONSERVATION AND DEMAND MANAGEMENT

Short-term yield-reliability characteristics:
10% net FSC: Bloemhof Sub-system

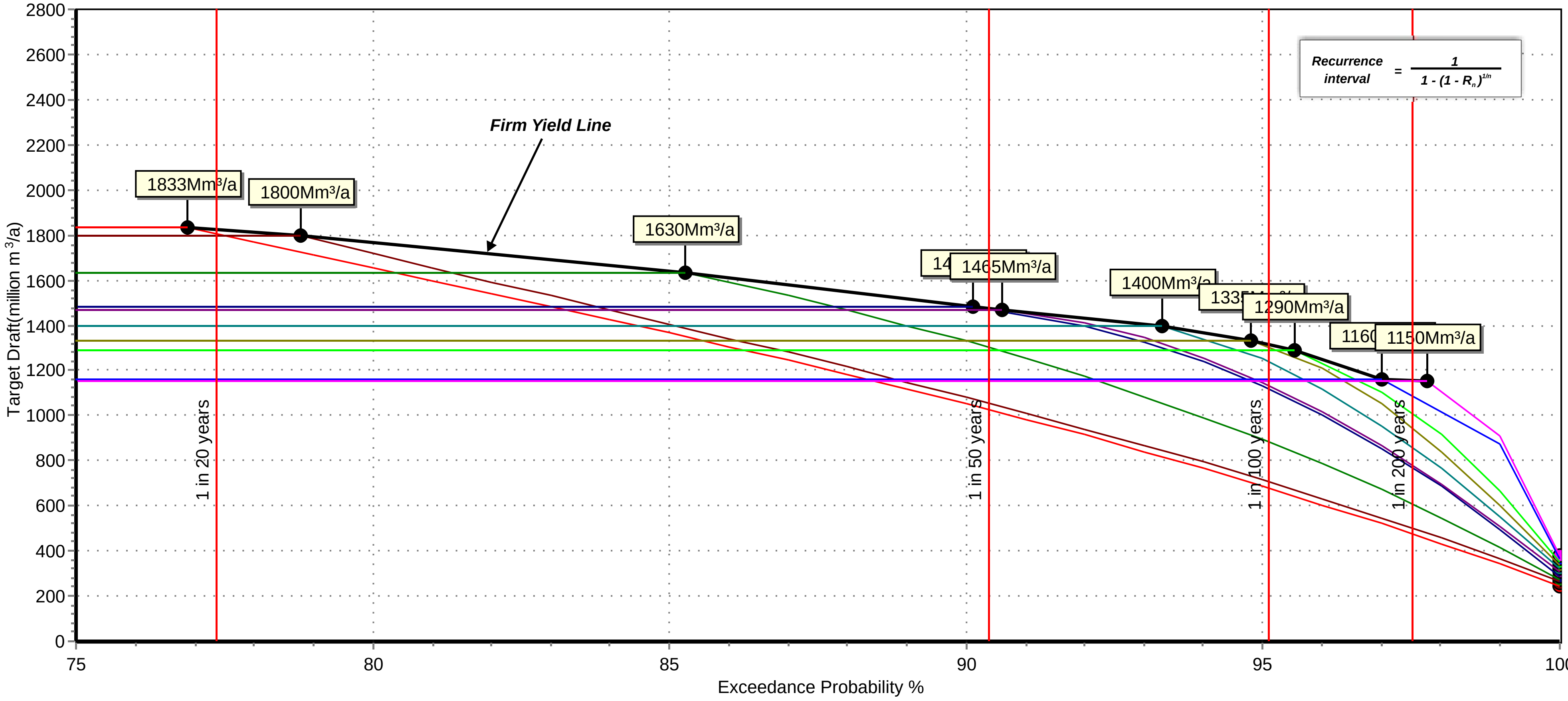
C-10

Reliability of base yield derived from 501 5-year generated sequences



WRP_ P0138_Vaal Recon Study_Graphics_Fig33.cdr

Reliability of base yield derived from
501 5-year generated sequences



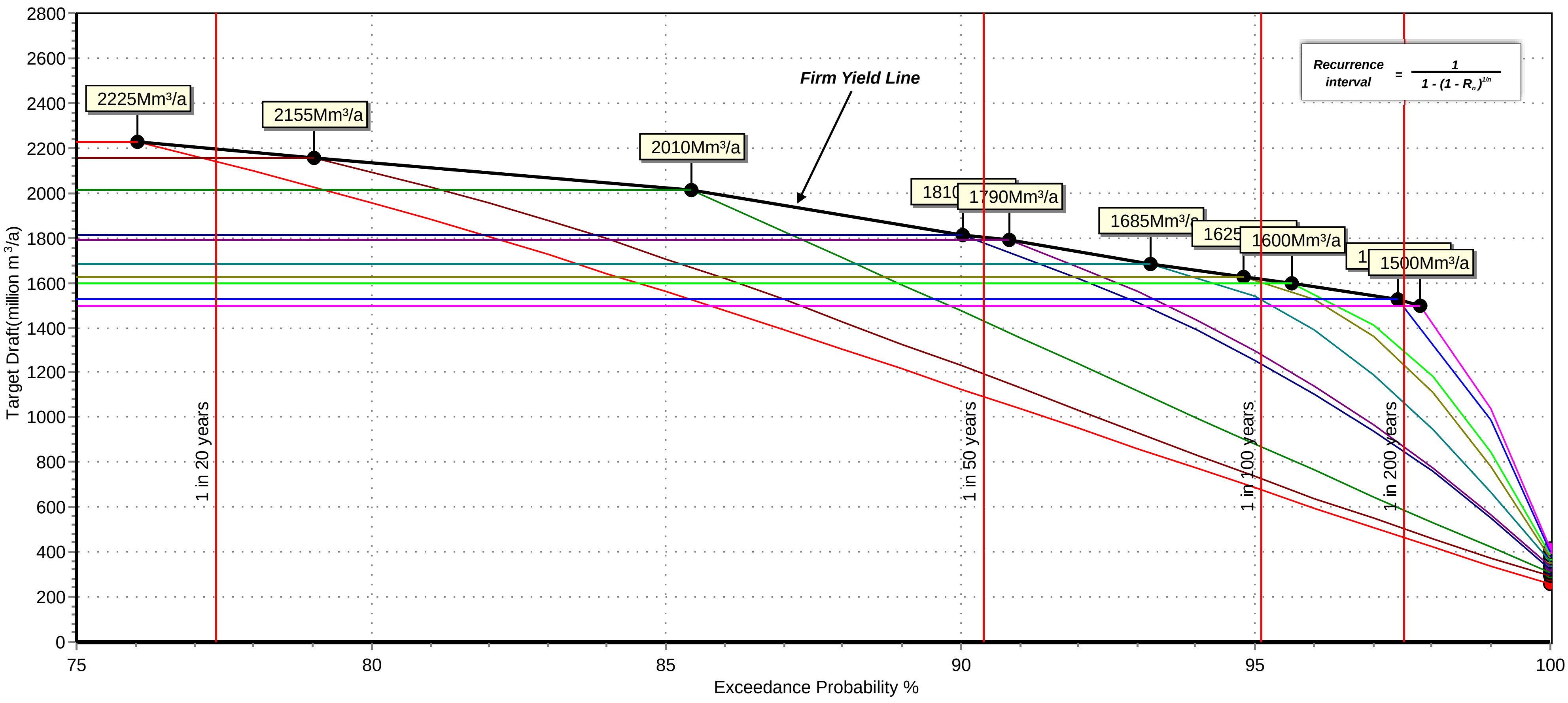
WRP_ P0138_Vaal Recon Study_Graphics_Fig33.cdr

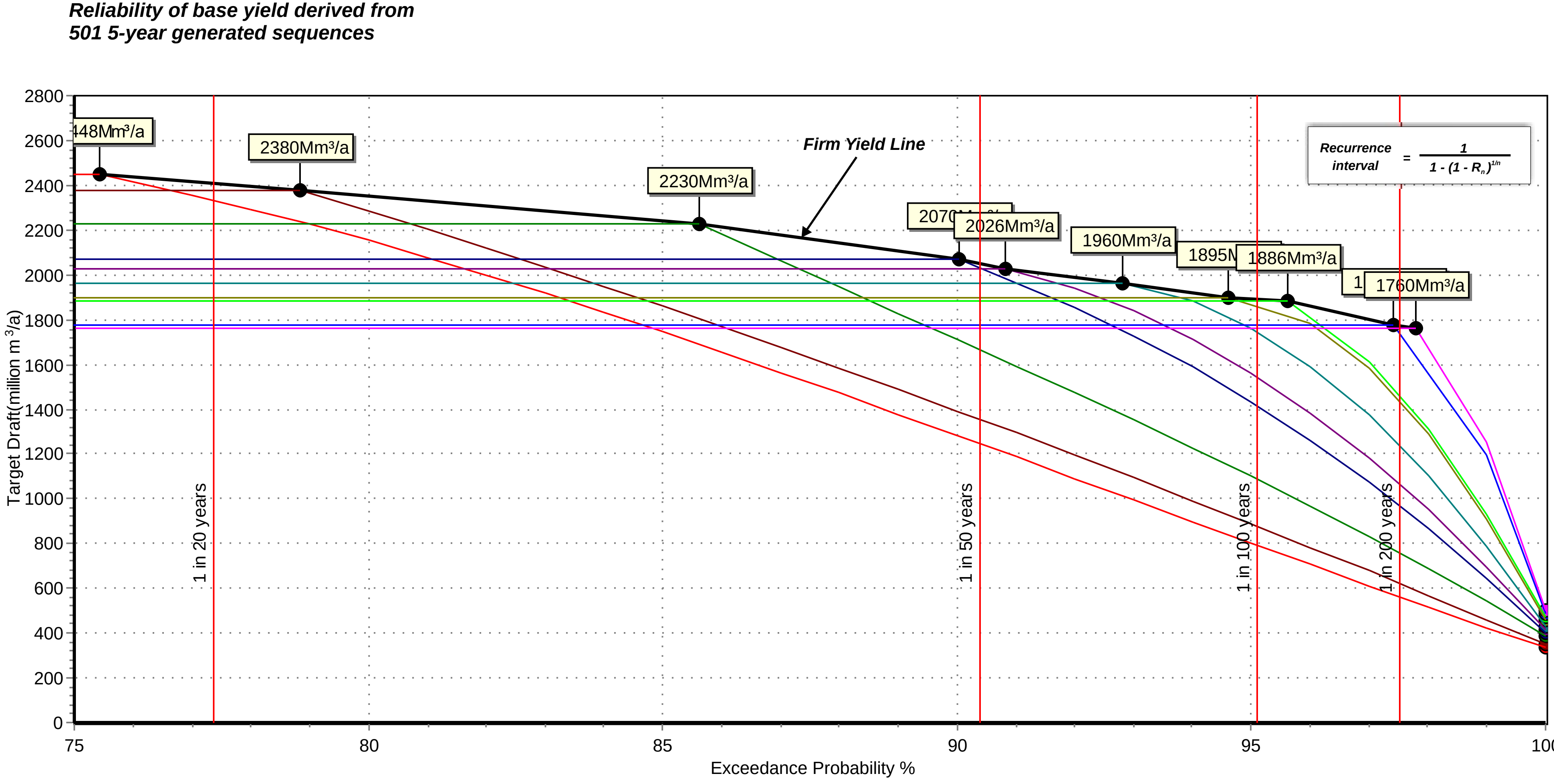
VAAL RIVER SYSTEM: LARGE BULK WATER SUPPLY RECONCILIATION STRATEGIES AND WATER CONSERVATION AND DEMAND MANAGEMENT

Short-term yield-reliability characteristics: 40% net FSC: Bloemhof Sub-system

C-12

Reliability of base yield derived from
501 5-year generated sequences





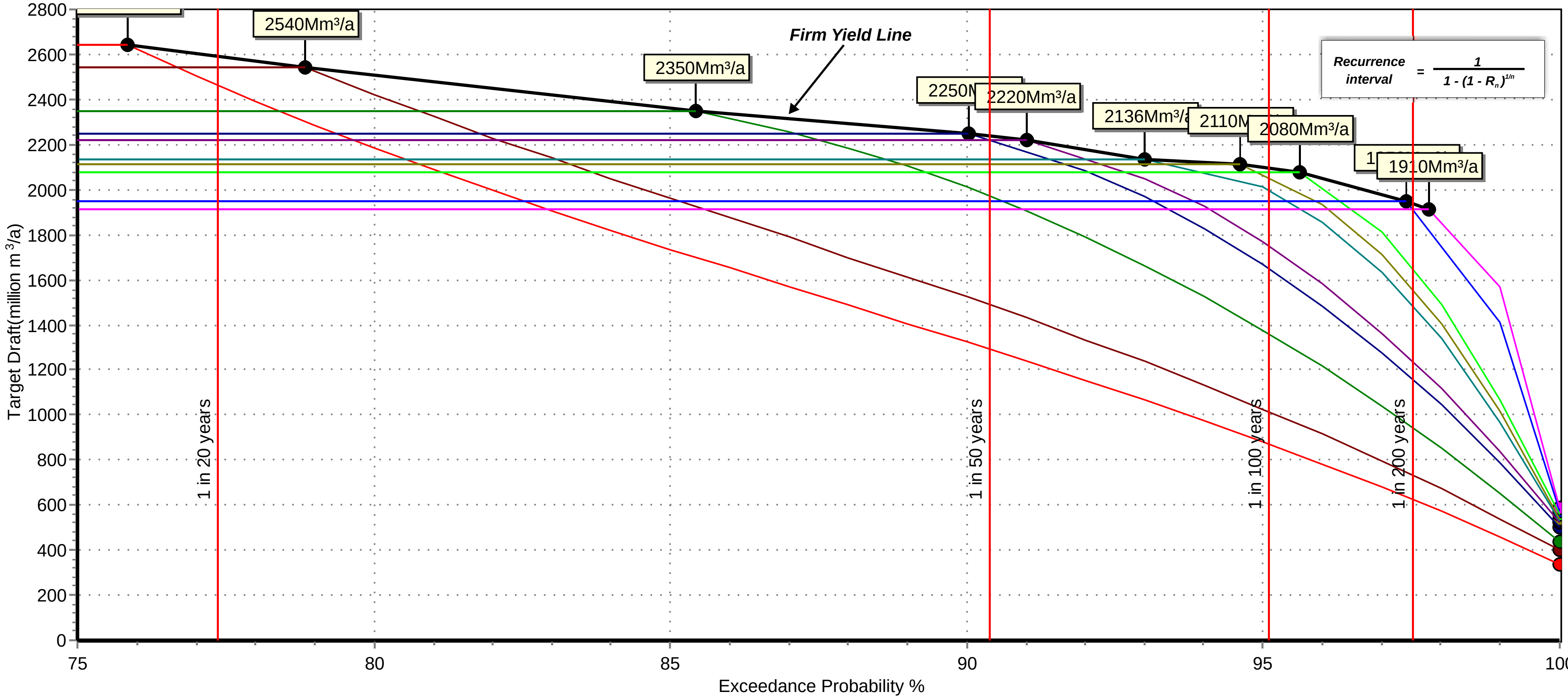
WRP_ P0138_Vaal Recon Study_Graphics_Fig33.cdr

VAAL RIVER SYSTEM: LARGE BULK WATER
SUPPLY RECONCILIATION STRATEGIES AND
WATER CONSERVATION AND DEMAND MANAGEMENT

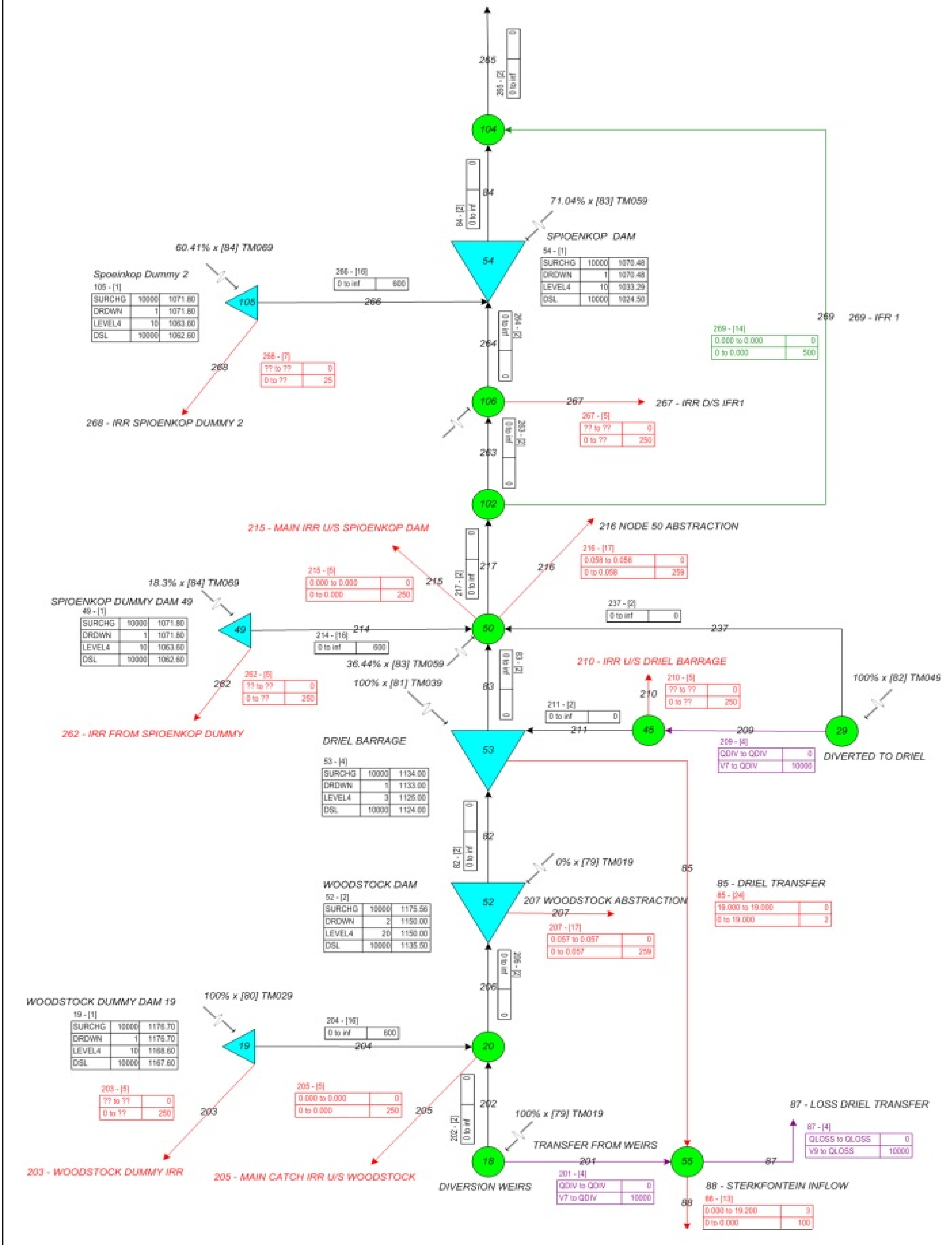
Short-term yield-reliability characteristics:
80% net FSC: Bloemhof Sub-system

C-14

Reliability of base yield derived from 501 5-year generated sequences



WRP_ P0138_Vaal Recon Study_Graphics_Fig33.cdr



WRP_ P0138_Vaal Recon Study_Graphics_Fig34.cdr

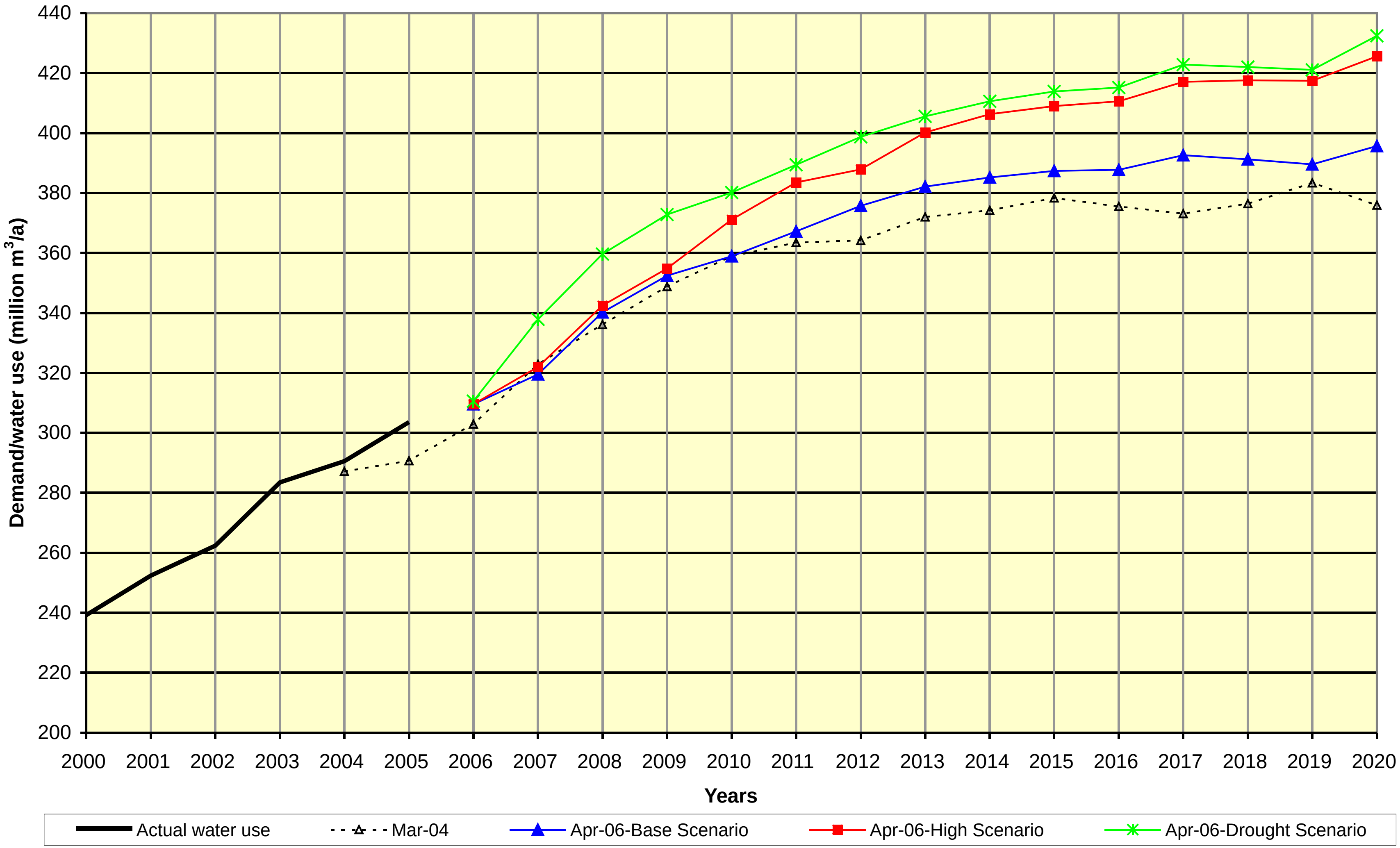
VAAL RIVER SYSTEM: LARGE BULK WATER SUPPLY RECONCILIATION STRATEGIES AND WATER CONSERVATION AND DEMAND MANAGEMENT

Network diagram of the upper portion of the Thukela

C-16

Appendix D

Water requirements and return flows

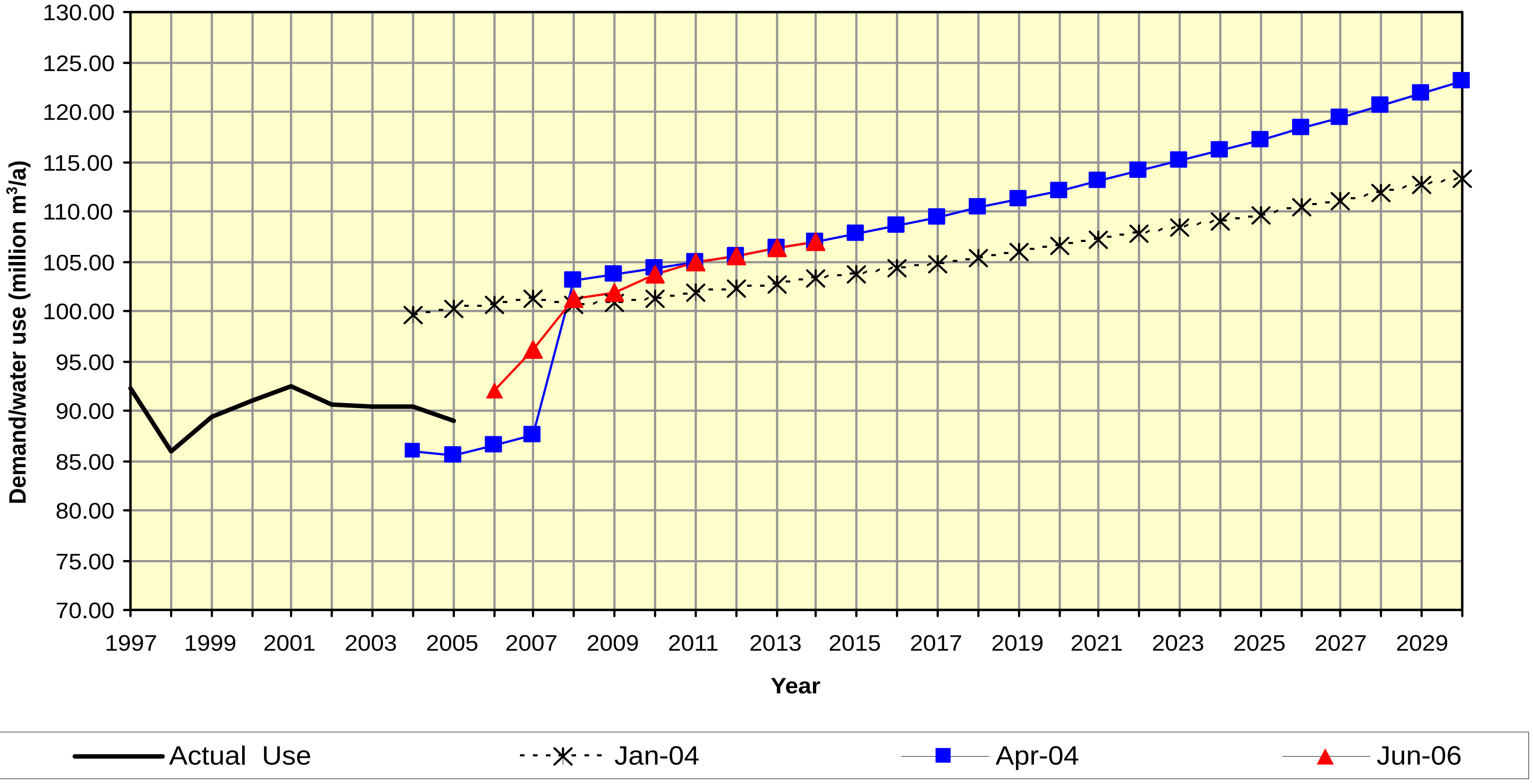


WRP_ P0138_Vaal Recon Study_Graphics_Fig27.cdr

VAAL RIVER SYSTEM: LARGE BULK WATER SUPPLY RECONCILIATION STRATEGIES AND WATER CONSERVATION AND DEMAND MANAGEMENT

ESKOM : Comparison of total demand projections for Power Stations supplied from the Integrated Vaal River System (DWAF Third Party Users not included)

D-1

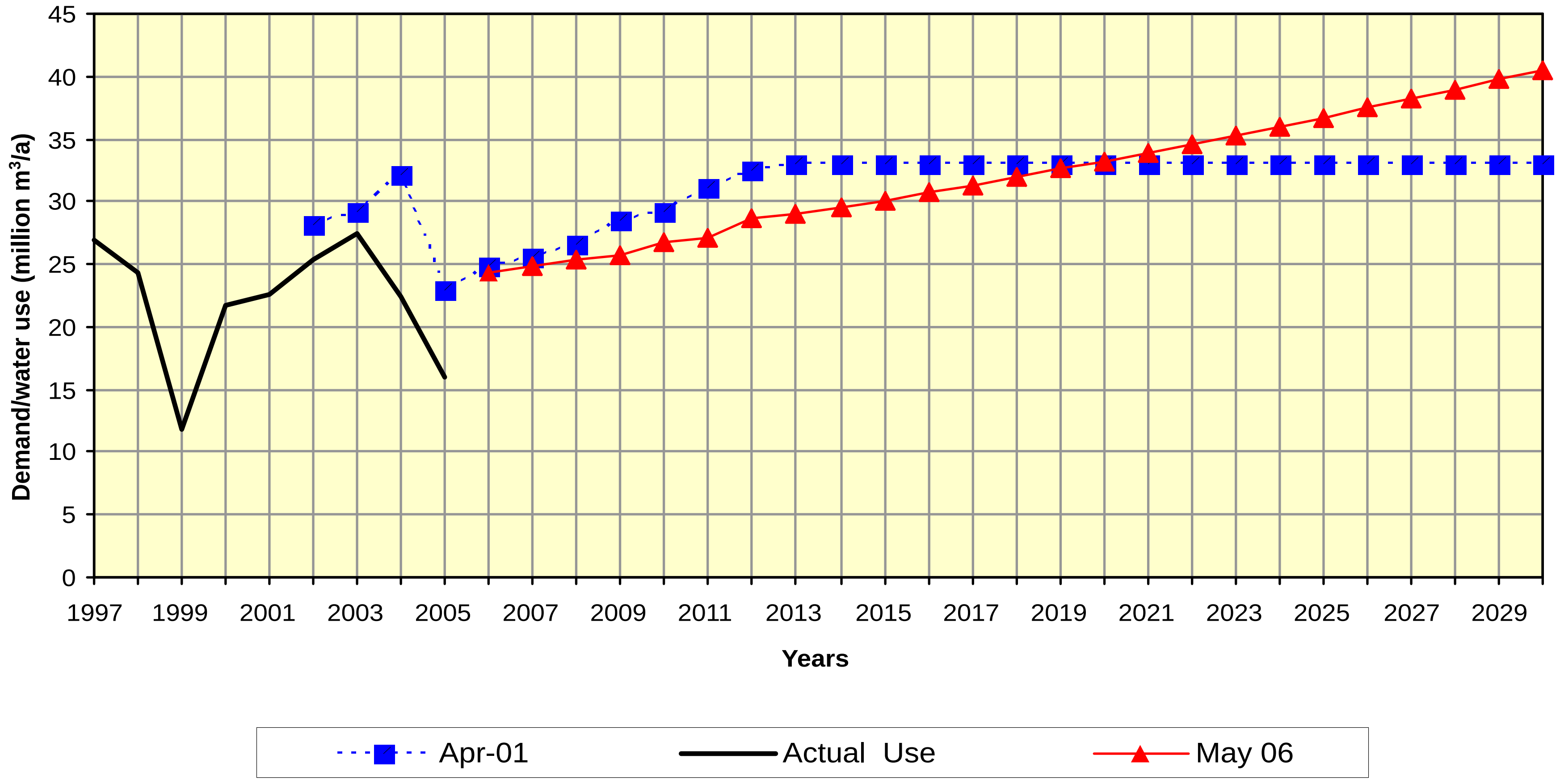


WRP_ P0138_Vaal Recon Study_Graphics_Fig27.cdr

VAAL RIVER SYSTEM: LARGE BULK WATER SUPPLY RECONCILIATION STRATEGIES AND WATER CONSERVATION AND DEMAND MANAGEMENT

Sasol Secunda : Comparison of actual water use and projections

D-2

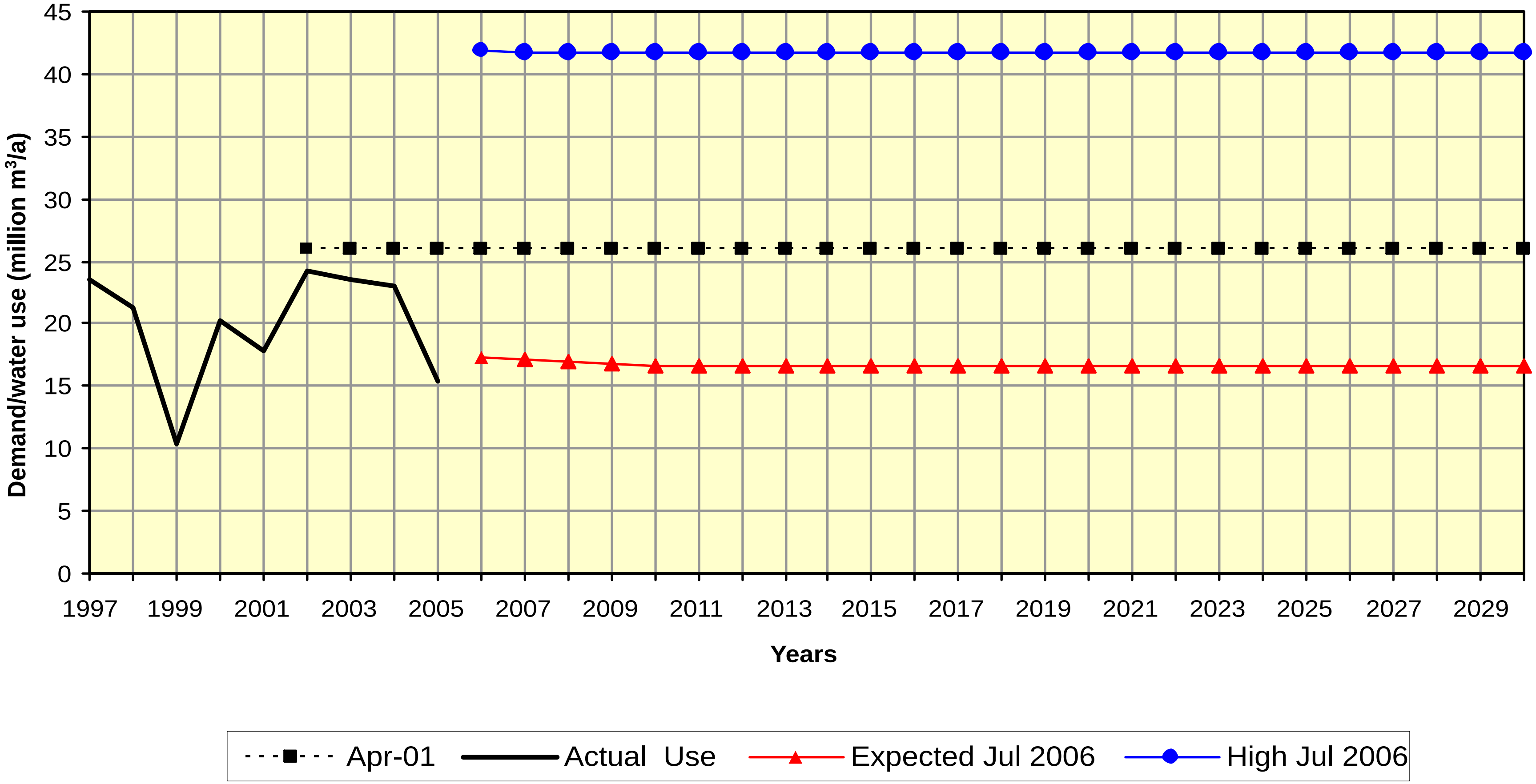


WRP_ P0138_Vaal Recon Study_Graphics_Fig27.cdr

VAAL RIVER SYSTEM: LARGE BULK WATER SUPPLY RECONCILIATION STRATEGIES AND WATER CONSERVATION AND DEMAND MANAGEMENT

Sasol Sasolburg : Comparison of water use and demand projection

D-3



WRP_ P0138_Vaal Recon Study_Graphics_Fig27.cdr

Table D-1: **Scenario A water demand and return flow projections for the Integrated Vaal River System (2006/2007) as adopted for the WRPM Scenario VT06R03.**
Based on Rand Water Scenario A (NWRS adjusted Demographics projections excluding WDM), Midvaal and Sedibeng Water April 2006 projections, Eskom April 2006
Sasol Secunda March 2004 projections, 2006 projections for Sasol 1 and Mittal Steel and the NWRS demand projections (Ratio Method) for smaller demand centres.

		Projected Demands and Return Flows (million m^3/a)															Extrapolated	
DESCRIPTION		**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2025**	**2030**
DEMANDS:	Rand Water (1)	1297.27	1307.66	1318.14	1328.70	1338.13	1353.34	1368.98	1384.80	1400.81	1417.01	1429.65	1442.40	1455.28	1468.27	1481.38	1567.76	1666.19
	Magalies Water (Vaalkop Scheme) (11)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Mittal Steel (10)	17.35	17.17	16.98	16.80	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62
	ESKOM (8)	330.31	344.34	362.69	373.50	381.08	389.44	397.28	402.57	405.33	406.89	408.74	411.57	410.07	410.98	415.73	416.57	415.57
	SASOL Sasolburg (9)	24.25	24.76	25.38	25.68	26.74	27.07	28.64	28.96	29.54	30.13	30.74	31.35	31.98	32.62	33.27	36.73	40.56
	SASOL Secunda	92.04	96.06	101.17	101.90	103.73	104.83	105.56	106.29	107.02	107.81	108.61	109.46	110.34	111.21	112.13	117.21	123.03
	Midvaal Water Company	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00
	Sedibeng Water (Balkfontein only)	40.95	41.31	41.32	41.32	41.32	41.32	41.32	41.32	41.32	41.33	41.33	41.33	41.33	41.33	41.33	41.92	42.53
	Other towns and industries (Vaal)	160.90	161.51	162.12	162.73	163.34	163.97	164.60	165.24	165.87	166.50	166.57	166.64	166.71	166.78	166.85	167.38	168.35
	Other towns and industries(Zaai)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Vaalharts/Lower Vaal irrigation (2)	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53
	Diffuse Irrig and Aff (Vaal)	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31
	Diffuse Irrig and AFF (Sup systems)	72.05	72.05	72.05	72.05	72.05	72.05	72.05	72.05	72.05	72.05	72.05	72.05	72.05	72.05	72.05	72.05	72.05
	Other irrigation in Vaal (3)	613.60	648.15	687.68	588.94	490.21	391.47	391.47	391.47	391.47	391.47	391.47	391.47	391.47	391.47	391.47	391.47	391.47
	Other irrigation in sup subsystems (3)	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10
	Wetland losses (4)	44.11	44.35	44.60	44.86	45.11	45.36	45.62	45.88	46.14	46.40	46.66	46.91	47.17	47.43	47.70	48.99	50.24
	Bed losses (5)	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20
	Mooi River (net losses) (6)	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80
RETURN FLOWS:	Southern Gauteng (Rand Water)	-331.18	-334.19	-337.22	-340.28	-343.37	-346.52	-349.69	-352.90	-356.14	-359.41	-361.98	-364.56	-367.17	-369.80	-372.44	-386.12	-400.46
	Midvaal Water Company	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.86	-0.86	-0.86	-0.86	-0.86	-0.86	-0.86	-0.87
	Sedibeng Water	-1.64	-1.65	-1.65	-1.65	-1.65	-1.65	-1.65	-1.65	-1.65	-1.65	-1.65	-1.65	-1.65	-1.65	-1.65	-1.68	-1.70
	Other towns and industries	-61.48	-62.26	-63.16	-63.71	-64.88	-65.32	-66.72	-67.30	-68.06	-68.97	-69.63	-70.30	-70.97	-71.66	-72.47	-76.21	-80.38
	Irrigation (7)	-59.67	-62.98	-66.76	-57.30	-47.84	-38.38	-38.38	-38.38	-38.38	-38.38	-38.38	-38.38	-38.38	-38.38	-38.38	-38.38	-38.38
	Mine dewatering	-114.12	-111.84	-109.55	-107.27	-104.99	-104.54	-104.08	-104.08	-113.21	-121.24	-123.07	-123.07	-123.07	-123.07	-123.07	-121.24	-121.24
	Increased urban runoff	-100.94	-101.49	-102.06	-102.64	-103.24	-103.86	-104.49	-105.14	-105.82	-106.51	-107.81	-109.14	-110.50	-111.89	-113.32	-120.97	-129.39
OVERALL GROSS SYSTEM DEMAND:		3586.77	3651.30	3726.09	3650.43	3572.26	3499.41	3526.08	3549.14	3570.12	3590.15	3606.38	3623.74	3636.96	3652.70	3672.47	3770.63	3880.54
OVERALL NET SYSTEM DEMAND:		2916.90	2976.05	3044.84	2976.72	2905.43	2838.29	2860.21	2878.82	2886.00	2893.13	2903.00	2915.78	2924.36	2935.38	2950.27	3025.16	3108.12

Notes :

(1): Rand Water's total raw water abstraction includes Sasolburg but excludes Authorised Users (i.e. ESKOM, ISCOR, Sasol I , Mittal Steel and Small Users (Mining & Industrial)).
(2): Includes distribution losses within Vaalharts canal system
(3): "Other irrigation" excludes diffuse irrigation
(4): Includes evaporation losses associated with wetlands as well as bed losses occuring within the Suikerbosrand and Klip rivers
(5): Vaal River bed losses include evaporation and operating losses associated with releases made from Bloemhof Dam
(6): Mooi River (Wonderfonteinspruit catchment) : Net effect of bed losses and decanting from dolomitic eyes resulting from WQT calibration
(7): Includes flow contribution resulting from the tailwater component at Erfenis Dam
(8): Includes DWAF 3rd Party Users
(9): Raw water requirements only: It is assumed that Sasol's raw water requirements are not supplied through Rand Water, but the the projections of Rand Water include the potable water allocation of 6Ml/day.
(10): Represents Mittal Steel's total water requirements (i.e. includes the portion of the demand obtained from Rand Water)
(11): Represents portion of Rand Water's demand supplied by Magalies Water (drawn through the Vaalkop Scheme)

Table D-2: **Scenario B water demand and return flow projections for the Integrated Vaal River System (2006/2007) as adopted for WRPM Scenario VT06R04**
Based on Rand Water Scenario B (DWAF High Demographics projections excluding WDM), Midvaal and Sedibeng Water April 2006 projections, Eskom April 2006
Sasol Secunda March 2004 projections, 2006 projections for Sasol 1 and Mittal Steel and the NWRS demand projections (Ratio Method) for smaller demand centres.

DESCRIPTION		Projected Demands and Return Flows (million m^3/a)															Extrapolated	
		2006	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2025**	**2030**
DEMANDS:	Rand Water [1]	1307.87	1328.22	1348.91	1369.95	1390.11	1410.94	1432.32	1454.03	1476.08	1498.47	1514.81	1531.34	1548.05	1564.96	1582.06	1665.23	1752.76
	Magalies Water (Vaalkop Scheme) [11]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Mittal Steel [10]	17.35	17.17	16.98	16.80	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62
	ESKOM [8]	330.31	344.34	362.69	373.50	381.08	389.44	397.28	402.57	405.33	406.89	408.74	411.57	410.07	410.98	415.73	416.57	415.57
	SASOL Sasolburg [9]	24.25	24.76	25.38	25.68	26.74	27.07	28.64	28.96	29.54	30.13	30.74	31.35	31.98	32.62	33.27	36.73	40.56
	SASOL Secunda	92.04	96.06	101.17	101.90	103.73	104.83	105.56	106.29	107.02	107.81	108.61	109.46	110.34	111.21	112.13	117.21	123.03
	Midvaal Water Company	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00
	Sedibeng Water (Balkfontein only)	40.95	41.31	41.32	41.32	41.32	41.32	41.32	41.32	41.32	41.33	41.33	41.33	41.33	41.33	41.33	41.92	42.53
	Other towns and industries (Vaal)	160.90	161.51	162.12	162.73	163.34	163.97	164.60	165.24	165.87	166.50	166.57	166.64	166.71	166.78	166.85	167.38	168.35
	Other towns and industries(Zaai)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Vaalharts/Lower Vaal irrigation [2]	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53
	Diffuse Irrig and Aff (Vaal)	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31
	Diffuse Irrig and AFF (Sup systems)	72.05	72.05	72.05	72.05	72.05	72.05	72.05	72.05	72.05	72.05	72.05	72.05	72.05	72.05	72.05	72.05	72.05
	Other irrigation in Vaal [3]	613.60	648.15	687.68	588.94	490.21	391.47	391.47	391.47	391.47	391.47	391.47	391.47	391.47	391.47	391.47	391.47	391.47
	Other irrigation in sup subsystems [3]	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10
	Wetland losses [4]	44.11	44.35	44.60	44.86	45.11	45.36	45.62	45.88	46.14	46.40	46.66	46.91	47.17	47.43	47.70	48.99	50.24
	Bed losses [5]	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20
	Mooi River (net losses) [6]	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80
RETURN FLOWS:	Southern Gauteng (Rand Water)	-335.44	-341.87	-348.43	-355.13	-361.95	-367.69	-373.53	-379.46	-385.49	-391.63	-396.80	-402.05	-407.37	-412.76	-418.23	-438.02	-458.80
	Midvaal Water Company	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.86	-0.86	-0.86	-0.86	-0.86	-0.86	-0.86	-0.87
	Sedibeng Water	-1.64	-1.65	-1.65	-1.65	-1.65	-1.65	-1.65	-1.65	-1.65	-1.65	-1.65	-1.65	-1.65	-1.65	-1.65	-1.68	-1.70
	Other towns and industries	-61.48	-62.26	-63.16	-63.71	-64.88	-65.32	-66.72	-67.30	-68.06	-68.97	-69.63	-70.30	-70.97	-71.66	-72.47	-76.21	-80.38
	Irrigation [7]	-59.67	-62.98	-66.76	-57.30	-47.84	-38.38	-38.38	-38.38	-38.38	-38.38	-38.38	-38.38	-38.38	-38.38	-38.38	-38.38	-38.38
	Mine dewatering	-114.12	-111.84	-109.55	-107.27	-104.99	-104.54	-104.08	-104.08	-113.21	-121.24	-123.07	-123.07	-123.07	-123.07	-123.07	-121.24	-121.24
	Increased urban runoff	-100.94	-101.49	-102.06	-102.64	-103.24	-103.86	-104.49	-105.14	-105.82	-106.51	-107.81	-109.14	-110.50	-111.89	-113.32	-120.97	-129.39
OVERALL GROSS SYSTEM DEMAND:		3597.36	3671.86	3756.86	3691.67	3624.24	3557.00	3589.42	3618.37	3645.39	3671.61	3691.54	3712.68	3729.74	3749.39	3773.15	3868.11	3967.12
OVERALL NET SYSTEM DEMAND:		2923.23	2988.92	3064.40	3003.12	2938.83	2874.71	2899.72	2921.50	2931.92	2942.37	2953.34	2967.23	2976.94	2989.11	3005.17	3070.74	3136.36

Notes :

(1): Rand Water's total raw water abstraction includes Sasolburg but excludes Authorised Users (i.e. ESKOM, ISCOR, Sasol I , Mittal Steel and Small Users (Mining & Industrial)).
(2): Includes distribution losses within Vaalharts canal system
(3): "Other irrigation" excludes diffuse irrigation
(4): Includes evaporation losses associated with wetlands as well as bed losses occuring within the Suikerbosrand and Klip rivers
(5): Vaal River bed losses include evaporation and operating losses associated with releases made from Bloemhof Dam
(6): Mooi River (Wonderfonteinspruit catchment) : Net effect of bed losses and decanting from dolomitic eyes resulting from WQT calibration
(7): Includes flow contribution resulting from the tailwater component at Erfenis Dam
(8): Includes DWAF 3rd Party Users
(9): Raw water requirements only: It is assumed that Sasol's raw water requirements are not supplied through Rand Water, but the the projections of Rand Water include the potable water allocation of 6Ml/day.
(10): Represents Mittal Steel's total water requirements (i.e. includes the portion of the demand obtained from Rand Water)
(11): Represents portion of Rand Water's demand supplied by Magalies Water (drawn through the Vaalkop Scheme)

Table D-3: **Scenario C water demands and return flow projections for the Integrated Vaal River System (2006/2007) as adopted for Sc VT06R05**
Based on Rand Water Scenario C (DWAF High Demographics projections including WDM), Midvaal and Sedibeng Water April 2006 projections, Eskom April 2006
Sasol Secunda March 2004 projections, 2006 projections for Sasol 1 and Mittal Steel and the NWRS demand projections (Ratio Method) for smaller demand centres.

		Projected Demands and Return Flows (million m^3/a)															Extrapolated	
DESCRIPTION		**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2025**	**2030**
DEMANDS:	Rand Water [1]	1256.35	1245.07	1234.24	1223.85	1212.66	1215.23	1218.05	1220.89	1223.75	1226.63	1231.87	1237.14	1242.44	1247.78	1253.14	1286.48	1374.93
	Magalies Water (Vaalkop Scheme) [11]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Mittal Steel [10]	17.35	17.17	16.98	16.80	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62
	ESKOM [8]	330.31	344.34	362.69	373.50	381.08	389.44	397.28	402.57	405.33	406.89	408.74	411.57	410.07	410.98	415.73	416.57	415.57
	SASOL Sasolburg [9]	24.25	24.76	25.38	25.68	26.74	27.07	28.64	28.96	29.54	30.13	30.74	31.35	31.98	32.62	33.27	36.73	40.56
	SASOL Secunda	92.04	96.06	101.17	101.90	103.73	104.83	105.56	106.29	107.02	107.81	108.61	109.46	110.34	111.21	112.13	117.21	123.03
	Midvaal Water Company	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00
	Sedibeng Water (Balkfontein only)	40.95	41.31	41.32	41.32	41.32	41.32	41.32	41.32	41.32	41.33	41.33	41.33	41.33	41.33	41.33	41.92	42.53
	Other towns and industries (Vaal)	160.90	161.51	162.12	162.73	163.34	163.97	164.60	165.24	165.87	166.50	166.57	166.64	166.71	166.78	166.85	167.38	168.35
	Other towns and industries(Zaai)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Vaalharts/Lower Vaal irrigation [2]	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53
	Diffuse Irrig and Aff (Vaal)	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31
	Diffuse Irrig and AFF (Sup systems)	72.05	72.05	72.05	72.05	72.05	72.05	72.05	72.05	72.05	72.05	72.05	72.05	72.05	72.05	72.05	72.05	72.05
	Other irrigation in Vaal [3]	613.60	648.15	687.68	588.94	490.21	391.47	391.47	391.47	391.47	391.47	391.47	391.47	391.47	391.47	391.47	391.47	391.47
	Other irrigation in sup subsystems [3]	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10
	Wetland losses [4]	44.11	44.35	44.60	44.86	45.11	45.36	45.62	45.88	46.14	46.40	46.66	46.91	47.17	47.43	47.70	48.99	50.24
	Bed losses [5]	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20
	Mooi River (net losses) [6]	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80
RETURN FLOWS:	Southern Gauteng (Rand Water)	-318.79	-312.08	-305.56	-299.23	-293.08	-294.61	-296.16	-297.72	-299.29	-300.87	-302.27	-303.69	-305.11	-306.54	-307.99	-311.89	-324.00
	Midvaal Water Company	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.86	-0.86	-0.86	-0.86	-0.86	-0.86	-0.86	-0.87
	Sedibeng Water	-1.64	-1.65	-1.65	-1.65	-1.65	-1.65	-1.65	-1.65	-1.65	-1.65	-1.65	-1.65	-1.65	-1.65	-1.65	-1.68	-1.70
	Other towns and industries	-61.48	-62.26	-63.16	-63.71	-64.88	-65.32	-66.72	-67.30	-68.06	-68.97	-69.63	-70.30	-70.97	-71.66	-72.47	-76.21	-80.38
	Irrigation [7]	-59.67	-62.98	-66.76	-57.30	-47.84	-38.38	-38.38	-38.38	-38.38	-38.38	-38.38	-38.38	-38.38	-38.38	-38.38	-38.38	-38.38
	Mine dewatering	-114.12	-111.84	-109.55	-107.27	-104.99	-104.54	-104.08	-104.08	-113.21	-121.24	-123.07	-123.07	-123.07	-123.07	-123.07	-121.24	-121.24
	Increased urban runoff	-100.94	-101.49	-102.06	-102.64	-103.24	-103.86	-104.49	-105.14	-105.82	-106.51	-107.81	-109.14	-110.50	-111.89	-113.32	-120.97	-129.39
OVERALL GROSS SYSTEM DEMAND:		3545.85	3588.71	3642.19	3545.58	3446.79	3361.29	3375.15	3385.23	3393.06	3399.77	3408.60	3418.48	3424.13	3432.20	3444.23	3489.36	3589.29
OVERALL NET SYSTEM DEMAND:		2888.37	2935.56	2992.60	2912.93	2830.26	2752.08	2762.81	2770.10	2765.79	2761.29	2764.93	2771.39	2773.59	2778.15	2786.49	2818.12	2893.33

Notes :

(1): Rand Water's total raw water abstraction includes Sasolburg but excludes Authorised Users (i.e. ESKOM, ISCOR, Sasol I , Mittal Steel and Small Users (Mining & Industrial)).
(2): Includes distribution losses within Vaalharts canal system
(3): "Other irrigation" excludes diffuse irrigation
(4): Includes evaporation losses associated with wetlands as well as bed losses occuring within the Suikerbosrand and Klip rivers
(5): Vaal River bed losses include evaporation and operating losses associated with releases made from Bloemhof Dam
(6): Mooi River (Wonderfonteinspruit catchment) : Net effect of bed losses and decanting from dolomitic eyes resulting from WQT calibration
(7): Includes flow contribution resulting from the tailwater component at Erfenis Dam
(8): Includes DWAF 3rd Party Users
(9): Raw water requirements only: It is assumed that Sasol's raw water requirements are not supplied through Rand Water, but the the projections of Rand Water include the potable water allocation of 6Ml/day.
(10): Represents Mittal Steel's total water requirements (i.e. includes the portion of the demand obtained from Rand Water)
(11): Represents portion of Rand Water's demand supplied by Magalies Water (drawn through the Vaalkop Scheme)

Table D-4: **Scenario D water demands and return flow projections for the Integrated Vaal River System (2006/2007) as adopted for the WRPM Scenario VT06R08**
Based on Rand Water Scenario C (DWAF 2005 High Population projections including 5yr Loss Management), Midvaal and Sedibeng Water April 2006 projections, Eskom April 2006
Sasol Secunda March 2004 projections, 2006 projections for Sasol 1 and Mittal Steel and the NWRS demand projections (Ratio Method) for smaller demand centres.

DESCRIPTION		Projected Demands and Return Flows (million m^3/a)															Extrapolated	
		2006	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2025**	**2030**
DEMANDS:	Rand Water [1]	1271.05	1255.01	1239.67	1224.99	1209.70	1228.39	1247.61	1267.15	1287.00	1307.17	1321.71	1336.42	1351.29	1366.34	1381.56	1451.90	1539.64
	Magalies Water (Vaalkop Scheme) [11]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Mittal Steel [10]	17.35	17.17	16.98	16.80	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62
	ESKOM [8]	330.31	344.34	362.69	373.50	381.08	389.44	397.28	402.57	405.33	406.89	408.74	411.57	410.07	410.98	415.73	416.57	415.57
	SASOL Sasolburg [9]	24.25	24.76	25.38	25.68	26.74	27.07	28.64	28.96	29.54	30.13	30.74	31.35	31.98	32.62	33.27	36.73	40.56
	SASOL Secunda	92.04	96.06	101.17	101.90	103.73	104.83	105.56	106.29	107.02	107.81	108.61	109.46	110.34	111.21	112.13	117.21	123.03
	Midvaal Water Company	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00
	Sedibeng Water (Balkfontein only)	40.95	41.31	41.32	41.32	41.32	41.32	41.32	41.32	41.32	41.33	41.33	41.33	41.33	41.33	41.33	41.92	42.53
	Other towns and industries (Vaal)	160.90	161.51	162.12	162.73	163.34	163.97	164.60	165.24	165.87	166.50	166.57	166.64	166.71	166.78	166.85	167.38	168.35
	Other towns and industries(Zaai)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Vaalharts/Lower Vaal irrigation [2]	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53
	Diffuse Irrig and Aff (Vaal)	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31
	Diffuse Irrig and AFF (Sup systems)	72.05	72.05	72.05	72.05	72.05	72.05	72.05	72.05	72.05	72.05	72.05	72.05	72.05	72.05	72.05	72.05	72.05
	Other irrigation in Vaal [3]	613.60	648.15	687.68	588.94	490.21	391.47	391.47	391.47	391.47	391.47	391.47	391.47	391.47	391.47	391.47	391.47	391.47
	Other irrigation in sup subsystems [3]	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10
	Wetland losses [4]	44.11	44.35	44.60	44.86	45.11	45.36	45.62	45.88	46.14	46.40	46.66	46.91	47.17	47.43	47.70	48.99	50.24
	Bed losses [5]	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20
	Mooi River (net losses) [6]	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80
RETURN FLOWS:	Southern Gauteng (Rand Water)	-321.55	-314.22	-307.14	-300.30	-293.67	-298.19	-302.78	-307.45	-312.19	-317.01	-321.00	-325.04	-329.14	-333.29	-337.49	-350.75	-365.74
	Midvaal Water Company	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.86	-0.86	-0.86	-0.86	-0.86	-0.86	-0.86	-0.87
	Sedibeng Water	-1.64	-1.65	-1.65	-1.65	-1.65	-1.65	-1.65	-1.65	-1.65	-1.65	-1.65	-1.65	-1.65	-1.65	-1.65	-1.68	-1.70
	Other towns and industries	-61.48	-62.26	-63.16	-63.71	-64.88	-65.32	-66.72	-67.30	-68.06	-68.97	-69.63	-70.30	-70.97	-71.66	-72.47	-76.21	-80.38
	Irrigation [7]	-59.67	-62.98	-66.76	-57.30	-47.84	-38.38	-38.38	-38.38	-38.38	-38.38	-38.38	-38.38	-38.38	-38.38	-38.38	-38.38	-38.38
	Mine dewatering	-114.12	-111.84	-109.55	-107.27	-104.99	-104.54	-104.08	-104.08	-113.21	-121.24	-123.07	-123.07	-123.07	-123.07	-123.07	-121.24	-121.24
	Increased urban runoff	-100.94	-101.49	-102.06	-102.64	-103.24	-103.86	-104.49	-105.14	-105.82	-106.51	-107.81	-109.14	-110.50	-111.89	-113.32	-120.97	-129.39
OVERALL GROSS SYSTEM DEMAND:		3560.55	3598.65	3647.62	3546.71	3443.83	3374.45	3404.72	3431.49	3456.31	3480.31	3498.44	3517.76	3532.98	3550.77	3572.65	3654.77	3754.00
OVERALL NET SYSTEM DEMAND:		2900.31	2943.36	2996.44	2912.99	2826.70	2761.67	2785.76	2806.63	2816.14	2825.68	2836.03	2849.31	2858.41	2869.97	2885.41	2944.67	3016.29

Notes :

(1): Rand Water's total raw water abstraction includes Sasolburg but excludes Authorised Users (i.e. ESKOM, ISCOR, Sasol I , Mittal Steel and Small Users (Mining & Industrial)).
(2): Includes distribution losses within Vaalharts canal system
(3): "Other irrigation" excludes diffuse irrigation
(4): Includes evaporation losses associated with wetlands as well as bed losses occuring within the Suikerbosrand and Klip rivers
(5): Vaal River bed losses include evaporation and operating losses associated with releases made from Bloemhof Dam
(6): Mooi River (Wonderfonteinspruit catchment) : Net effect of bed losses and decanting from dolomitic eyes resulting from WQT calibration
(7): Includes flow contribution resulting from the tailwater component at Erfenis Dam
(8): Includes DWAF 3rd Party Users
(9): Raw water requirements only: It is assumed that Sasol's raw water requirements are not supplied through Rand Water, but the the projections of Rand Water include the potable water allocation of 6Ml/day.
(10): Represents Mittal Steel's total water requirements (i.e. includes the portion of the demand obtained from Rand Water)
(11): Represents portion of Rand Water's demand supplied by Magalies Water (drawn through the Vaalkop Scheme)

Table D-5: **Scenario E water demands and return flow projections for the Integrated Vaal River System (2006/2007) as adopted for the WRPM Scenario VT06R09**
Based on Rand Water Scenario C (DWAF 2005 High Population projections including 10yr Loss Management), Midvaal and Sedibeng Water April 2006 projections, Eskom April 2006
Sasol Secunda March 2004 projections, 2006 projections for Sasol 1 and Mittal Steel and the NWRS demand projections (Ratio Method) for smaller demand centres.

		Projected Demands and Return Flows (million m^3/a)															Extrapolated	
DESCRIPTION		**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2025**	**2030**
DEMANDS:	Rand Water [1]	1286.05	1284.55	1283.32	1282.35	1280.41	1288.30	1296.56	1304.94	1313.46	1322.11	1335.27	1348.57	1362.02	1375.61	1389.35	1459.34	1545.23
	Magalies Water (Vaalkop Scheme) [11]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Mittal Steel [10]	17.35	17.17	16.98	16.80	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62
	ESKOM [8]	330.31	344.34	362.69	373.50	381.08	389.44	397.28	402.57	405.33	406.89	408.74	411.57	410.07	410.98	415.73	416.57	415.57
	SASOL Sasolburg [9]	24.25	24.76	25.38	25.68	26.74	27.07	28.64	28.96	29.54	30.13	30.74	31.35	31.98	32.62	33.27	36.73	40.56
	SASOL Secunda	92.04	96.06	101.17	101.90	103.73	104.83	105.56	106.29	107.02	107.81	108.61	109.46	110.34	111.21	112.13	117.21	123.03
	Midvaal Water Company	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00
	Sedibeng Water (Balkfontein only)	40.95	41.31	41.32	41.32	41.32	41.32	41.32	41.32	41.32	41.33	41.33	41.33	41.33	41.33	41.33	41.92	42.53
	Other towns and industries (Vaal)	160.90	161.51	162.12	162.73	163.34	163.97	164.60	165.24	165.87	166.50	166.57	166.64	166.71	166.78	166.85	167.38	168.35
	Other towns and industries(Zaai)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Vaalharts/Lower Vaal irrigation [2]	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53
	Diffuse Irrig and Aff (Vaal)	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31
	Diffuse Irrig and AFF (Sup systems)	72.05	72.05	72.05	72.05	72.05	72.05	72.05	72.05	72.05	72.05	72.05	72.05	72.05	72.05	72.05	72.05	72.05
	Other irrigation in Vaal [3]	613.60	648.15	687.68	588.94	490.21	391.47	391.47	391.47	391.47	391.47	391.47	391.47	391.47	391.47	391.47	391.47	391.47
	Other irrigation in sup subsystems [3]	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10
	Wetland losses [4]	44.11	44.35	44.60	44.86	45.11	45.36	45.62	45.88	46.14	46.40	46.66	46.91	47.17	47.43	47.70	48.99	50.24
	Bed losses [5]	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20
	Mooi River (net losses) [6]	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80
RETURN FLOWS:	Southern Gauteng (Rand Water)	-326.66	-324.27	-321.93	-319.66	-317.45	-317.96	-318.49	-319.04	-319.60	-320.19	-324.19	-328.26	-332.37	-336.54	-340.76	-354.08	-368.80
	Midvaal Water Company	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.86	-0.86	-0.86	-0.86	-0.86	-0.86	-0.86	-0.87
	Sedibeng Water	-1.64	-1.65	-1.65	-1.65	-1.65	-1.65	-1.65	-1.65	-1.65	-1.65	-1.65	-1.65	-1.65	-1.65	-1.65	-1.68	-1.70
	Other towns and industries	-61.48	-62.26	-63.16	-63.71	-64.88	-65.32	-66.72	-67.30	-68.06	-68.97	-69.63	-70.30	-70.97	-71.66	-72.47	-76.21	-80.38
	Irrigation [7]	-59.67	-62.98	-66.76	-57.30	-47.84	-38.38	-38.38	-38.38	-38.38	-38.38	-38.38	-38.38	-38.38	-38.38	-38.38	-38.38	-38.38
	Mine dewatering	-114.12	-111.84	-109.55	-107.27	-104.99	-104.54	-104.08	-104.08	-113.21	-121.24	-123.07	-123.07	-123.07	-123.07	-123.07	-121.24	-121.24
	Increased urban runoff	-100.94	-101.49	-102.06	-102.64	-103.24	-103.86	-104.49	-105.14	-105.82	-106.51	-107.81	-109.14	-110.50	-111.89	-113.32	-120.97	-129.39
OVERALL GROSS SYSTEM DEMAND:		3575.55	3628.19	3691.27	3604.08	3514.54	3434.37	3453.66	3469.28	3482.77	3495.25	3512.00	3529.91	3543.71	3560.04	3580.44	3662.21	3759.59
OVERALL NET SYSTEM DEMAND:		2910.19	2962.86	3025.30	2950.99	2873.63	2801.81	2818.99	2832.83	2835.19	2837.45	2846.41	2858.25	2865.91	2875.99	2889.93	2948.79	3018.82

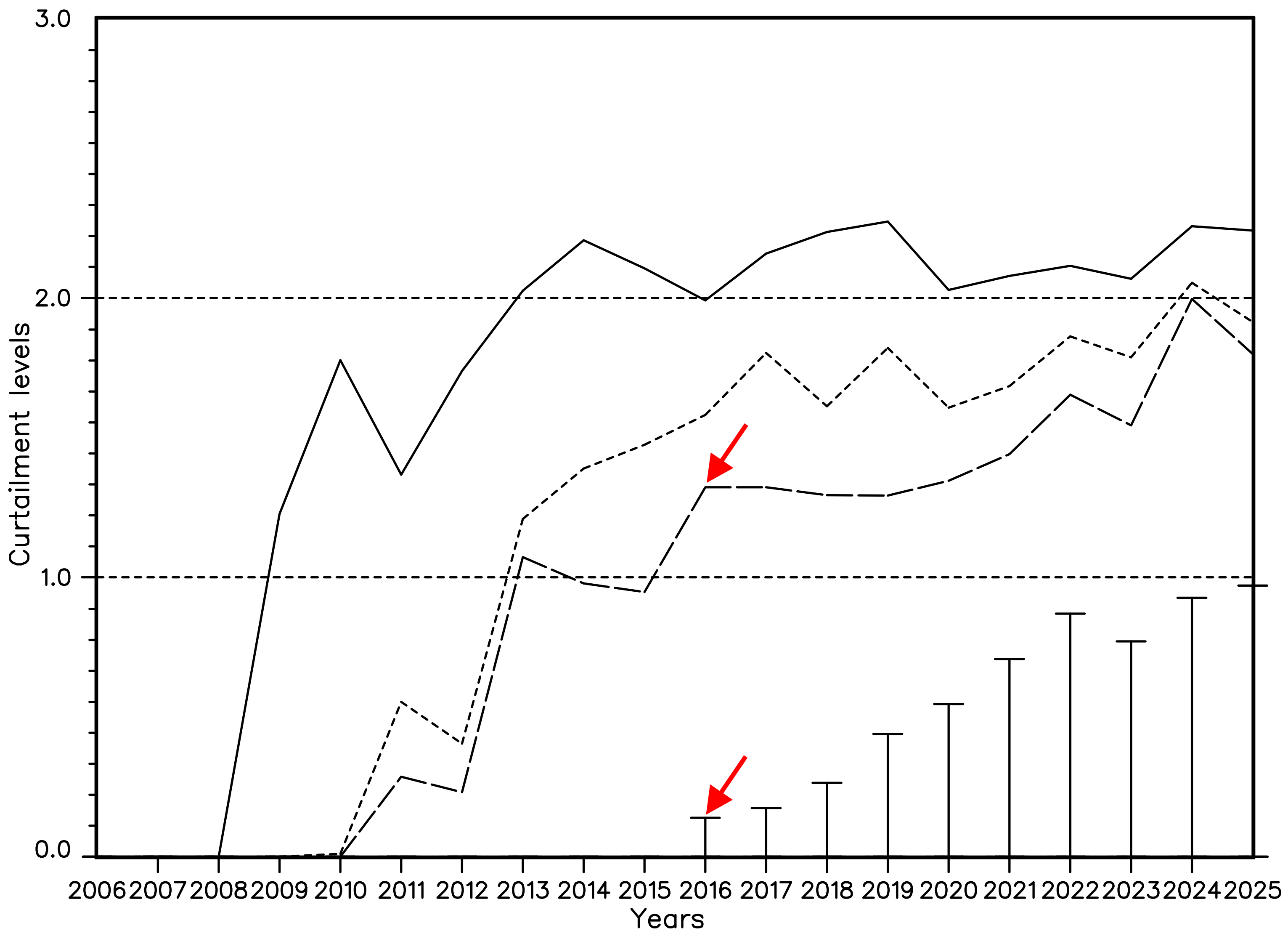
Notes :

(1): Rand Water's total raw water abstraction includes Sasolburg but excludes Authorised Users (i.e. ESKOM, ISCOR, Sasol I , Mittal Steel and Small Users (Mining & Industrial)).
(2): Includes distribution losses within Vaalharts canal system
(3): "Other irrigation" excludes diffuse irrigation
(4): Includes evaporation losses associated with wetlands as well as bed losses occuring within the Suikerbosrand and Klip rivers
(5): Vaal River bed losses include evaporation and operating losses associated with releases made from Bloemhof Dam
(6): Mooi River (Wonderfonteinspruit catchment) : Net effect of bed losses and decanting from dolomitic eyes resulting from WQT calibration
(7): Includes flow contribution resulting from the tailwater component at Erfenis Dam
(8): Includes DWAF 3rd Party Users
(9): Raw water requirements only: It is assumed that Sasol's raw water requirements are not supplied through Rand Water, but the the projections of Rand Water include the potable water allocation of 6Ml/day.
(10): Represents Mittal Steel's total water requirements (i.e. includes the portion of the demand obtained from Rand Water)
(11): Represents portion of Rand Water's demand supplied by Magalies Water (drawn through the Vaalkop Scheme)

Appendix E

Graphical results: Scenario A

No:	Description
E-1	Scenario A: Curtailment Levels
E-2	Scenario A: Demand/Supply
E-3	Scenario A: System Volume (Annual)
E-4	Scenario A: Transfer through Vaal Pipeline



WRP_ P0138_Vaal Recon Study_Graphics_Fig28.cdr

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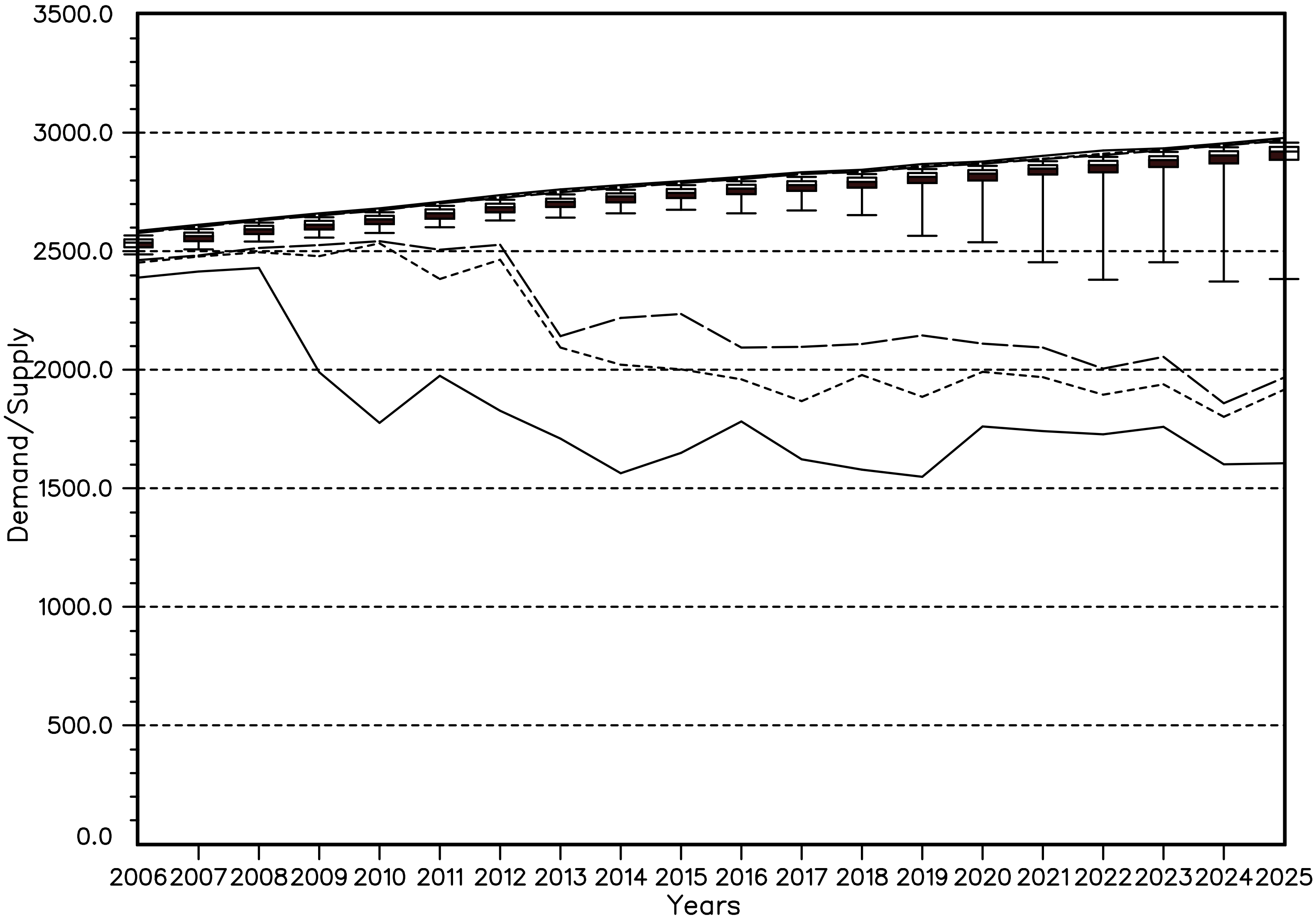
VAAL RIVER SYSTEM: LARGE BULK WATER
SUPPLY RECONCILIATION STRATEGIES AND
WATER CONSERVATION AND DEMAND MANAGEMENT

Scenario A: Curtailment Levels

E-1



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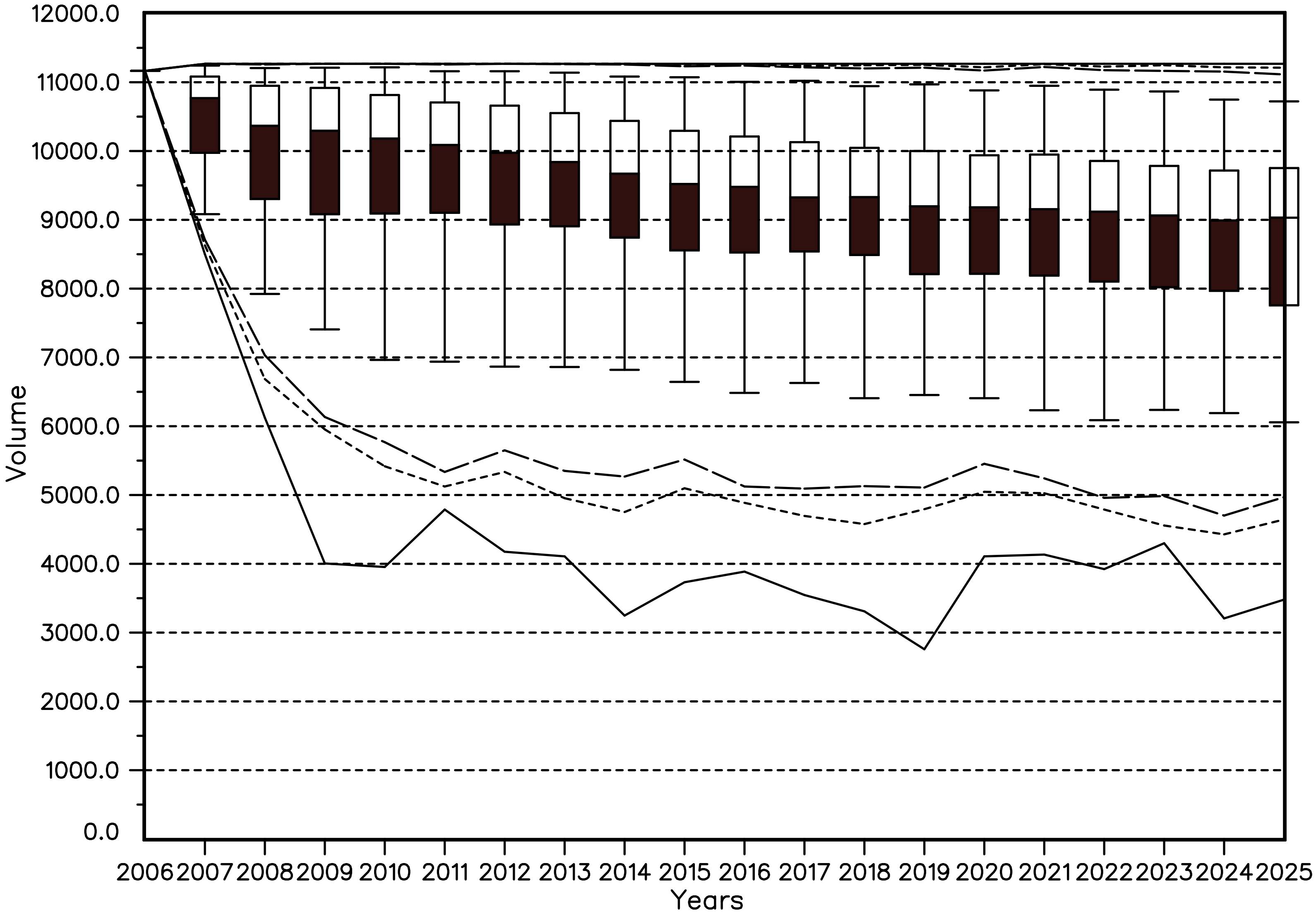
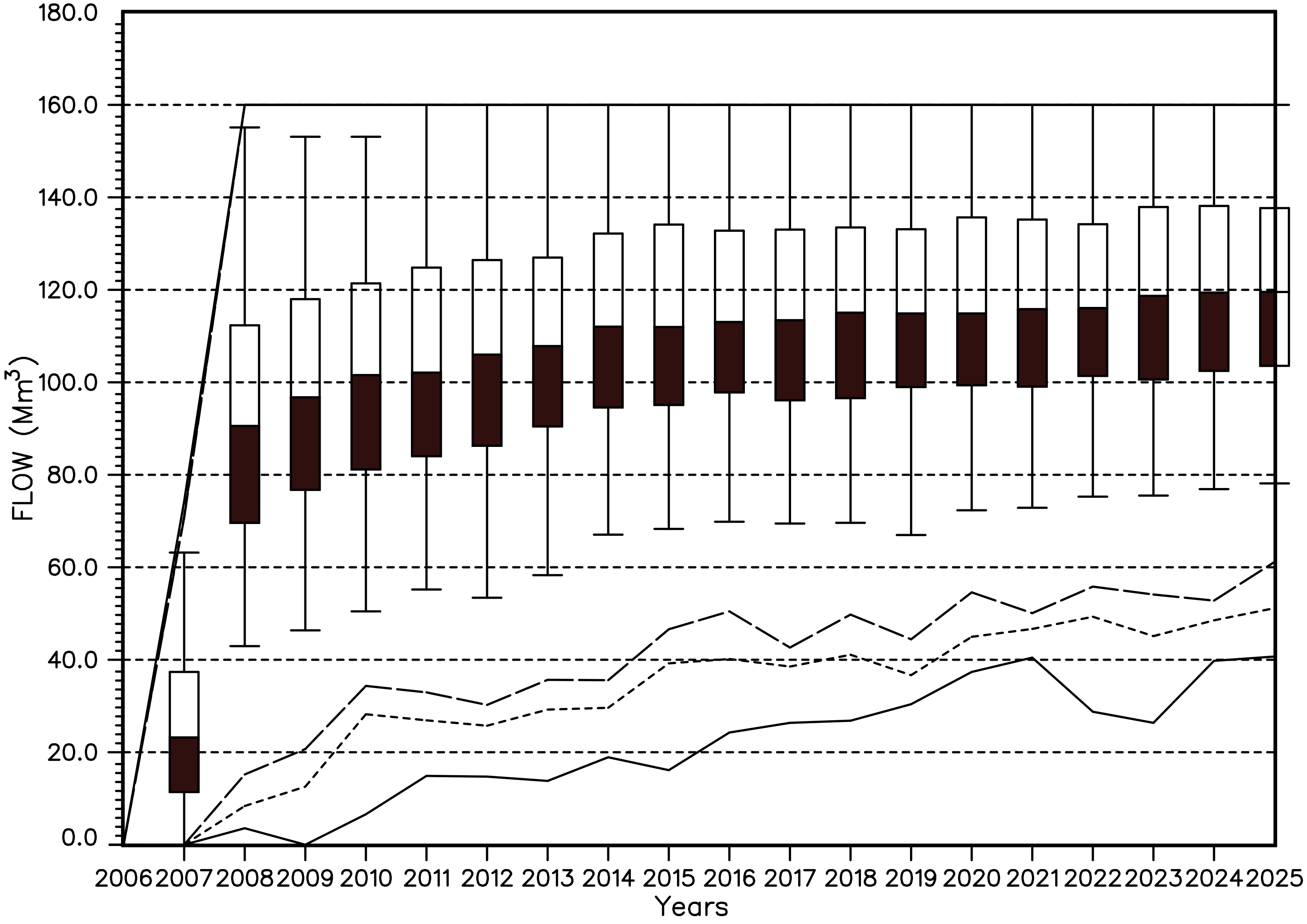
SUPPLY RECONCILIATION STRATEGIES AND
WATER CONSERVATION AND DEMAND MANAGEMENT

Scenario A: Demand / Supply

E-2



Scenario A: System Volume (Annual)



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SUPPLY RECONCILIATION STRATEGIES AND
WATER CONSERVATION AND DEMAND MANAGEMENT

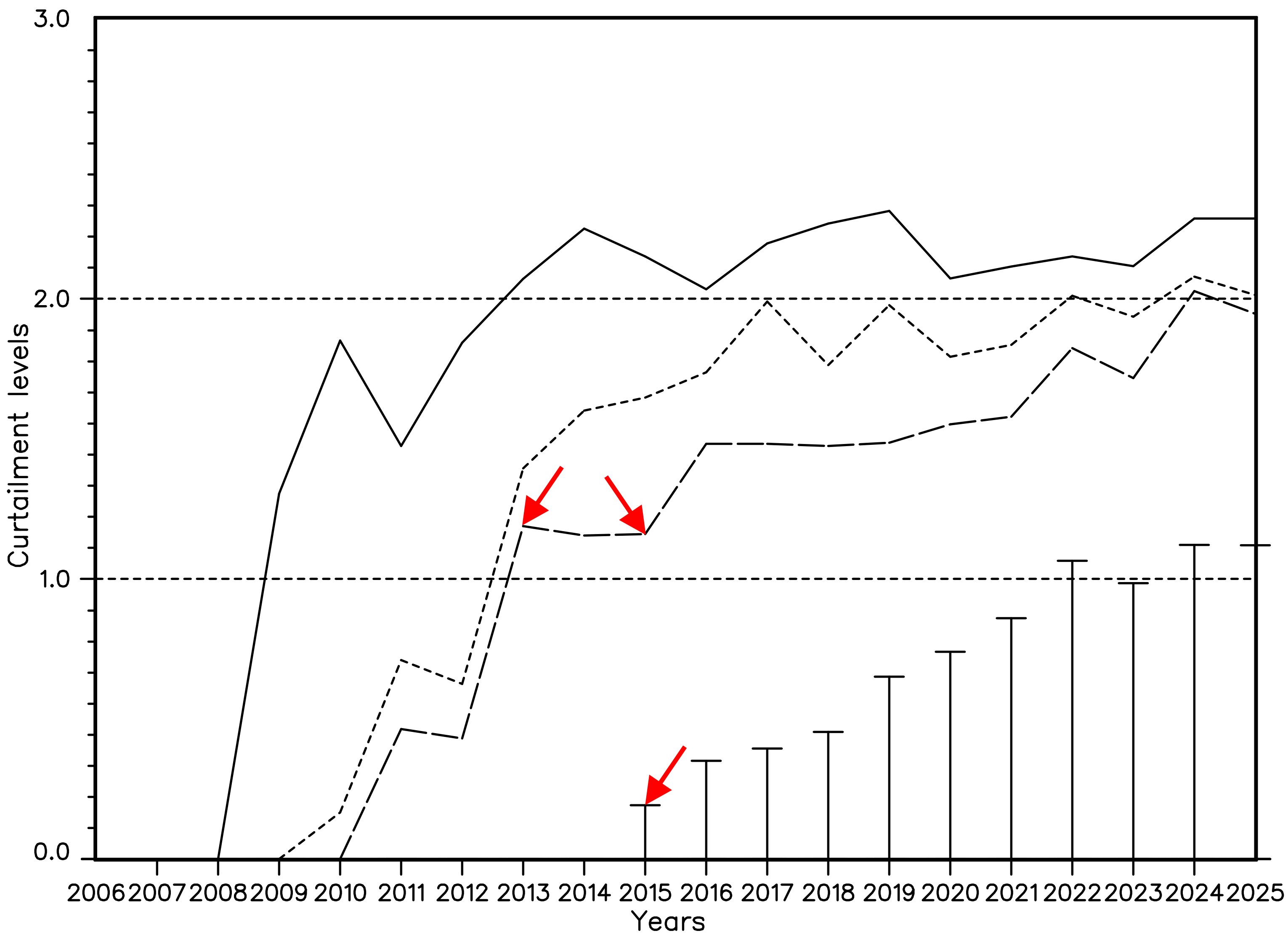
Scenario A: Transfer through Vaal Pipeline

E-4

Appendix F

Graphical results: Scenario B

No:	Description
F-1	Scenario B: Curtailment Levels
F-2	Scenario B: Demand/Supply
F-3	Scenario B: System Volume (Annual)
F-4	Scenario B: Transfer through Vaal Pipeline



WRP_ P0138_Vaal Recon Study_Graphics_Fig29.cdr

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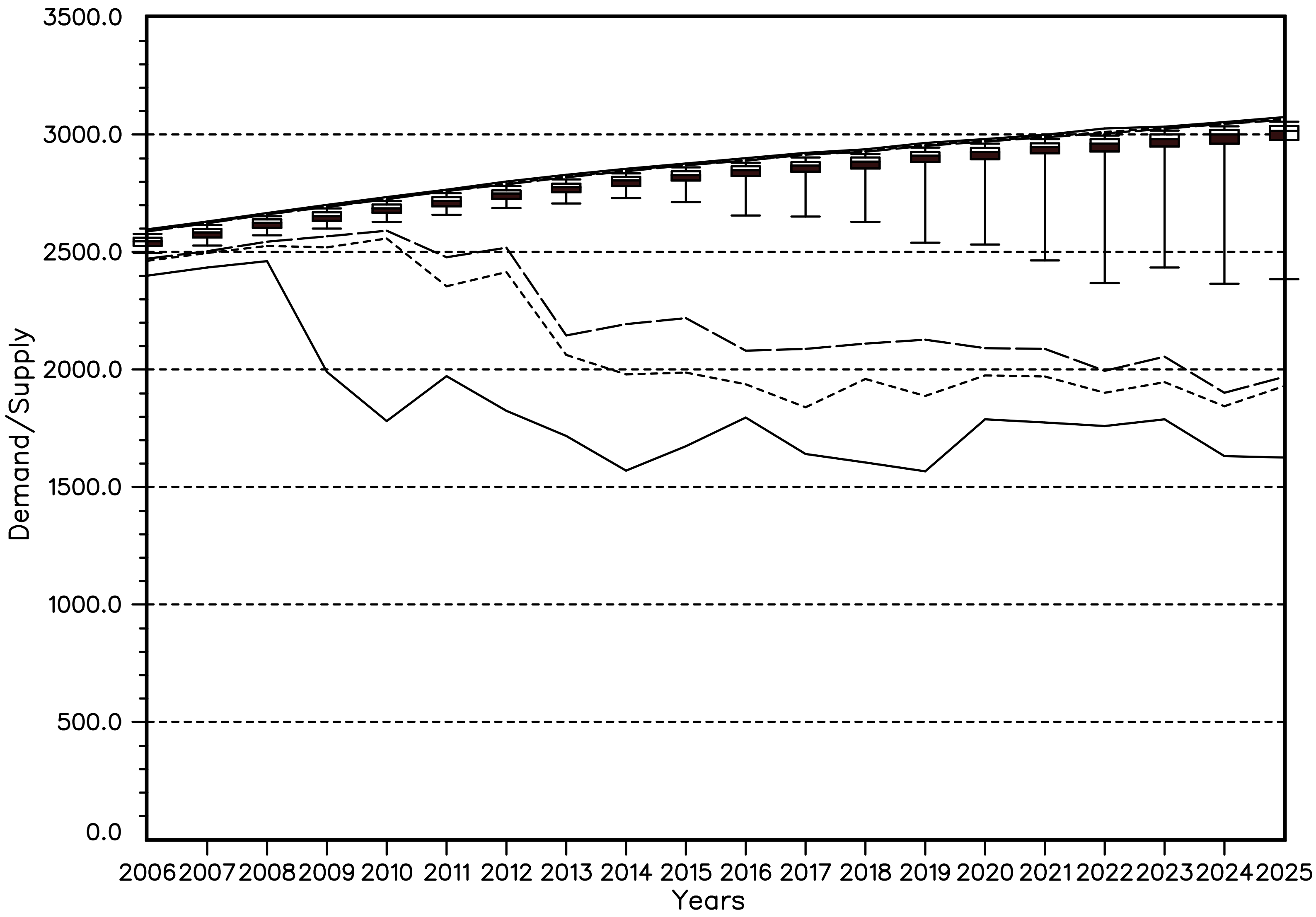
VAAL RIVER SYSTEM: LARGE BULK WATER SUPPLY RECONCILIATION STRATEGIES AND WATER CONSERVATION AND DEMAND MANAGEMENT

Scenario B: Curtailment Levels

F-1



WRP_ P0138_Vaal Recon Study_Graphics_Fig29.cdr

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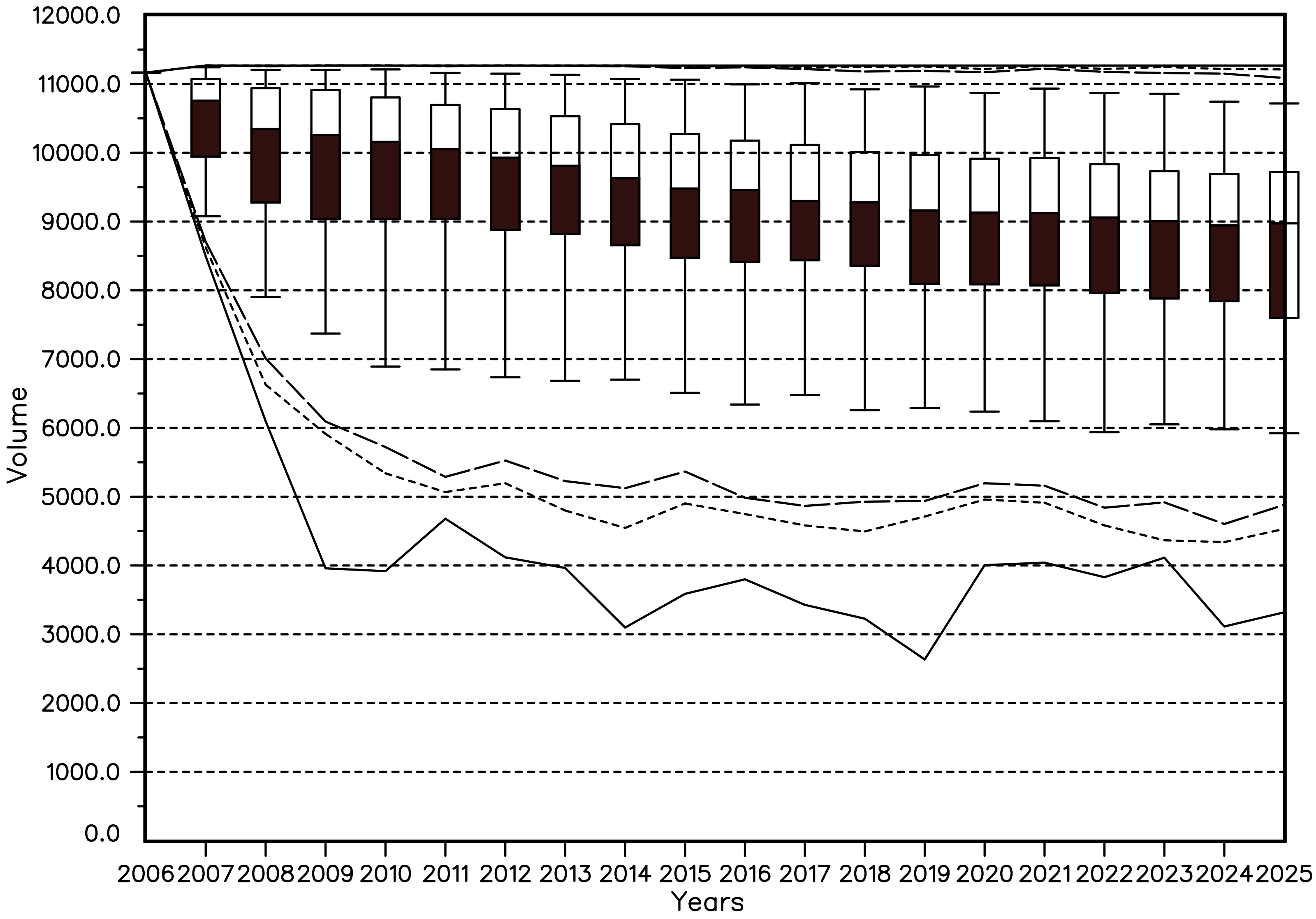
SUPPLY RECONCILIATION STRATEGIES AND
WATER CONSERVATION AND DEMAND MANAGEMENT

Scenario B: Demand / Supply

F-2



WRP_ P0138_Vaal Recon Study_Graphics_Fig29.cdr

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SUPPLY RECONCILIATION STRATEGIES AND
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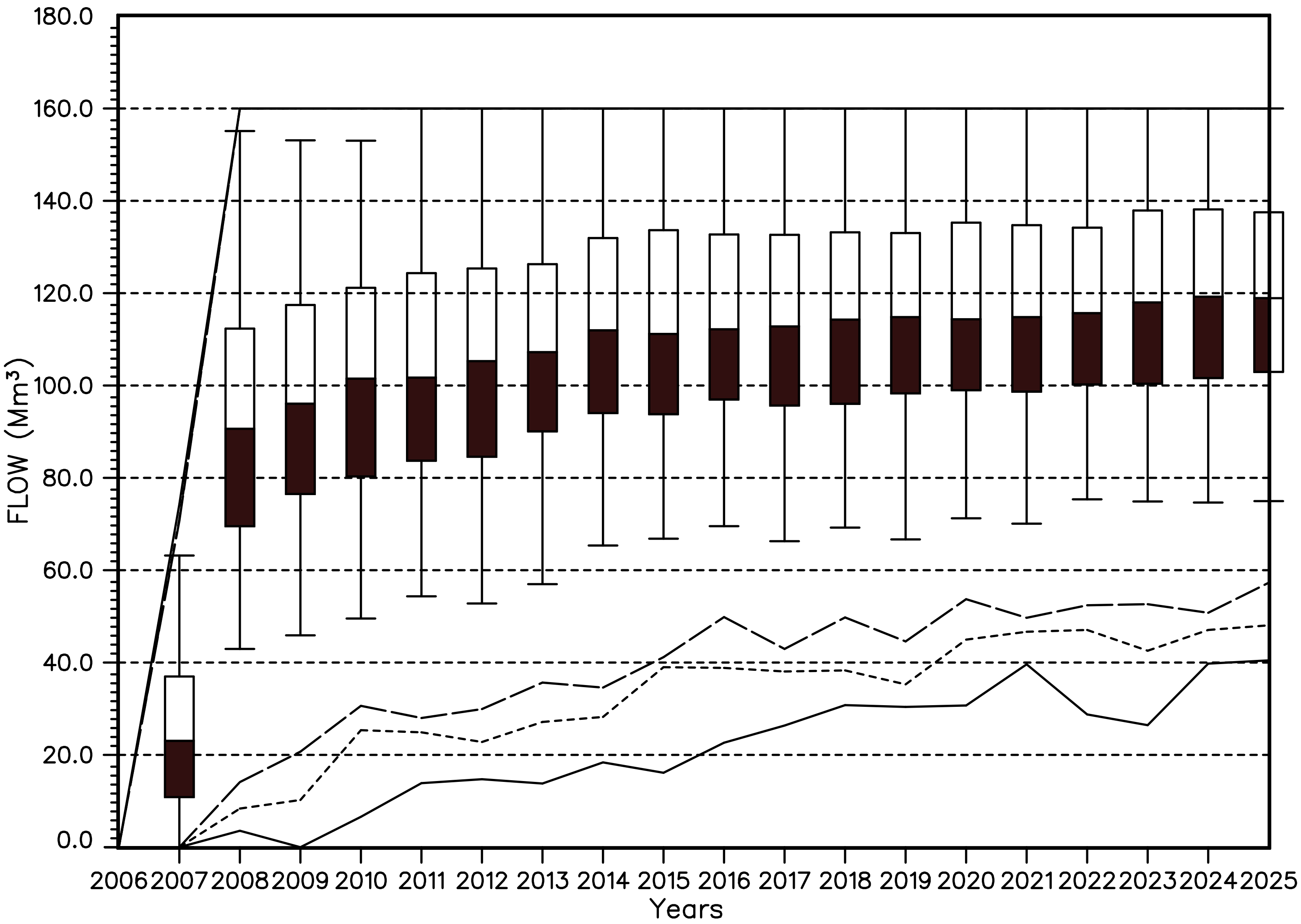
Scenario B: System Volume (Annual)

F-3



WRP_ P0138_Vaal Recon Study_Graphics_Fig29.cdr

VAAL RIVER SYSTEM: LARGE BULK WATER SUPPLY RECONCILIATION STRATEGIES AND WATER CONSERVATION AND DEMAND MANAGEMENT

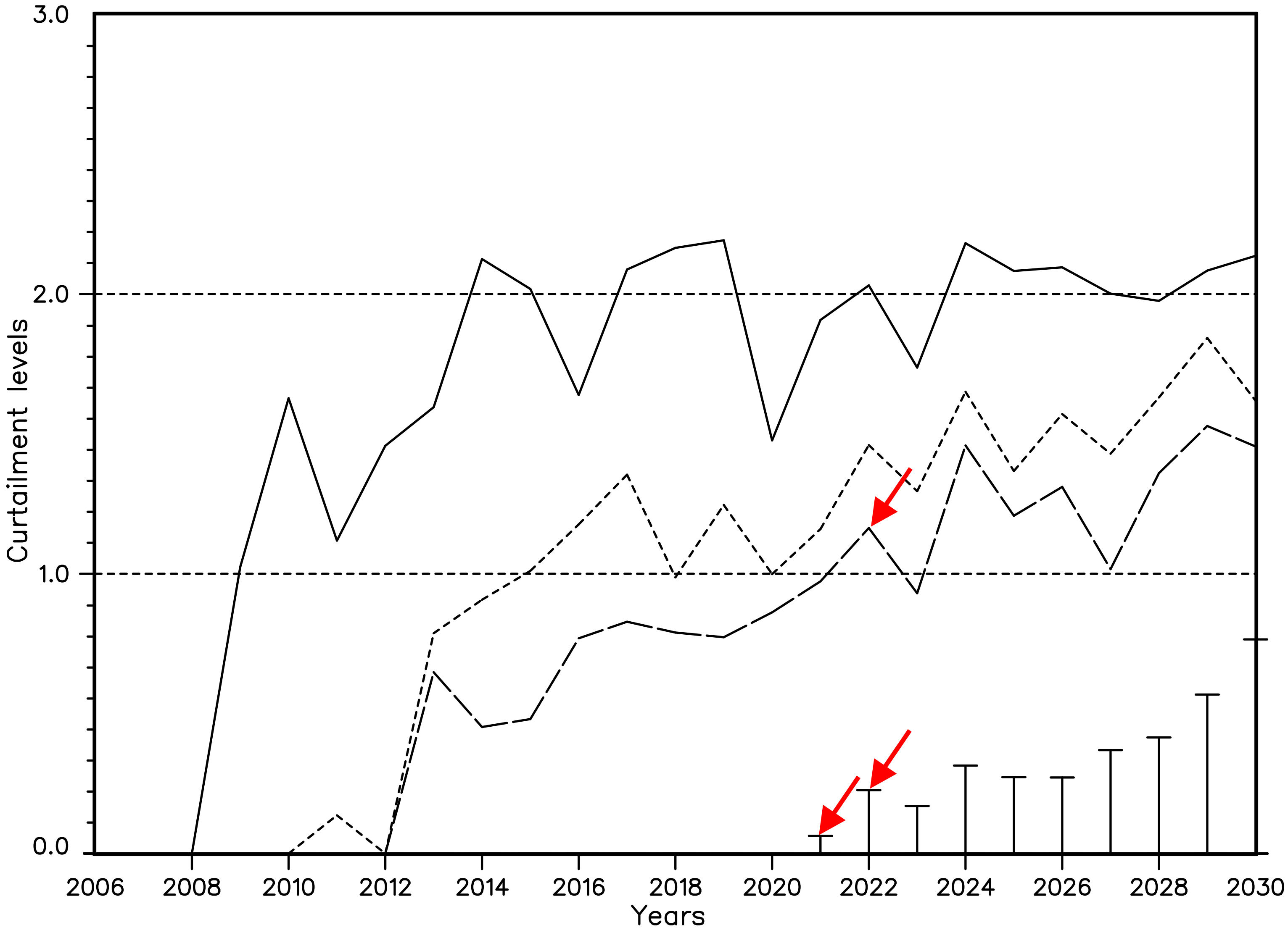
Scenario B: Transfer through Vaal Pipeline

F-4

Appendix G

Graphical results: Scenario C

No:	Description
G-1	Scenario C: Curtailment Levels
G-2	Scenario C: Demand/Supply
G-3	Scenario C: System Volume (Annual)
G-4	Scenario C: Transfer through Vaal Pipeline

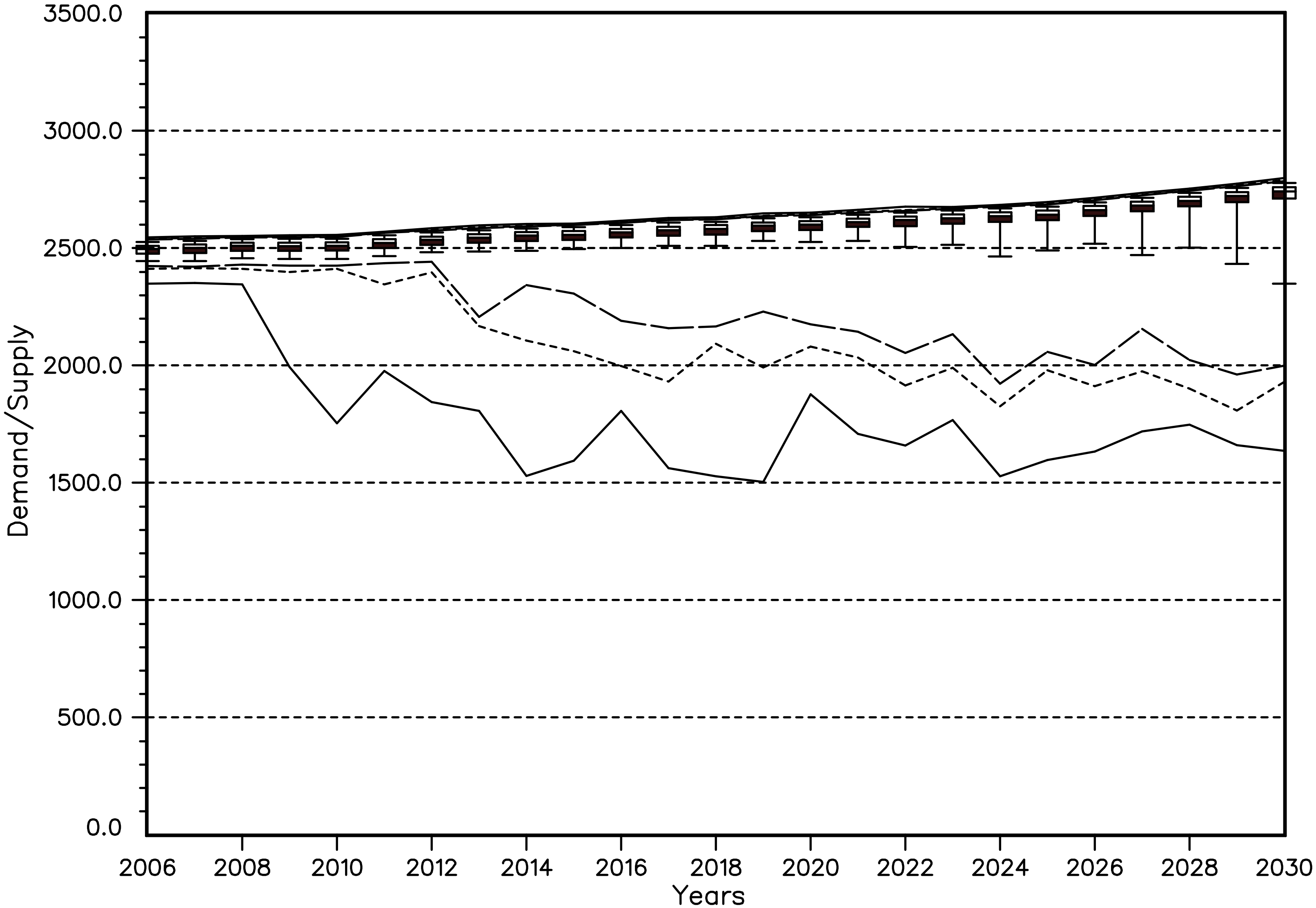


WRP_ P0138_Vaal Recon Study_Graphics_Fig30.cdr

VAAL RIVER SYSTEM: LARGE BULK WATER SUPPLY RECONCILIATION STRATEGIES AND WATER CONSERVATION AND DEMAND MANAGEMENT

Scenario C: Curtailment Levels

G-1



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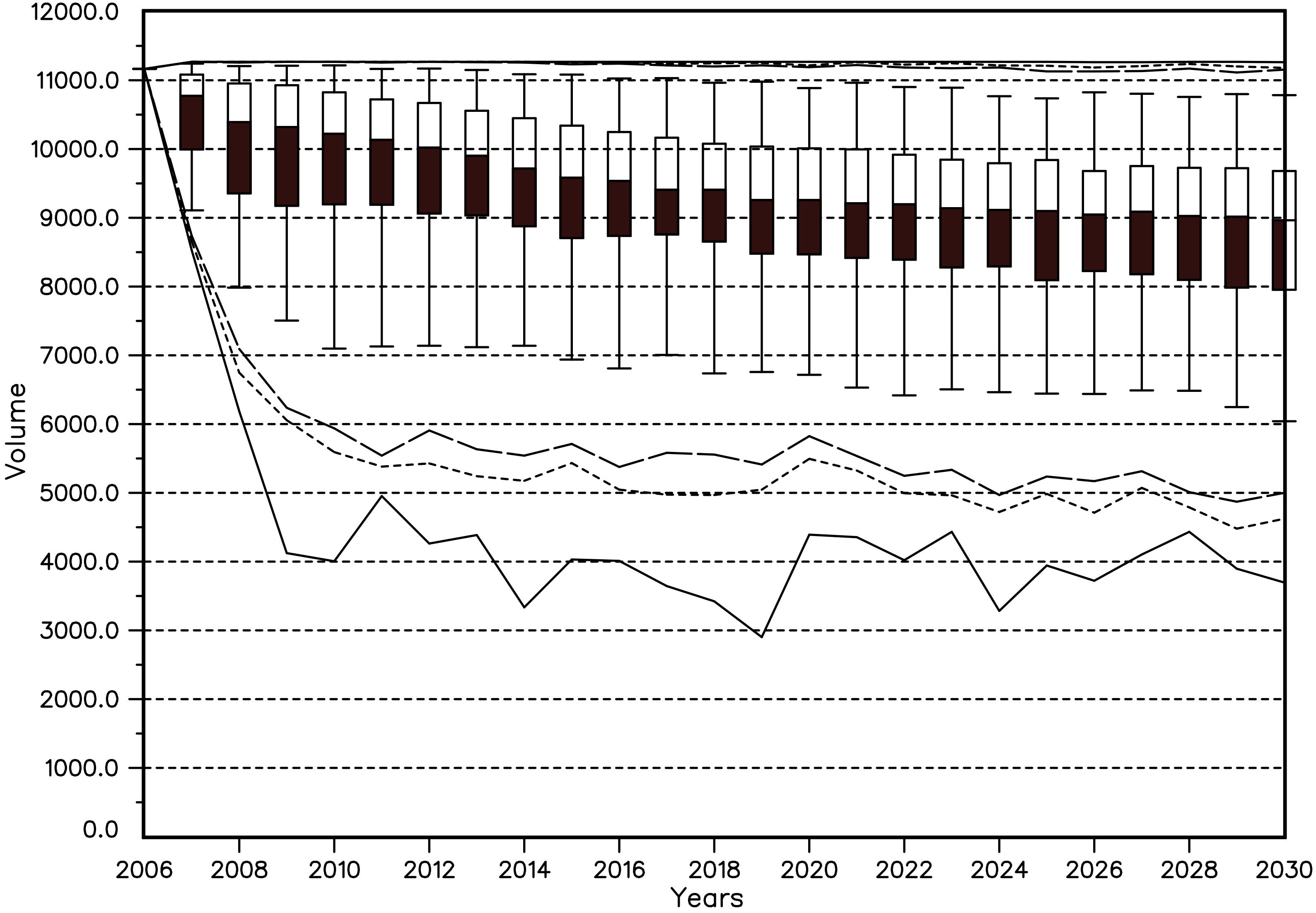
SUPPLY RECONCILIATION STRATEGIES AND
WATER CONSERVATION AND DEMAND MANAGEMENT

Scenario C: Demand / Supply

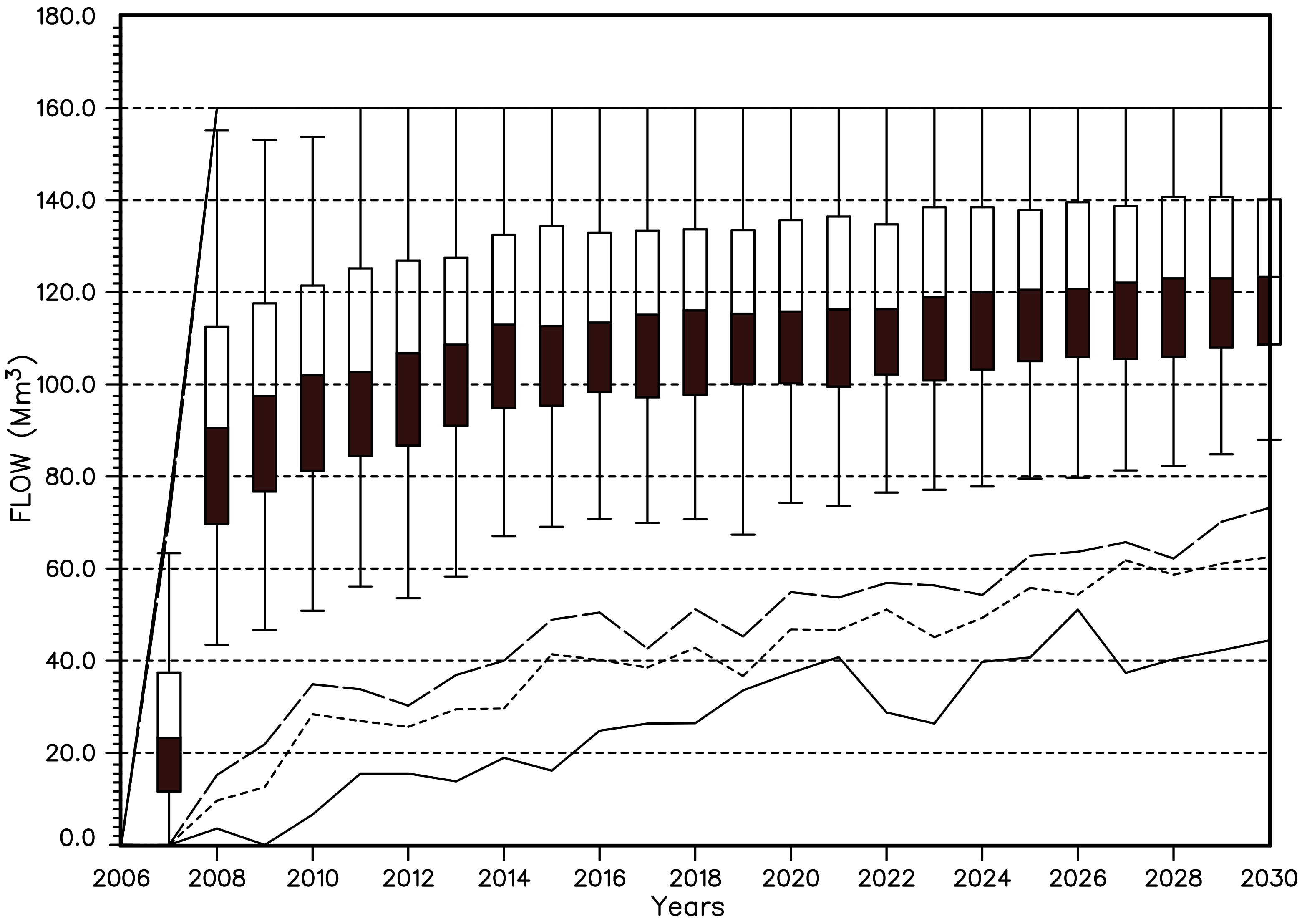
G-2



WRP_ P0138_Vaal Recon Study_Graphics_Fig30.cdr

Scenario C: System Volume (Annual)

G-3



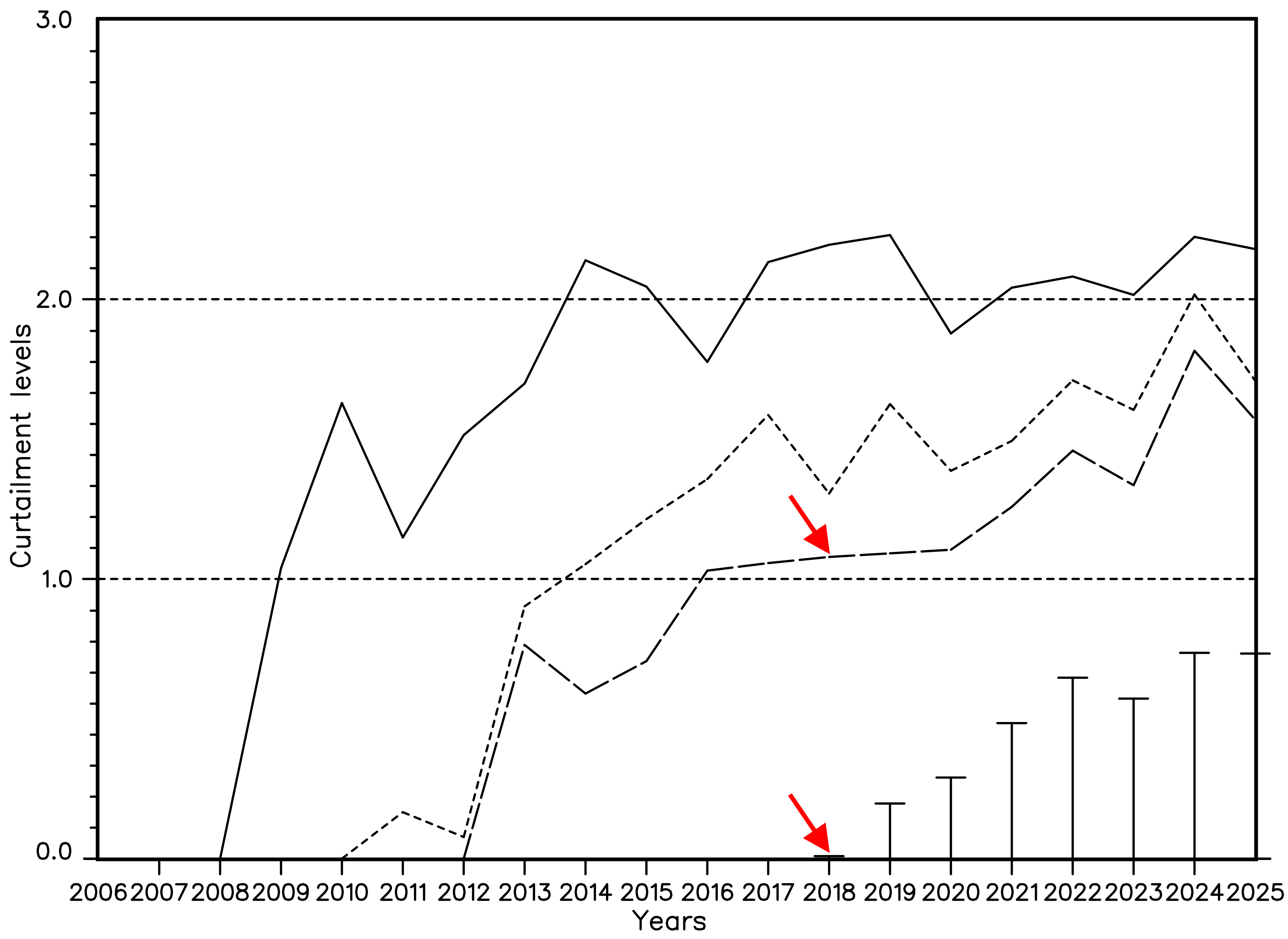
WRP_ P0138_Vaal Recon Study_Graphics_Fig30.cdr

Scenario C: Transfer through Vaal Pipeline

Appendix H

Graphical results: Scenario D

No:	Description
H-1	Scenario D: Curtailment Levels
H-2	Scenario D: Demand/Supply
H-3	Scenario D: System Volume (Annual)
H-4	Scenario D: Transfer through Vaal Pipeline



WRP_ P0138_Vaal Recon Study_Graphics_Fig31.cdr

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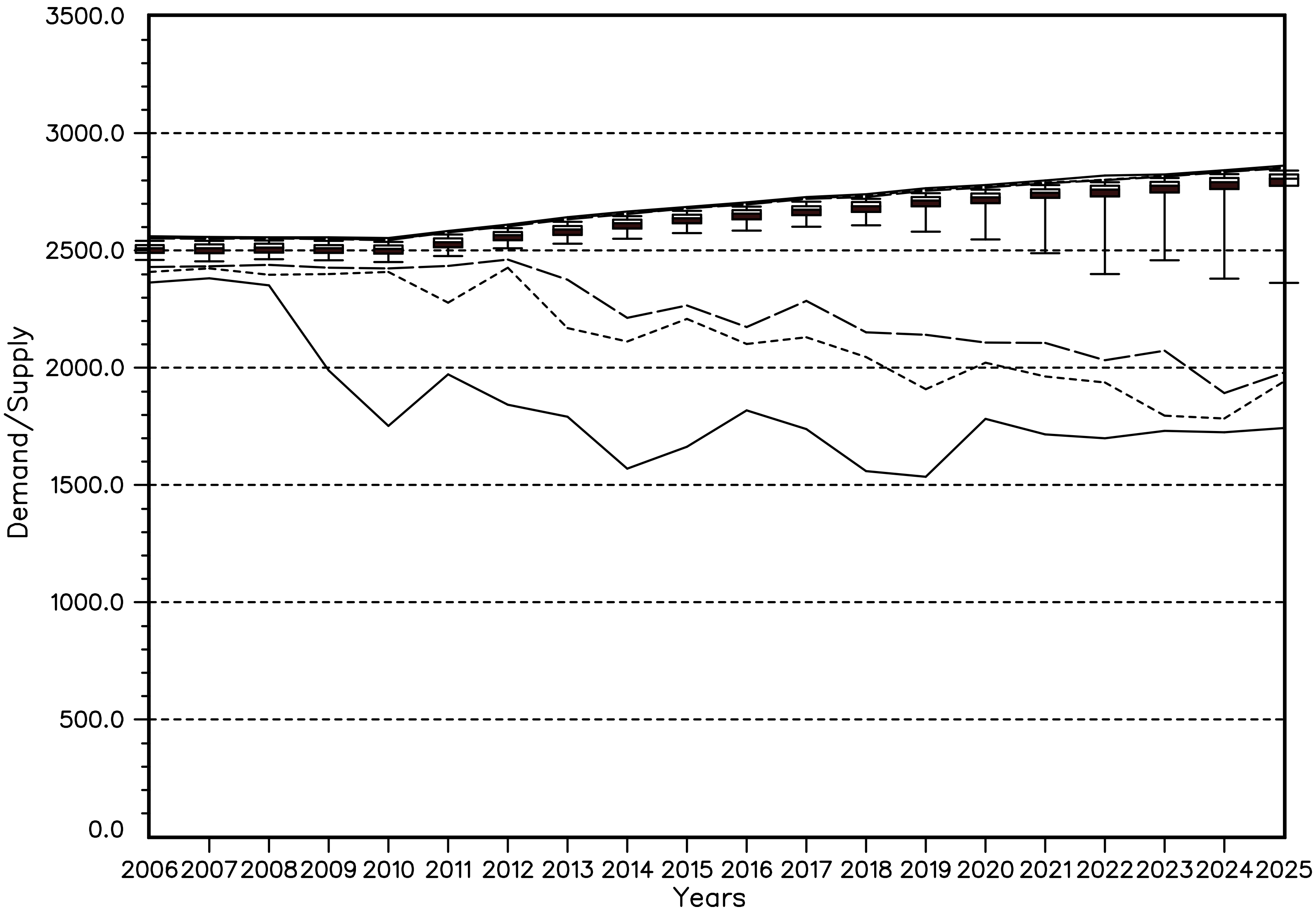
Scenario D: Curtailment Levels

H-1



WRP_ P0138_Vaal Recon Study_Graphics_Fig31.cdr

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SUPPLY RECONCILIATION STRATEGIES AND
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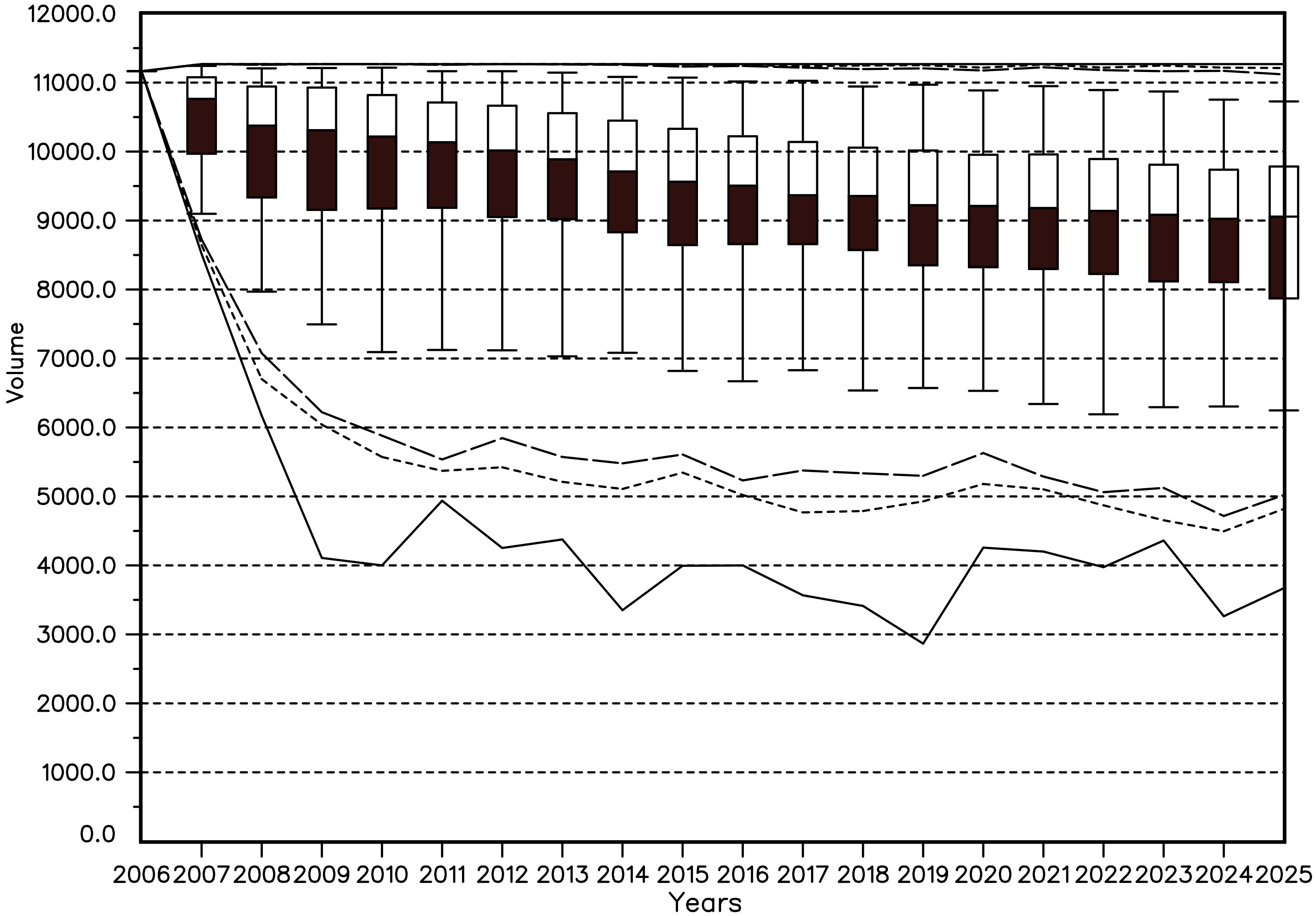
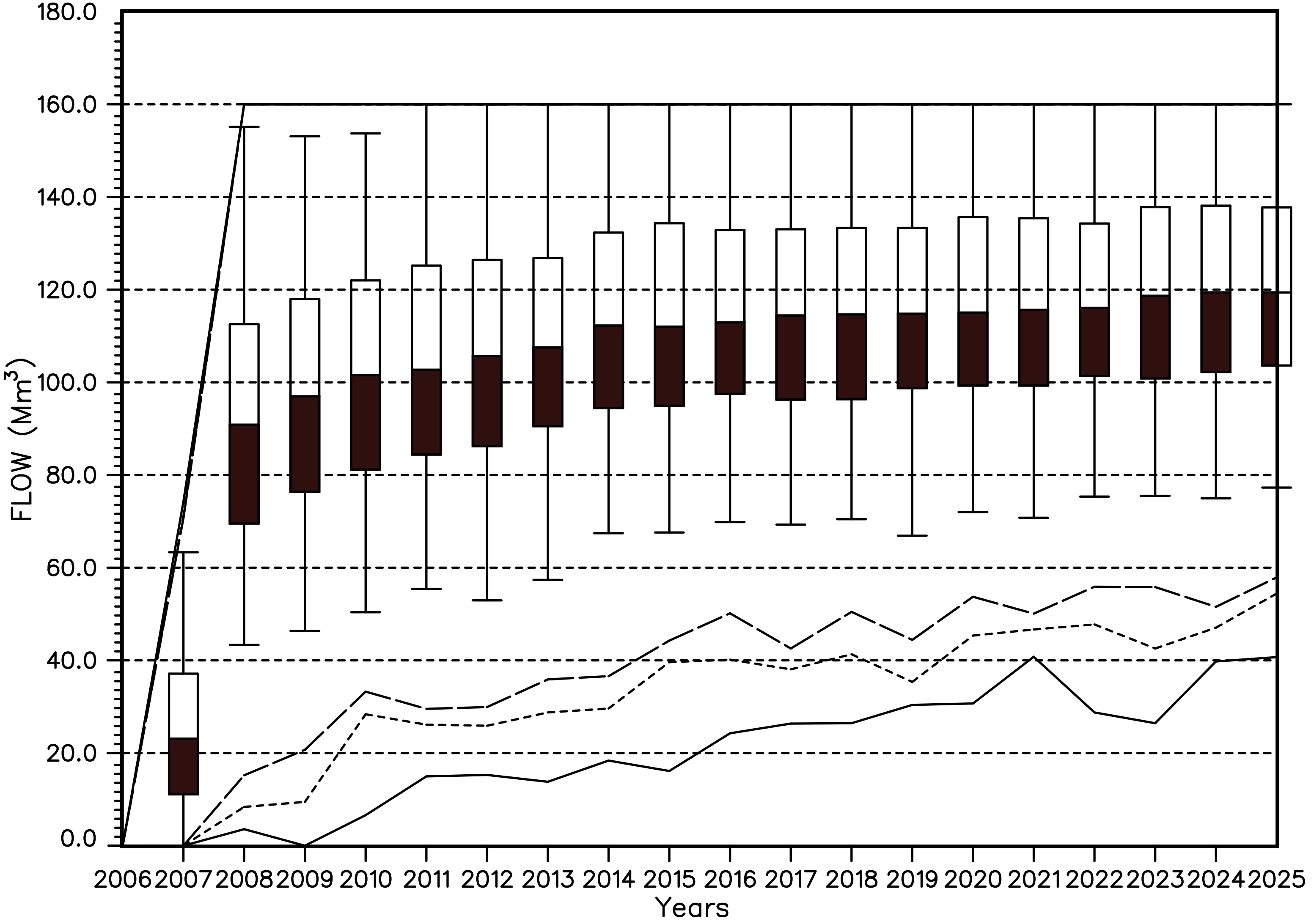
Scenario D: Demand / Supply

H-2



WRP_ P0138_Vaal Recon Study_Graphics_Fig31.cdr

Scenario D: System Volume (Annual)



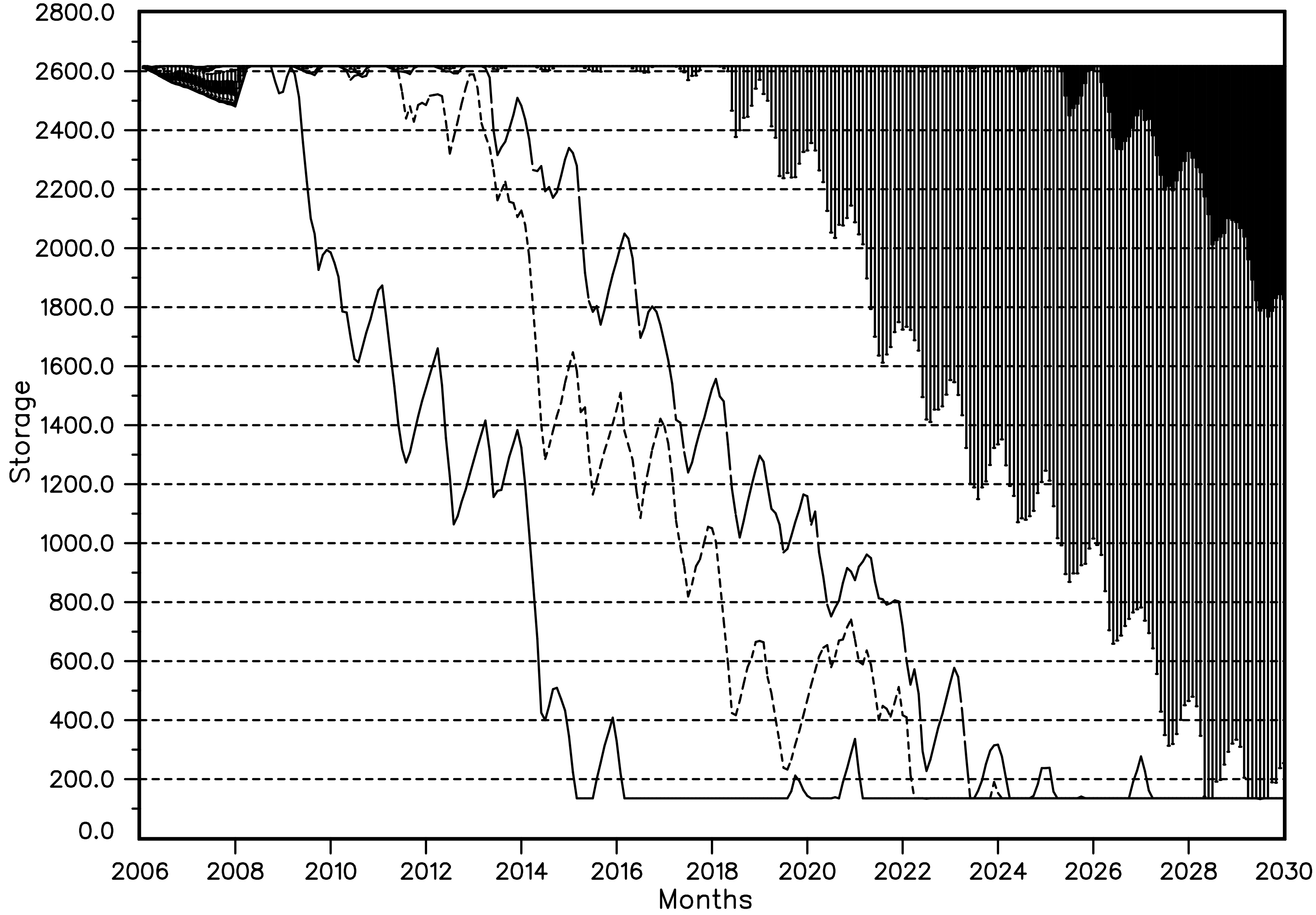
WRP_ P0138_Vaal Recon Study_Graphics_Fig31.cdr

Scenario D: Transfer through Vaal Pipeline

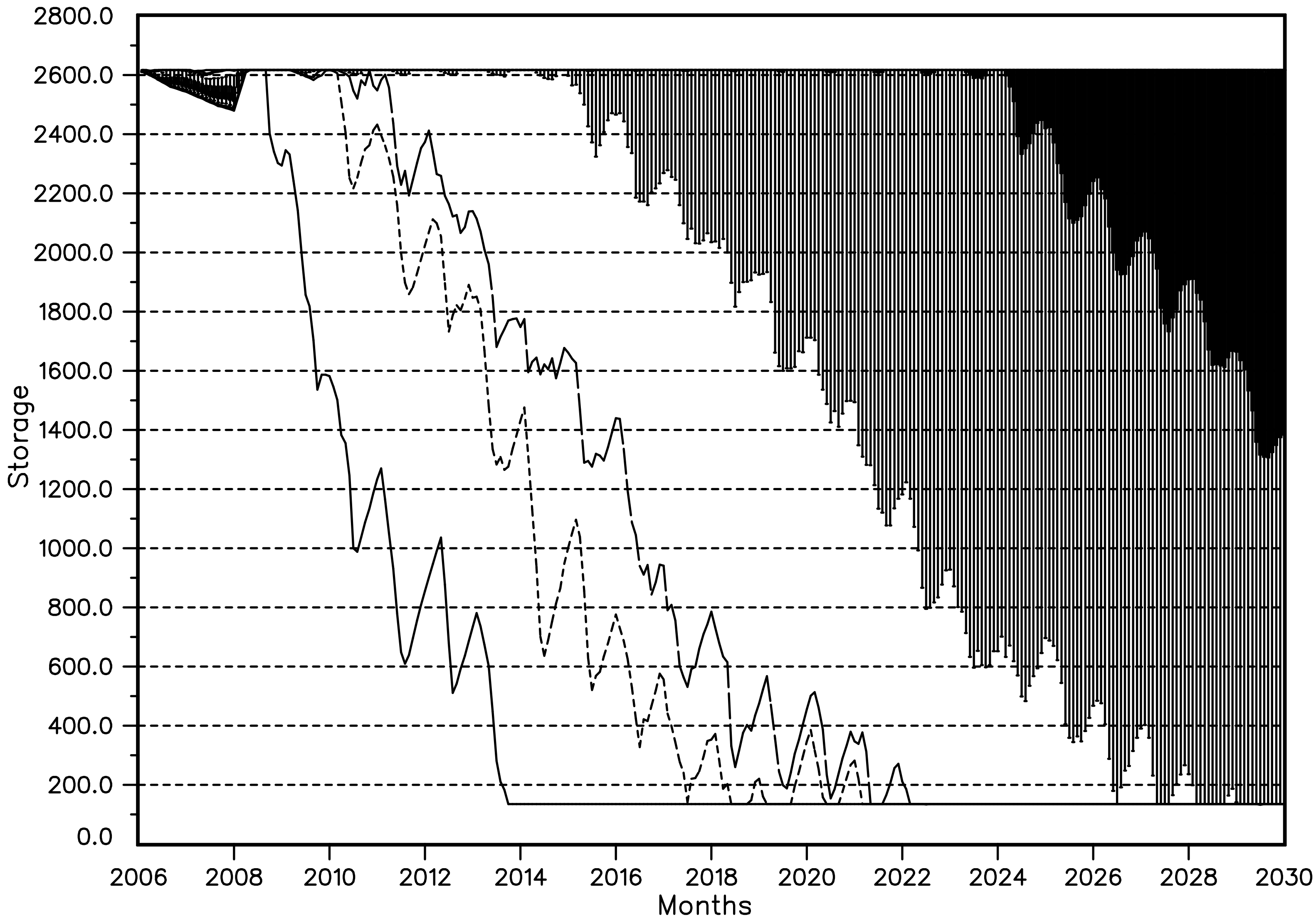
Appendix I

Graphical results: Scenario G

No:	Description
I-1	Scenario G: Sterkfontein Dam Storage excluding Ecological Water Requirements
I-2	Scenario G: Sterkfontein Dam Storage including Ecological Water Requirements Demand/Supply



Scenario G: Sterkfontein Dam Storage excluding Ecological Water Requirements

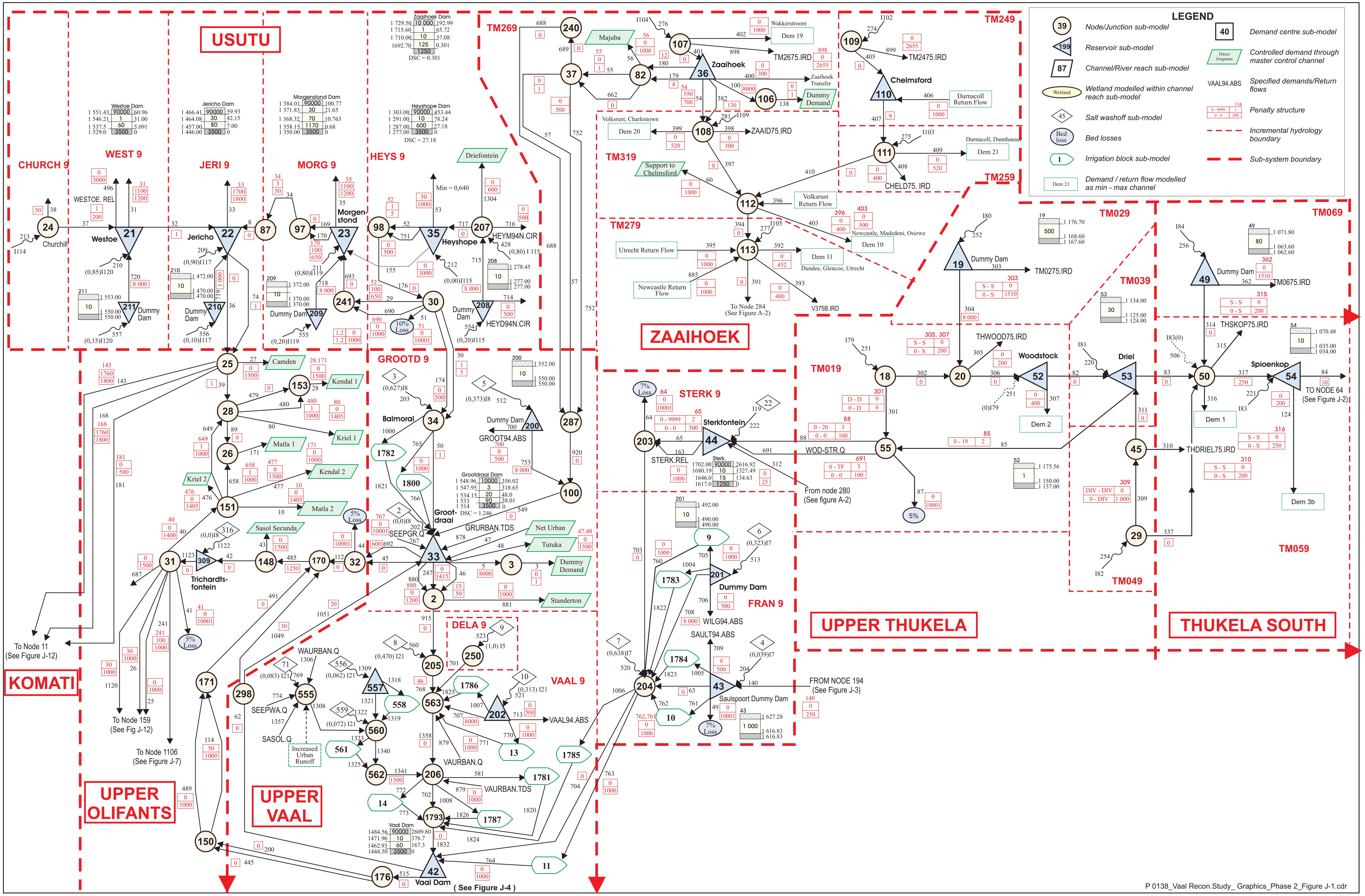


WRP_ P0138_Vaal Recon Study_Graphics_Fig32.cdr

Scenario G: Sterkfontein Dam Storage including Ecological Water Requirements

Appendix J

WRPM Schematic Diagrams of IVRS: Second Stage



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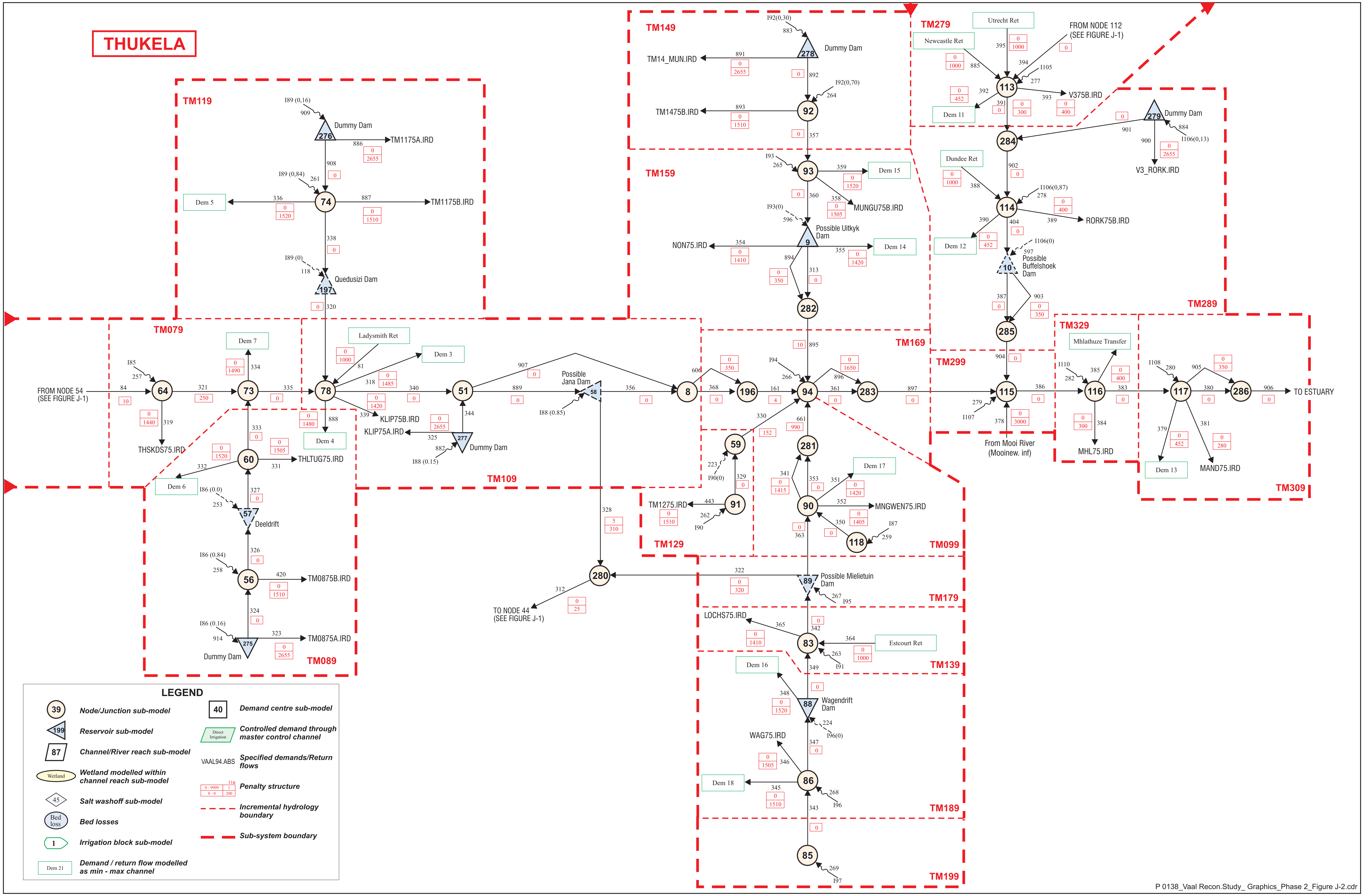
VAAL RIVER SYSTEM: LARGE BULK WATER SUPPLY RECONCILIATION STRATEGIES AND WATER CONSERVATION AND DEMAND MANAGEMENT

WRPM Schematic Diagram: Upper Vaal, Usutu, Thukela North, Upper Thukela and Thukela South Sub-systems

J-1



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SUPPLY RECONCILIATION STRATEGIES AND
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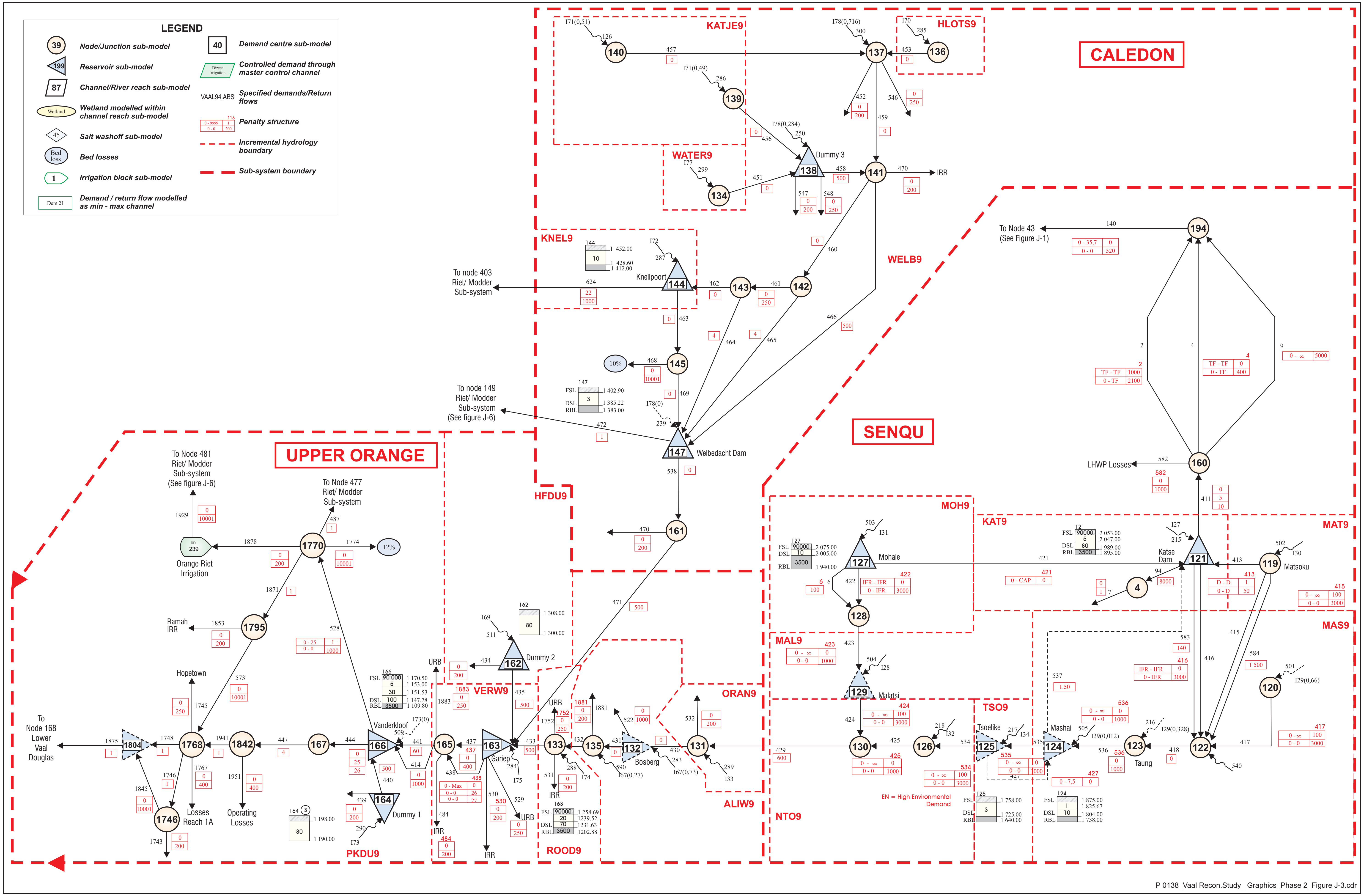
WRPM Schematic Diagram: Thukela Sub-system

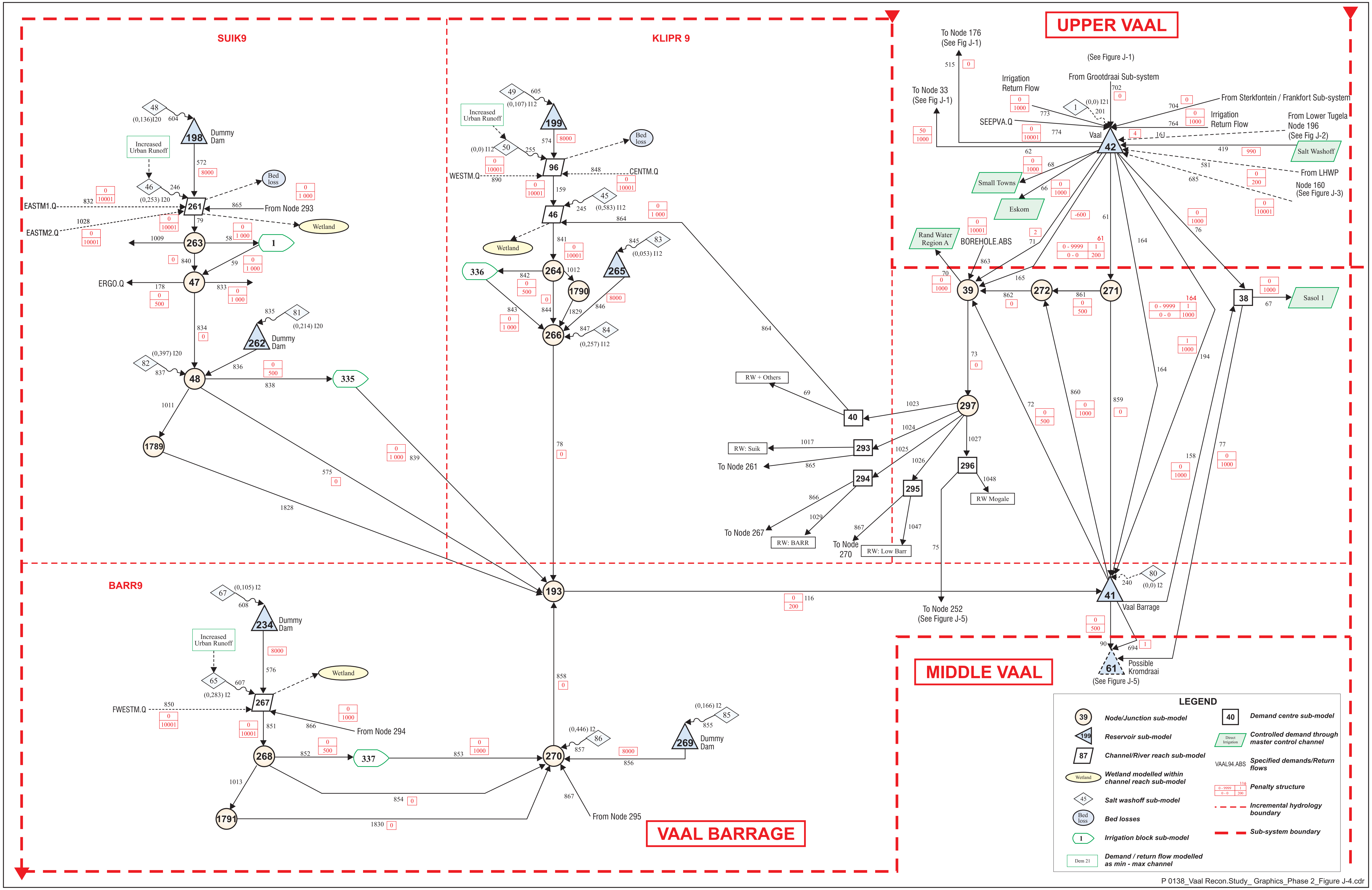
J-2



VAAL RIVER SYSTEM: LARGE BULK WATER SUPPLY RECONCILIATION STRATEGIES AND WATER CONSERVATION AND DEMAND MANAGEMENT

WRPM Schematic Diagram:
Senqu, Caledon and Upper Orange Sub-system

J-3



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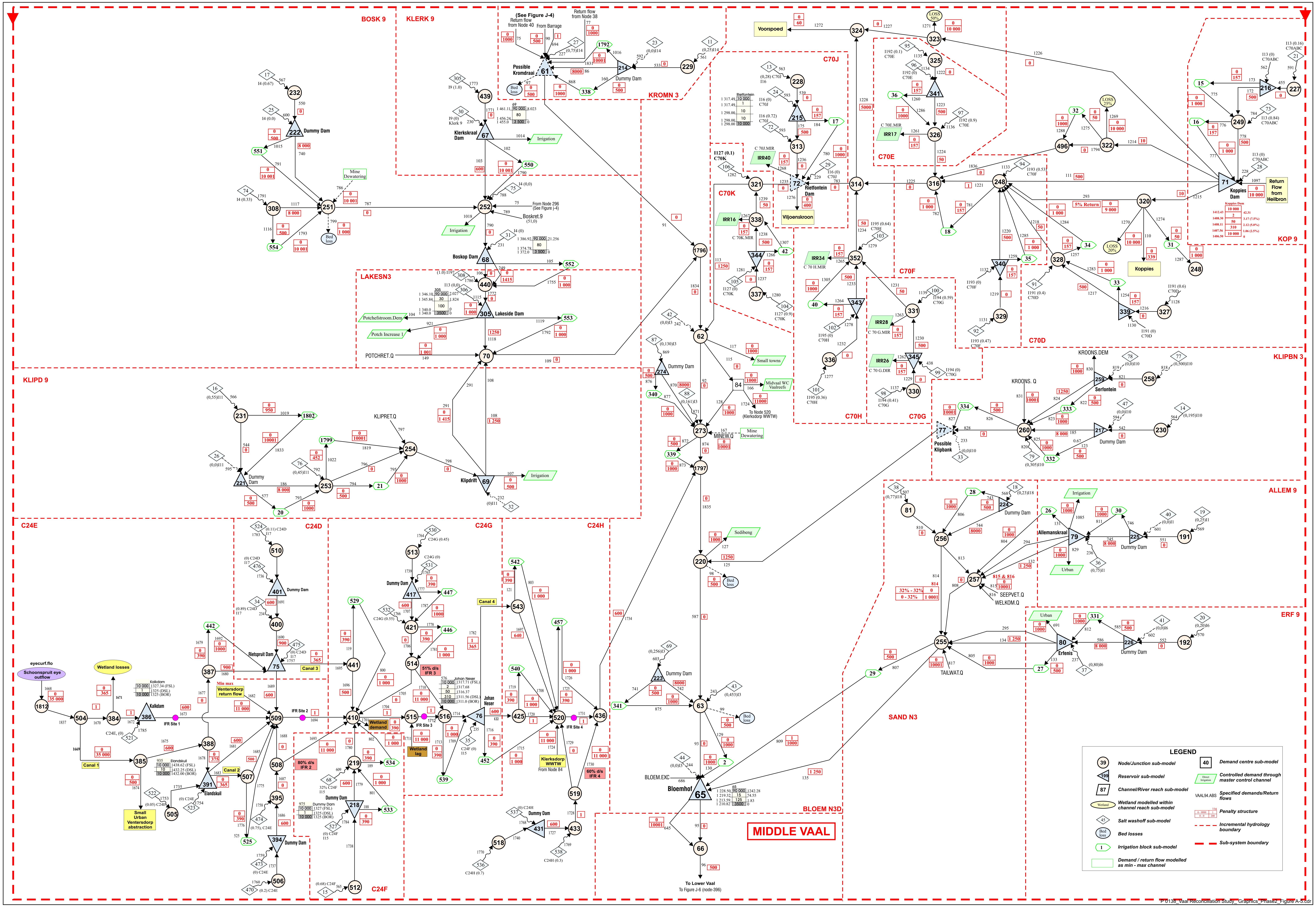
VAAL RIVER SYSTEM: LARGE BULK WATER SUPPLY RECONCILIATION STRATEGIES AND WATER CONSERVATION AND DEMAND MANAGEMENT

WRPM Schematic Diagram: Vaal Dam to Vaal Barrage

J-4



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SUPPLY RECONCILIATION STRATEGIES AND
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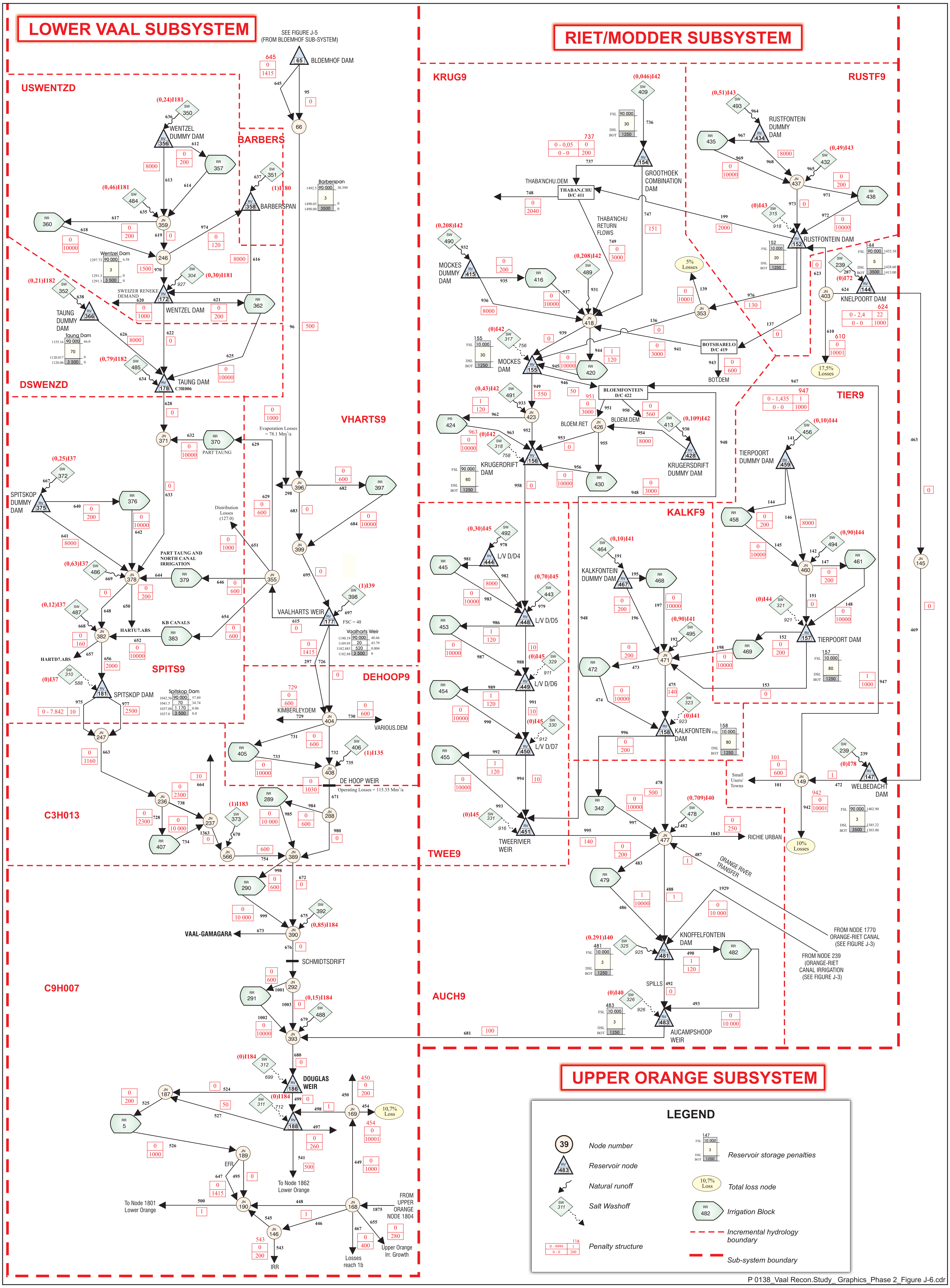
WRPM Schematic diagram: Middle Vaal Sub-system

J-5



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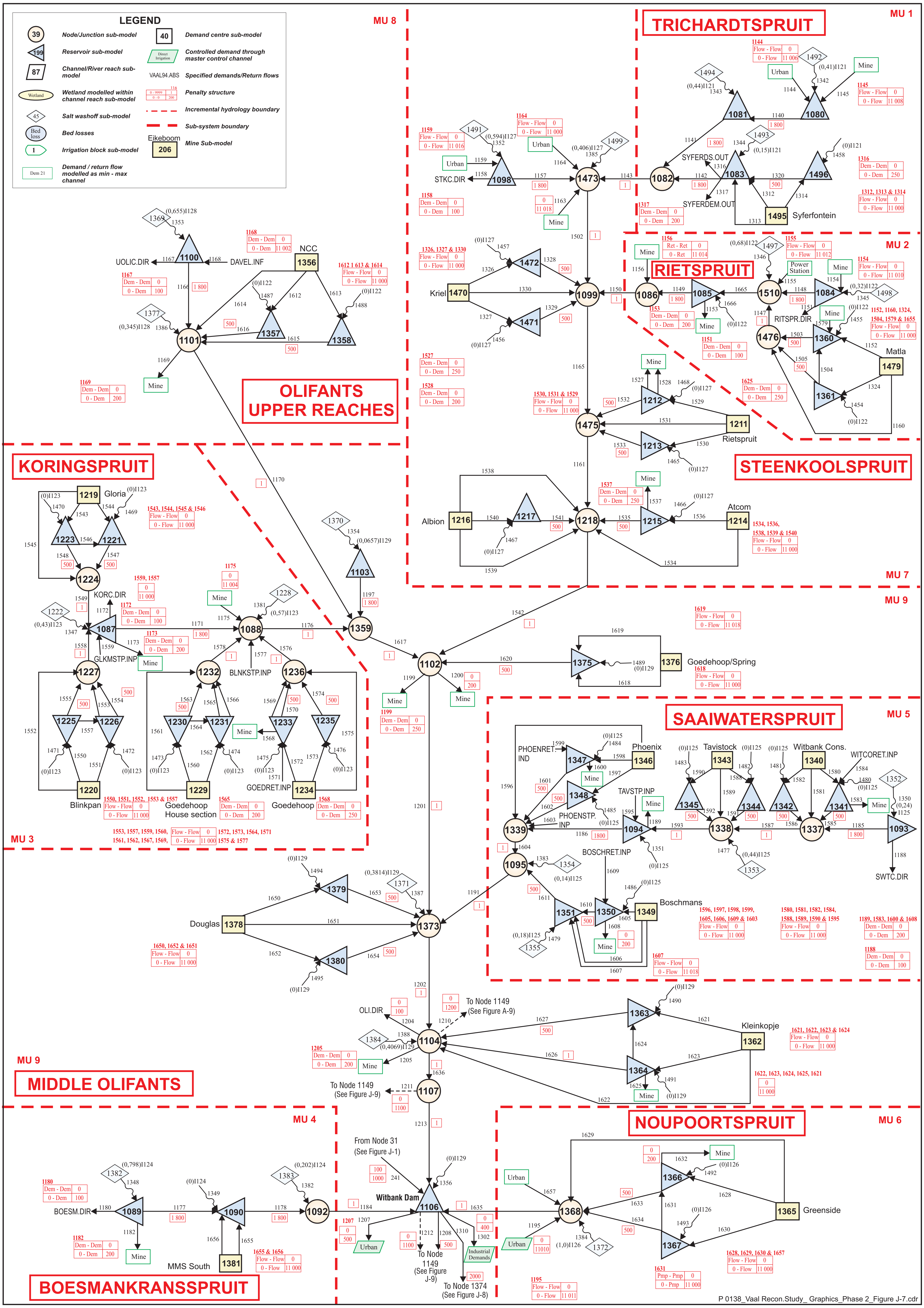
VAAL RIVER SYSTEM: LARGE BULK WATER SUPPLY RECONCILIATION STRATEGIES AND WATER CONSERVATION AND DEMAND MANAGEMENT

WRPM Schematic Diagram: Lower Vaal & Riet/ Modder Sub-systems

J-6



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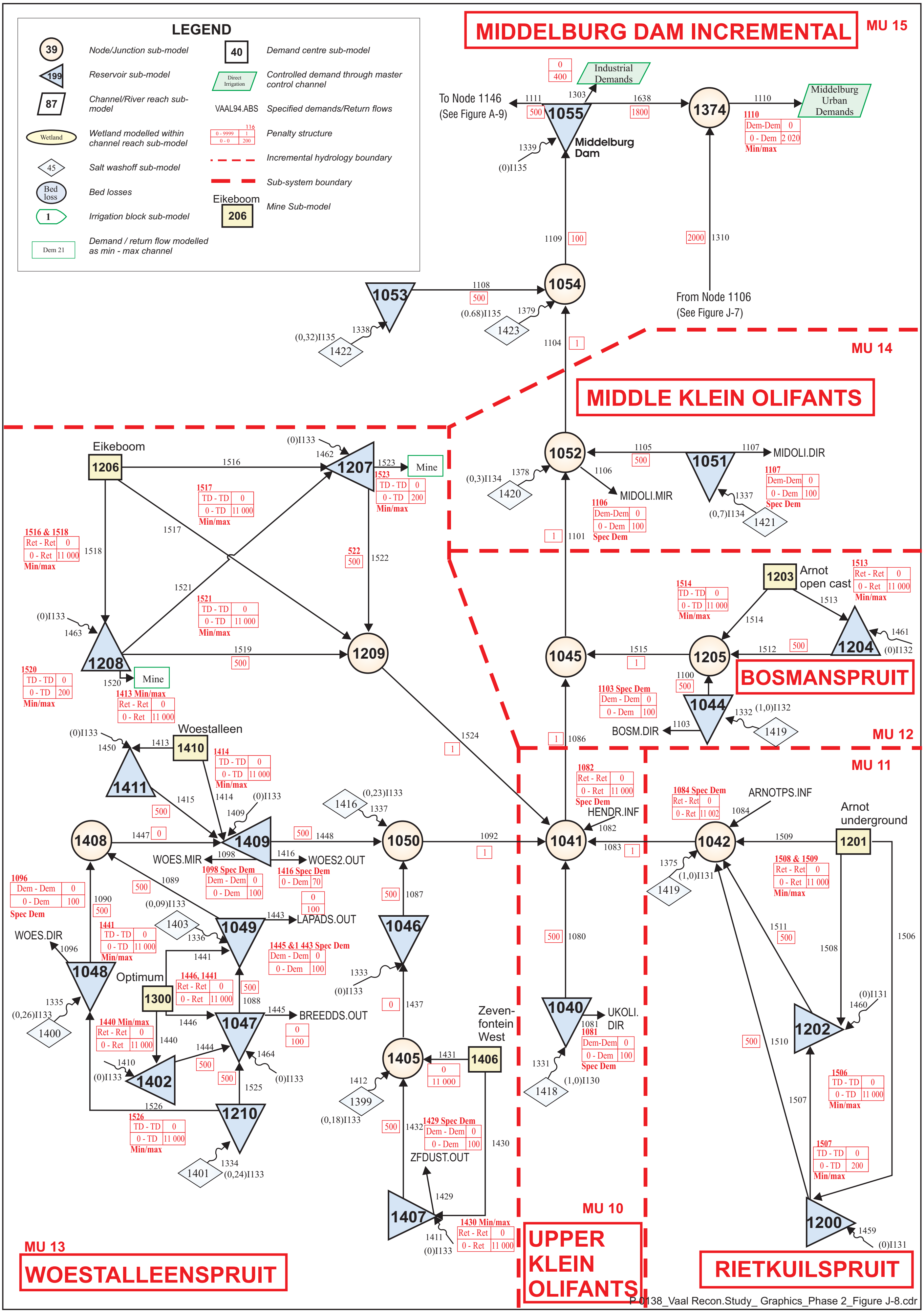
VAAL RIVER SYSTEM: LARGE BULK WATER SUPPLY RECONCILIATION STRATEGIES AND WATER CONSERVATION AND DEMAND MANAGEMENT

WRPM Schematic Diagram:
Witbank Dam Sub-system with Penalty Structure

J-7



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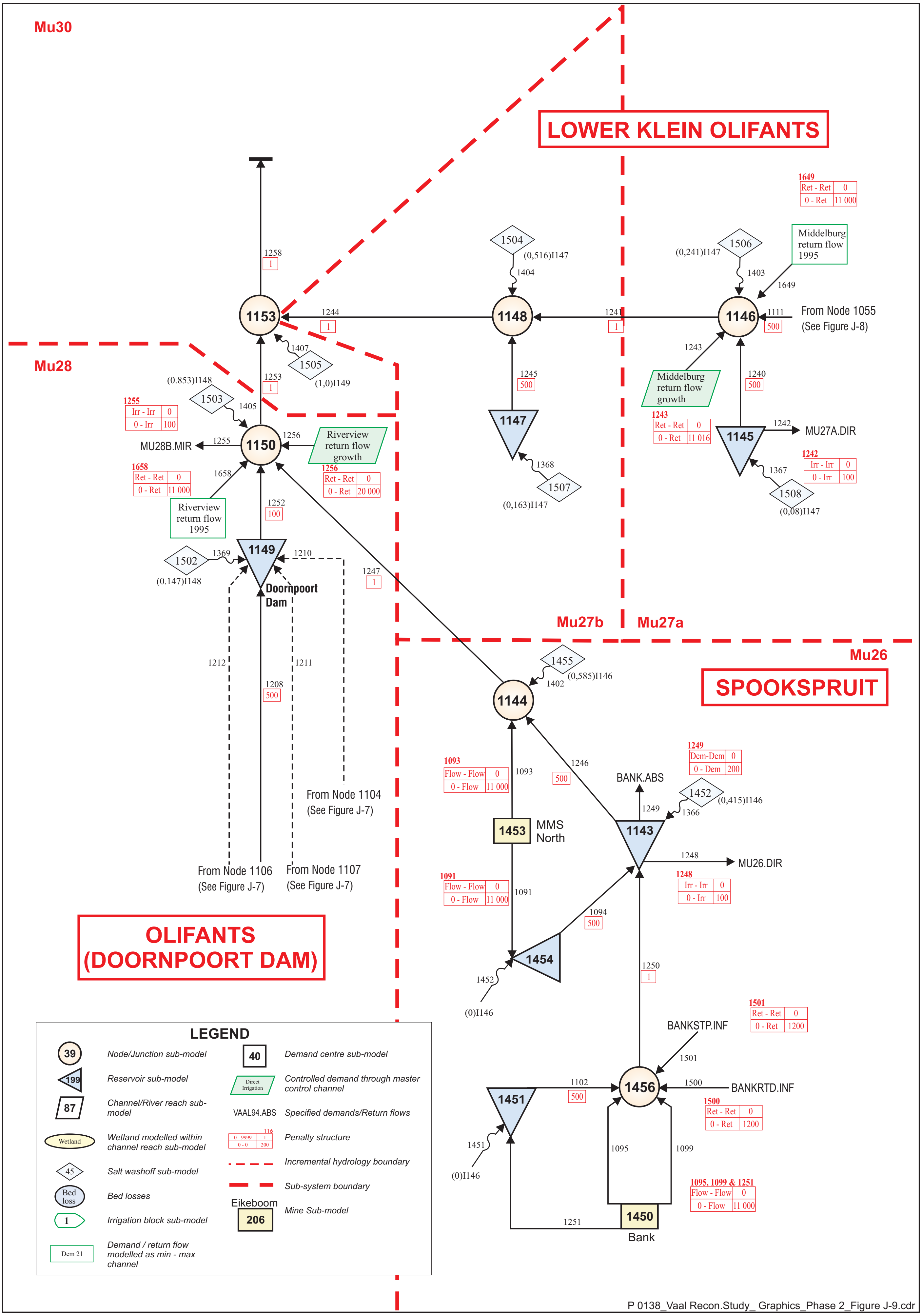
VAAL RIVER SYSTEM: LARGE BULK WATER SUPPLY RECONCILIATION STRATEGIES AND WATER CONSERVATION AND DEMAND MANAGEMENT

WRPM Schematic Diagram: Middelburg Dam Sub-system With Penalty Structures

J-8



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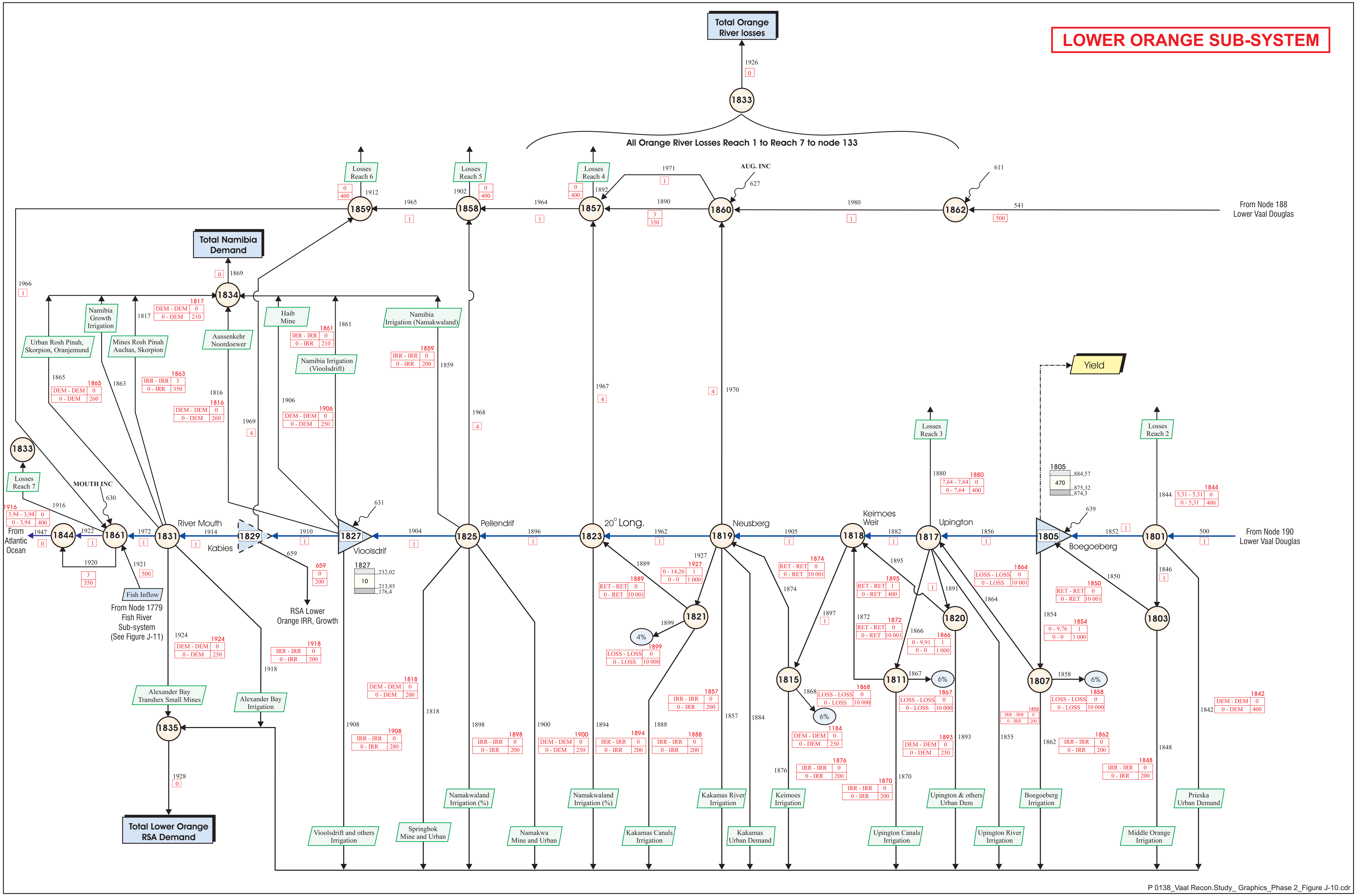
VAAL RIVER SYSTEM: LARGE BULK WATER SUPPLY RECONCILIATION STRATEGIES AND WATER CONSERVATION AND DEMAND MANAGEMENT

WRPM Schematic Diagram: Loskop Dam Incremental Sub-system With Penalty Structures

J-9

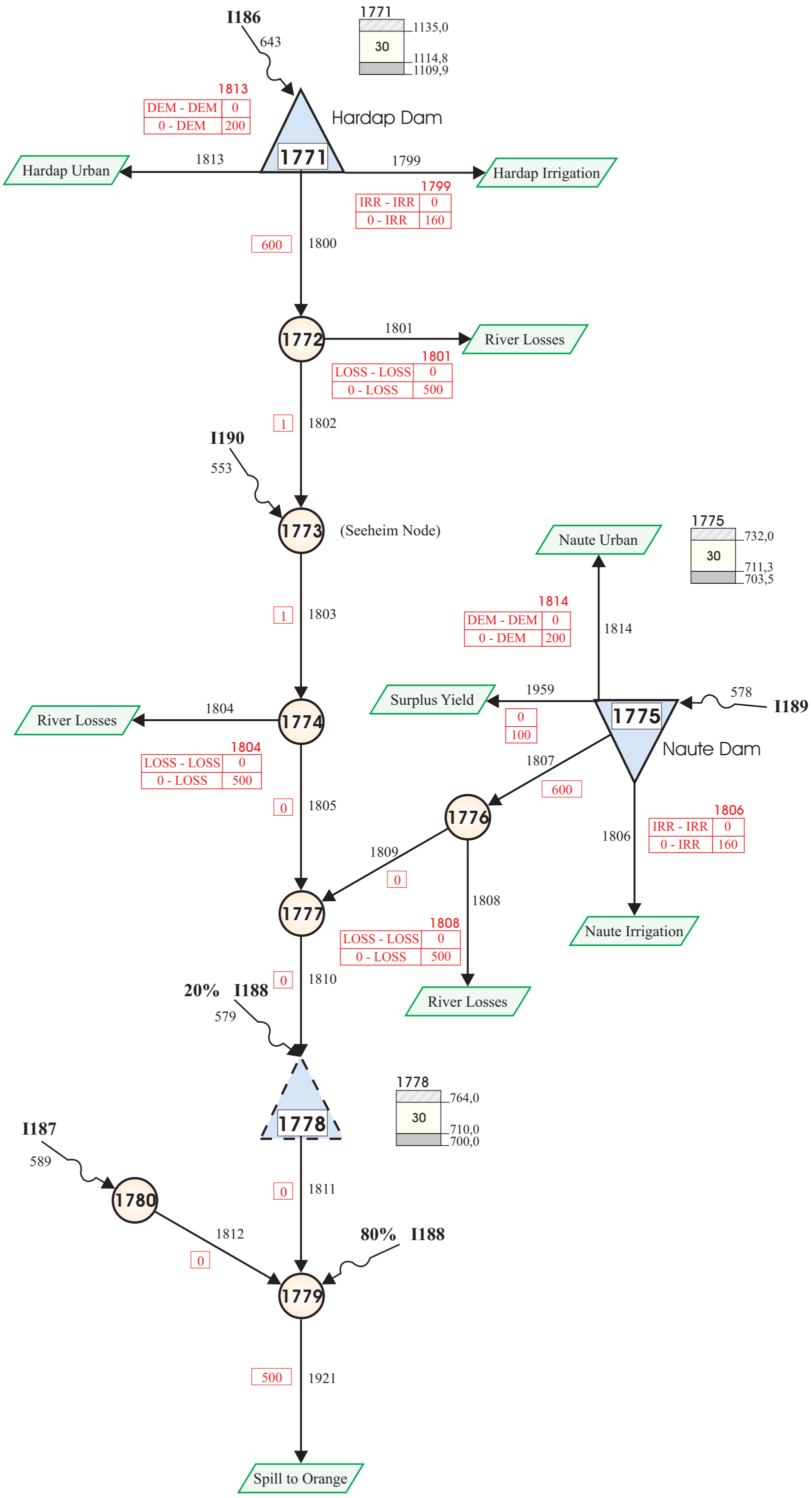


VAAL RIVER SYSTEM: LARGE BULK WATER
SUPPLY RECONCILIATION STRATEGIES AND
WATER CONSERVATION AND DEMAND MANAGEMENT

WRPM Schematic Diagram: Lower Orange Sub-system

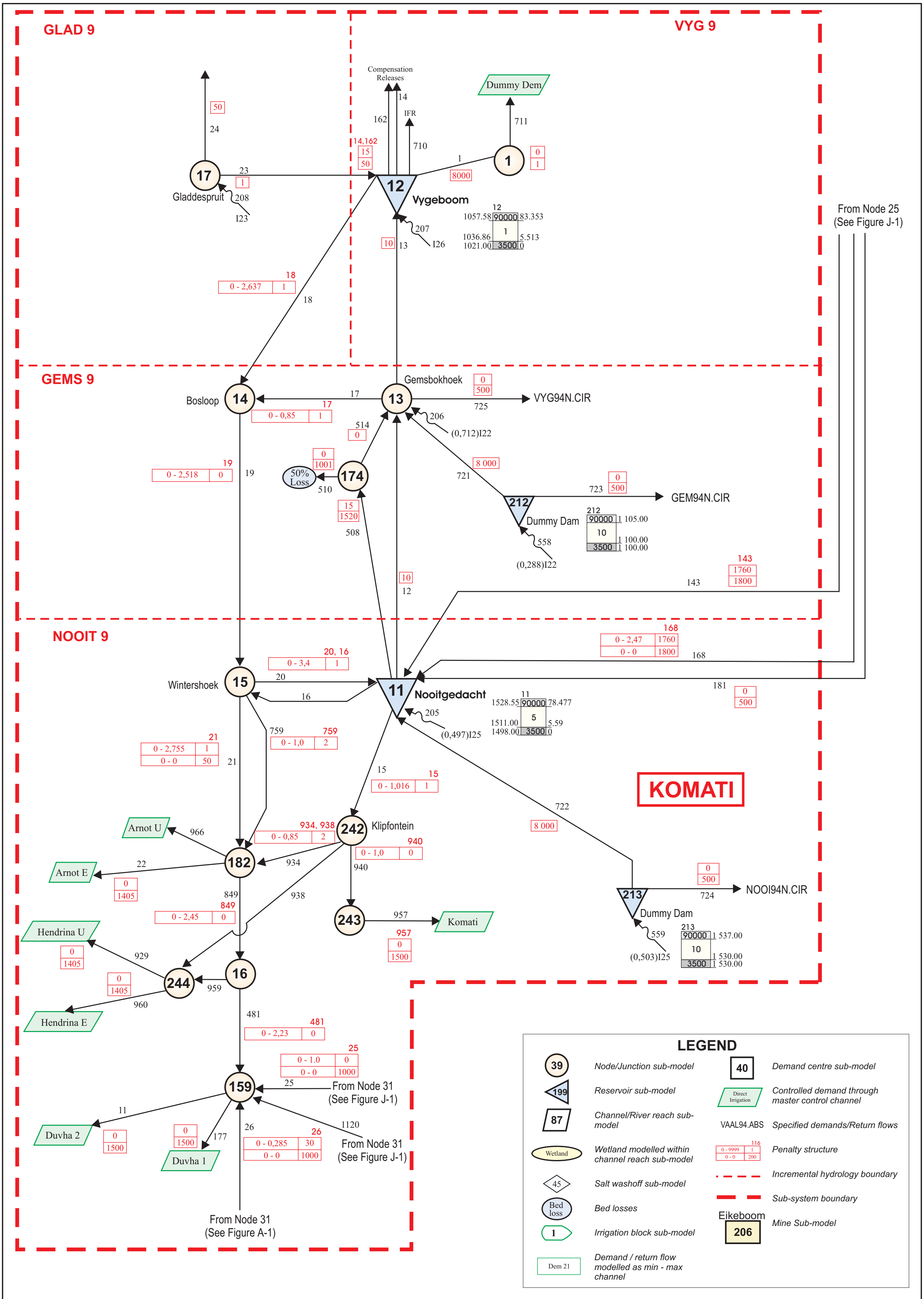
J-10

NAMIBIA: FISH RIVER SUB-SUSTEM



To Node 1861
(See Figure J-10)

P 0138_Vaal Recon.Study_ Graphics_Phase 2_Figure J-11.cdr



P 0138_Vaal Recon.Study_ Graphics_Phase2_Figure J-12.cdr

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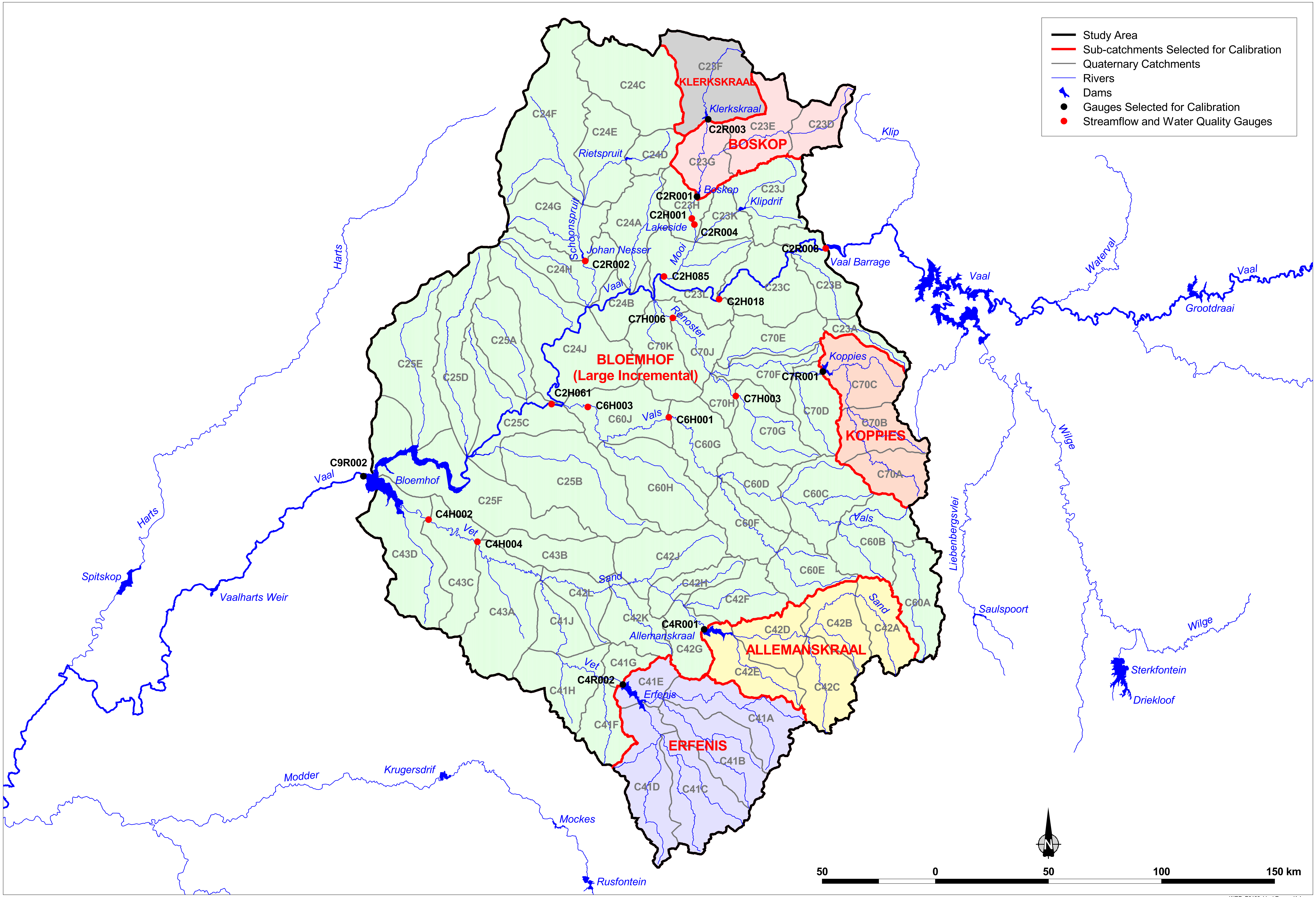
WRPM Schematic Diagram: Komati Sub-system

J-12

Appendix K

Figures



VAAL RIVER SYSTEM: LARGE BULK WATER SUPPLY RECONCILIATION STRATEGIES AND WATER CONSERVATION AND DEMAND MANAGEMENT STUDIES

Sub-catchments in Middle Vaal selected for calibration

K-1

WRP_P0139_Vaal Recon_K-1.apr

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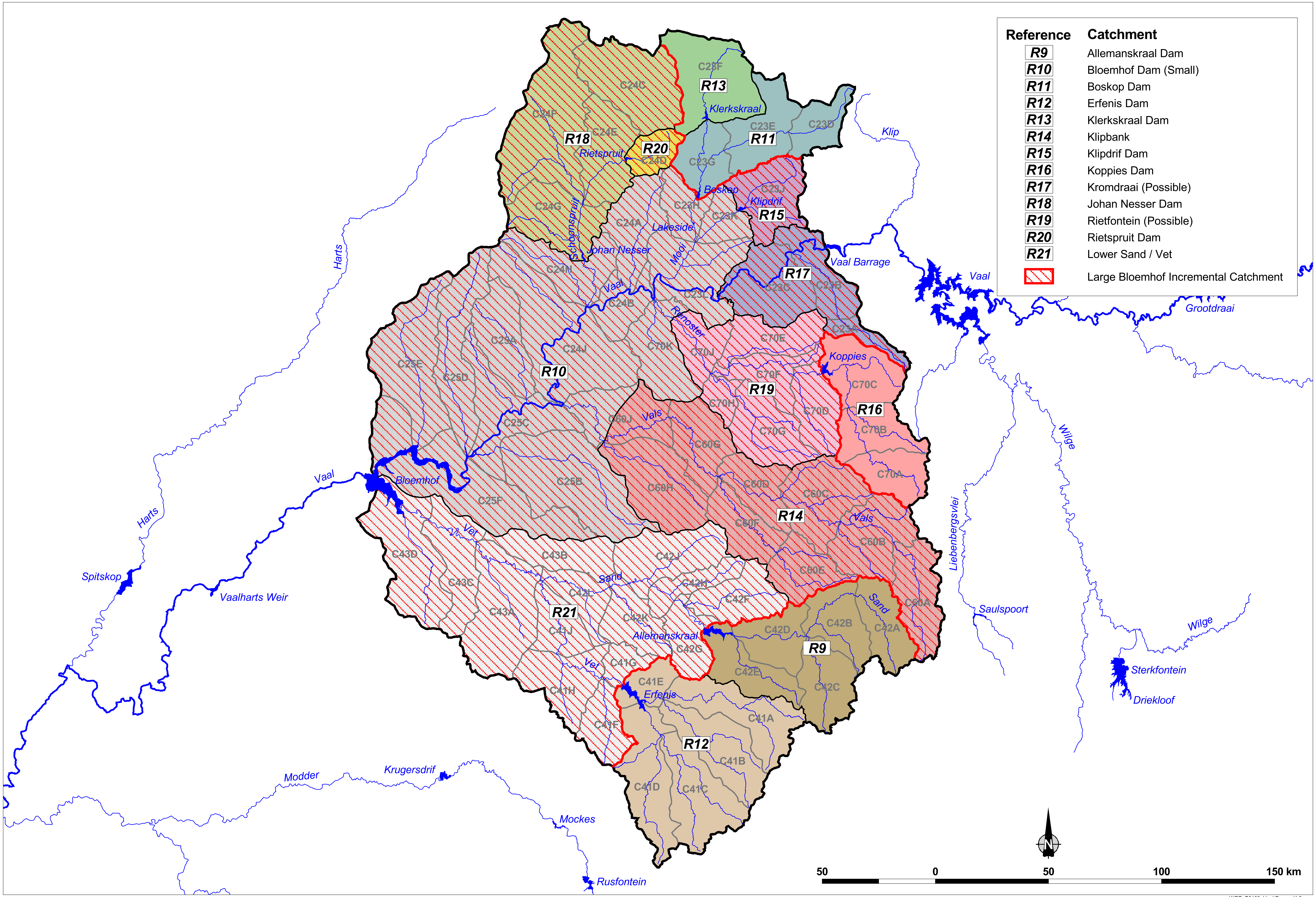
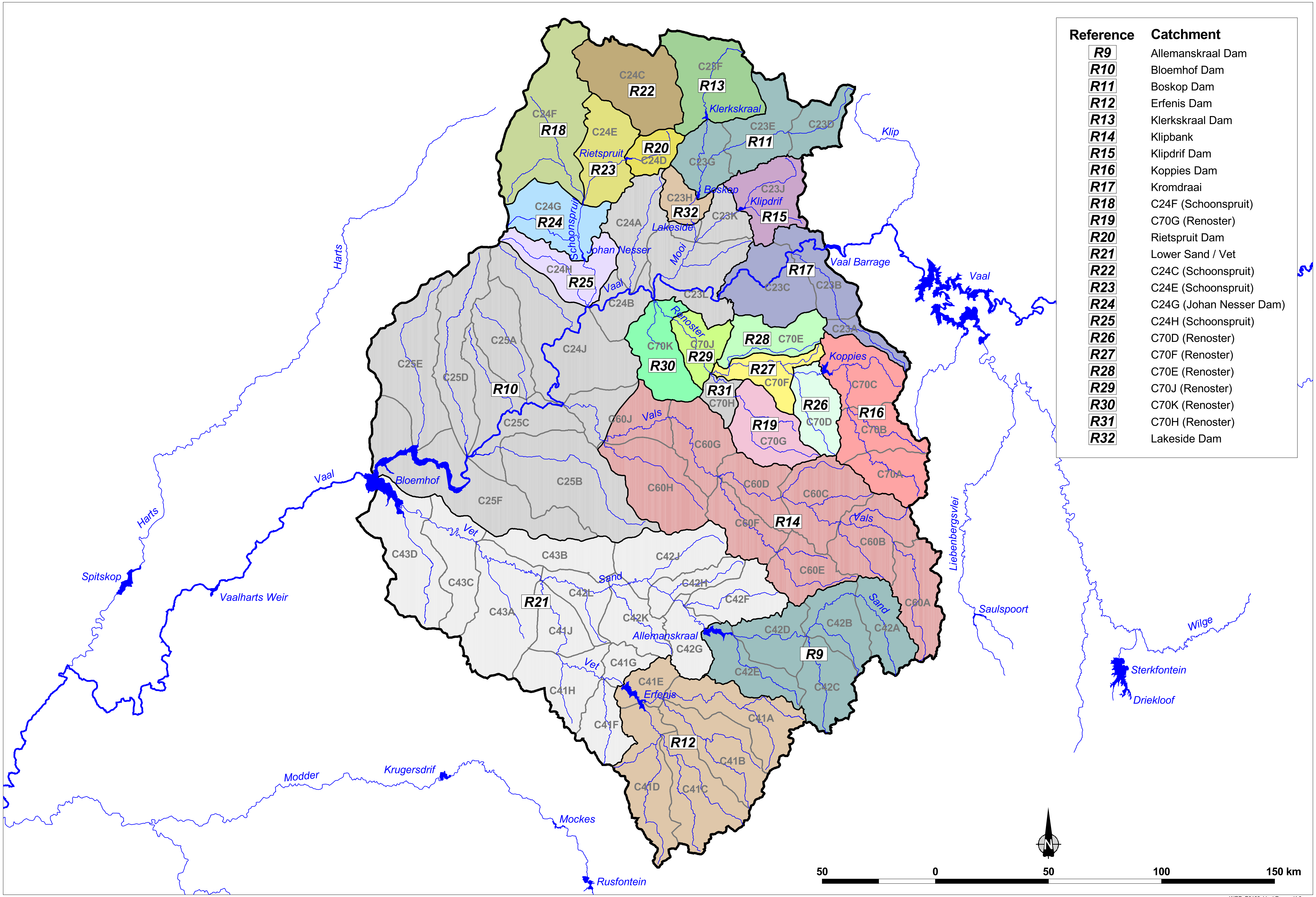


Sub-catchments used for system modelling purposes in the VRSAU study

K-2



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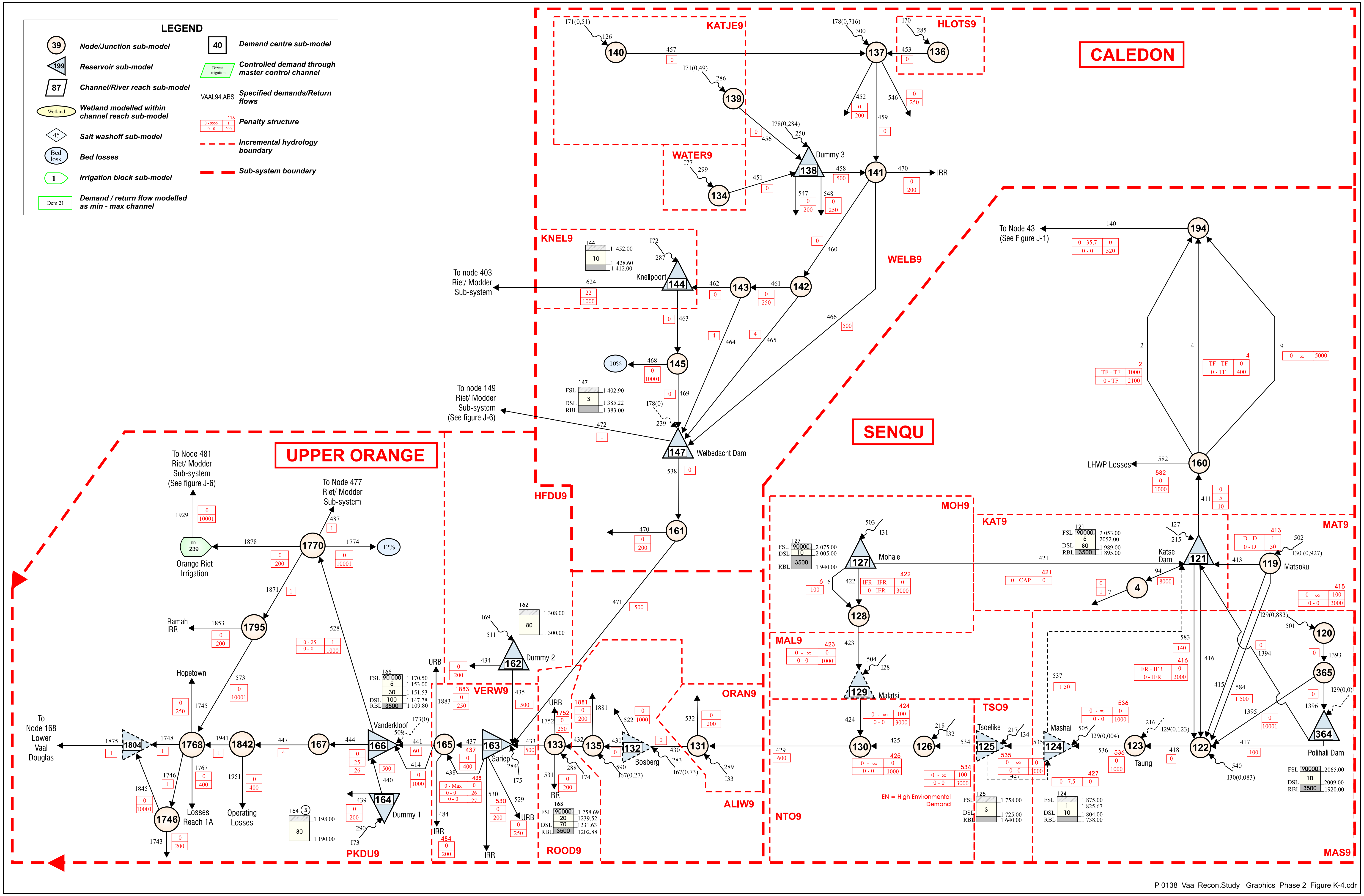
VAAL RIVER SYSTEM: LARGE BULK WATER SUPPLY RECONCILIATION STRATEGIES AND WATER CONSERVATION AND DEMAND MANAGEMENT STUDIES

Sub-catchments used for system modelling purposes in this study

K-3



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VAAL RIVER SYSTEM: LARGE BULK WATER SUPPLY RECONCILIATION STRATEGIES AND WATER CONSERVATION AND DEMAND MANAGEMENT

WRPM Schematic Diagram:
Senqu, Caledon and Upper Orange Sub-system

K-4

Appendix L

Water requirements and return flows

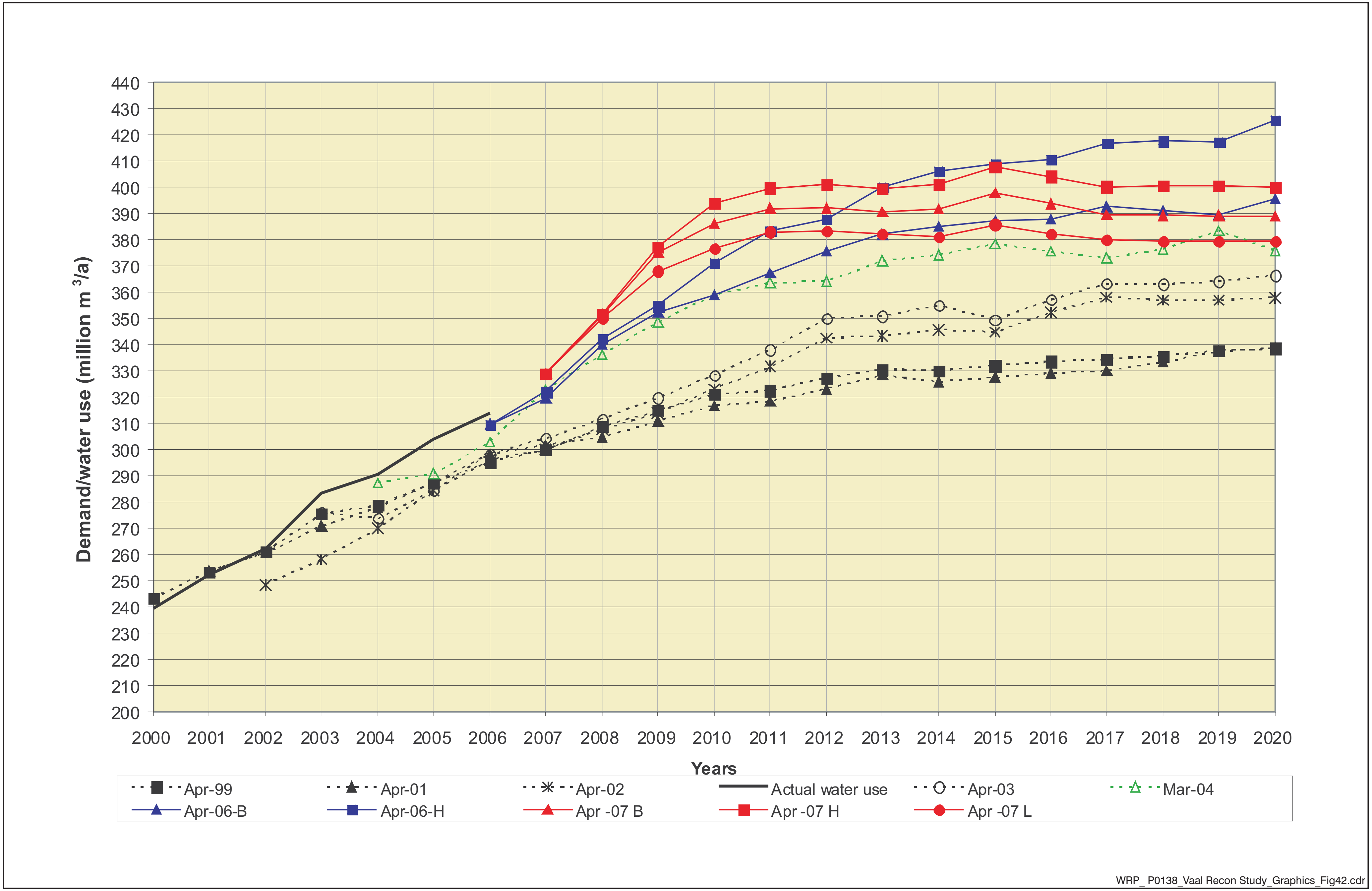
(Second Stage)

Appendix L (cont)

Water requirements and return flows

(Second Stage)

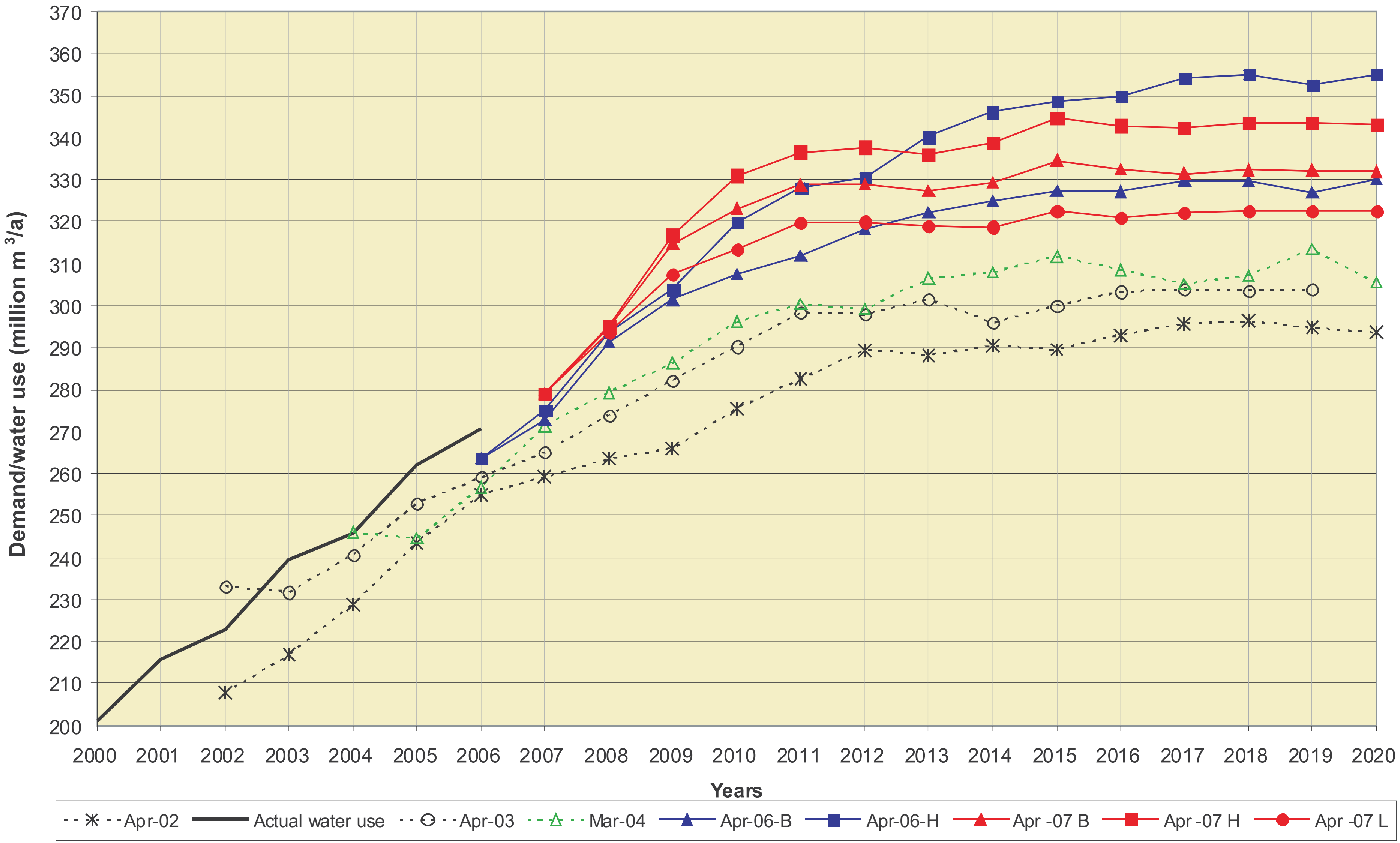
No:	Description
Table L-2	Scenario D_2 water demand and return flow projections for the IVRS
Table L-3	Scenario H_2 water demand and return flow projections for the IVRS
Table L-4	Scenario I_2 water demand and return flow projections for the IVRS
Table L-5	Scenario E_2 water demand and return flow projections for the IVRS
Table L-6	Scenario J_2 water demand and return flow projections for the IVRS



VAAL RIVER SYSTEM: LARGE BULK WATER SUPPLY RECONCILIATION STRATEGIES AND WATER CONSERVATION AND DEMAND MANAGEMENT

Comparison of total demand projections for Power Stations supplied from the Integrated Vaal River System (DWAF Third Party Users not included)

L-1

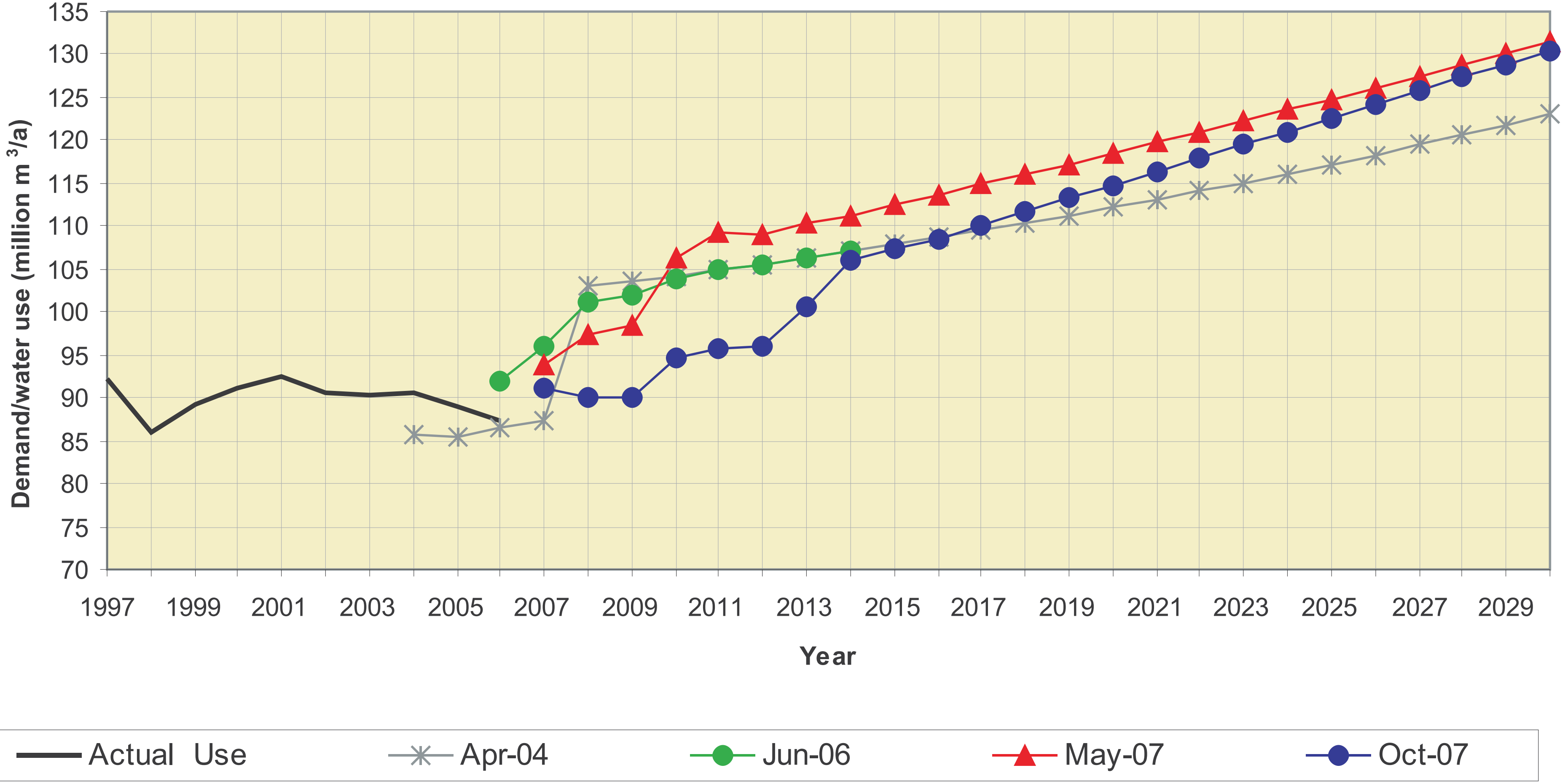


WRP_ P0138_Vaal Recon Study_Graphics_Fig42.cdr

VAAL RIVER SYSTEM: LARGE BULK WATER SUPPLY RECONCILIATION STRATEGIES AND WATER CONSERVATION AND DEMAND MANAGEMENT

Comparison of total demand projections for Power Stations supplied from the Easter Sub-system of the Integrated Vaal River System (DWAF Third Party Users not included)

L-2

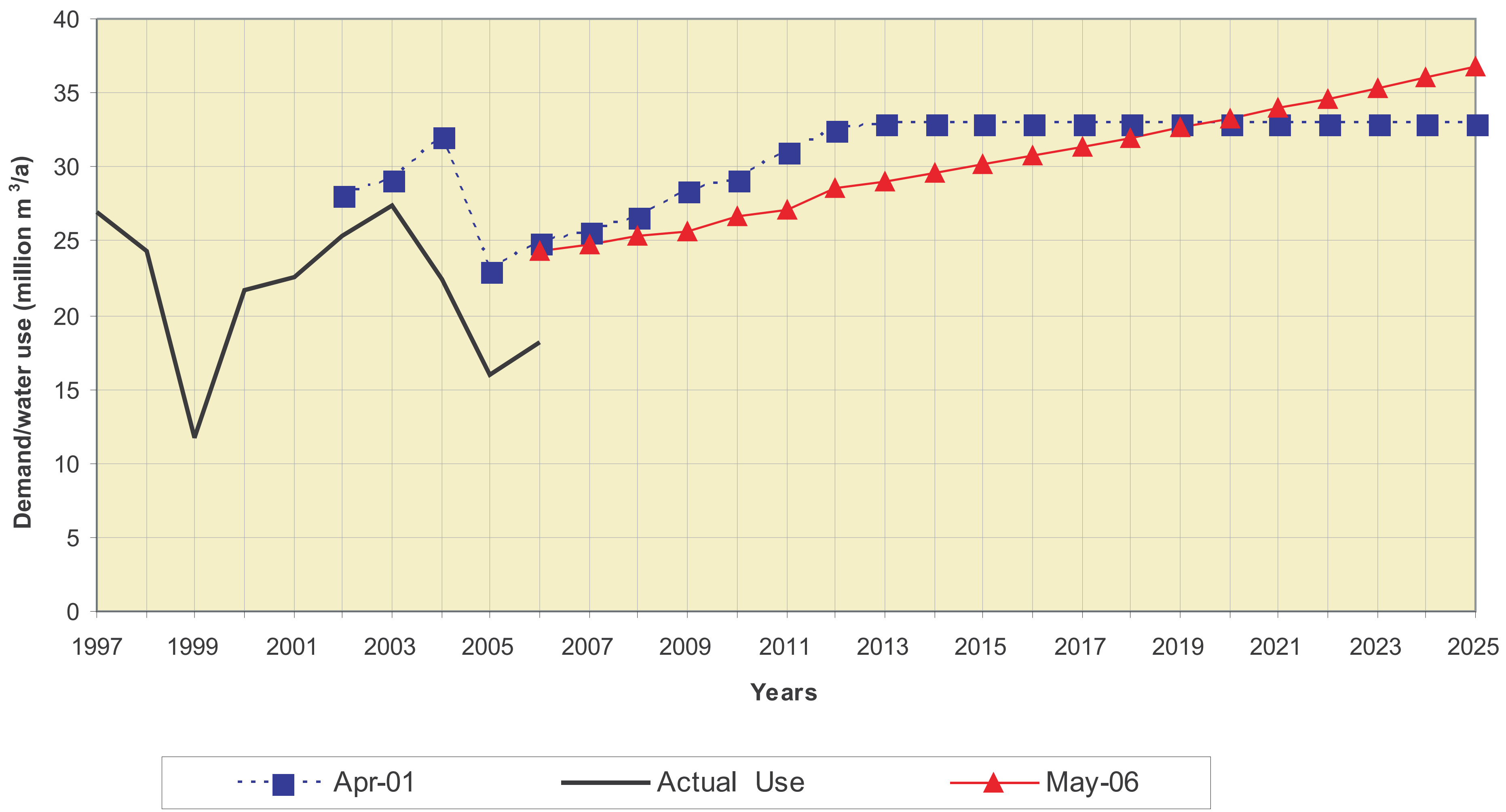


WRP_ P0138_Vaal Recon Study_Graphics_Fig42.cdr

VAAL RIVER SYSTEM: LARGE BULK WATER SUPPLY RECONCILIATION STRATEGIES AND WATER CONSERVATION AND DEMAND MANAGEMENT

Sasol Secunda : Comparison of actual water use and demand projections

L-3

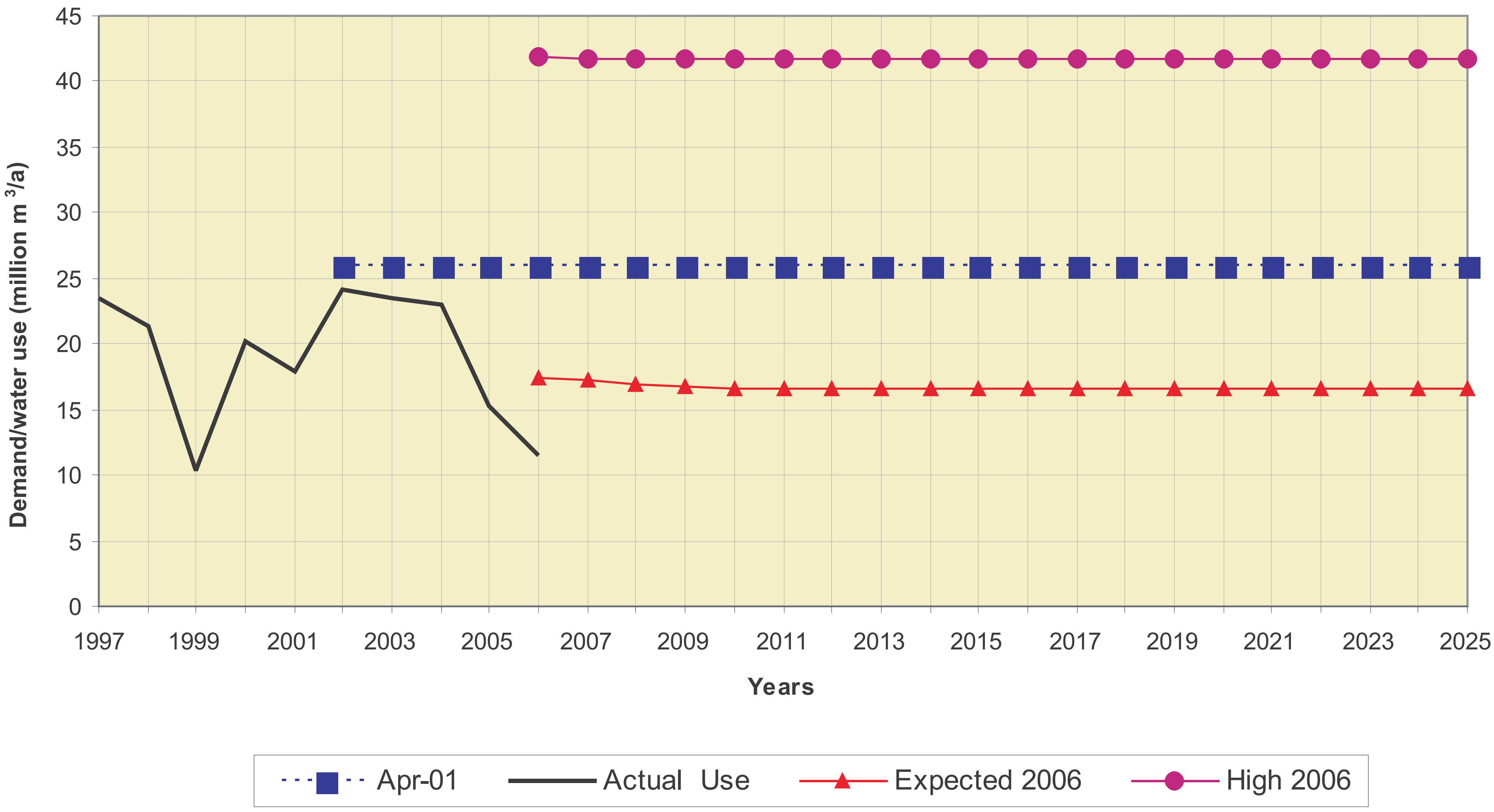


WRP_ P0138_Vaal Recon Study_Graphics_Fig42.cdr

VAAL RIVER SYSTEM: LARGE BULK WATER SUPPLY RECONCILIATION STRATEGIES AND WATER CONSERVATION AND DEMAND MANAGEMENT

Sasol Sasolburg : Comparison of actual water use and demand projections

L-4

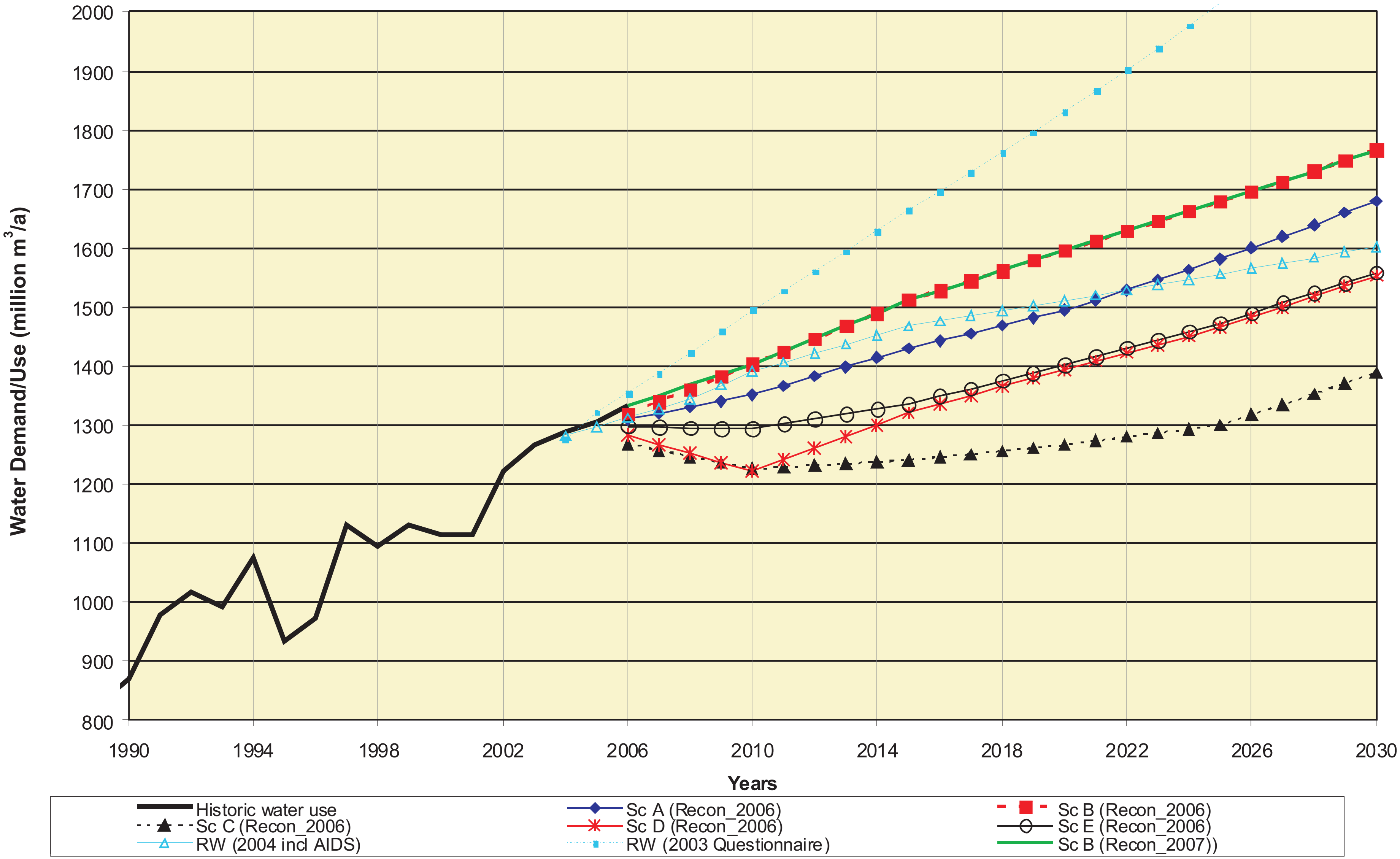


WRP_ P0138_Vaal Recon Study_Graphics_Fig42.cdr

VAAL RIVER SYSTEM: LARGE BULK WATER SUPPLY RECONCILIATION STRATEGIES AND WATER CONSERVATION AND DEMAND MANAGEMENT

Mittal Steel : Comparison of actual water use and demand projections

L-5

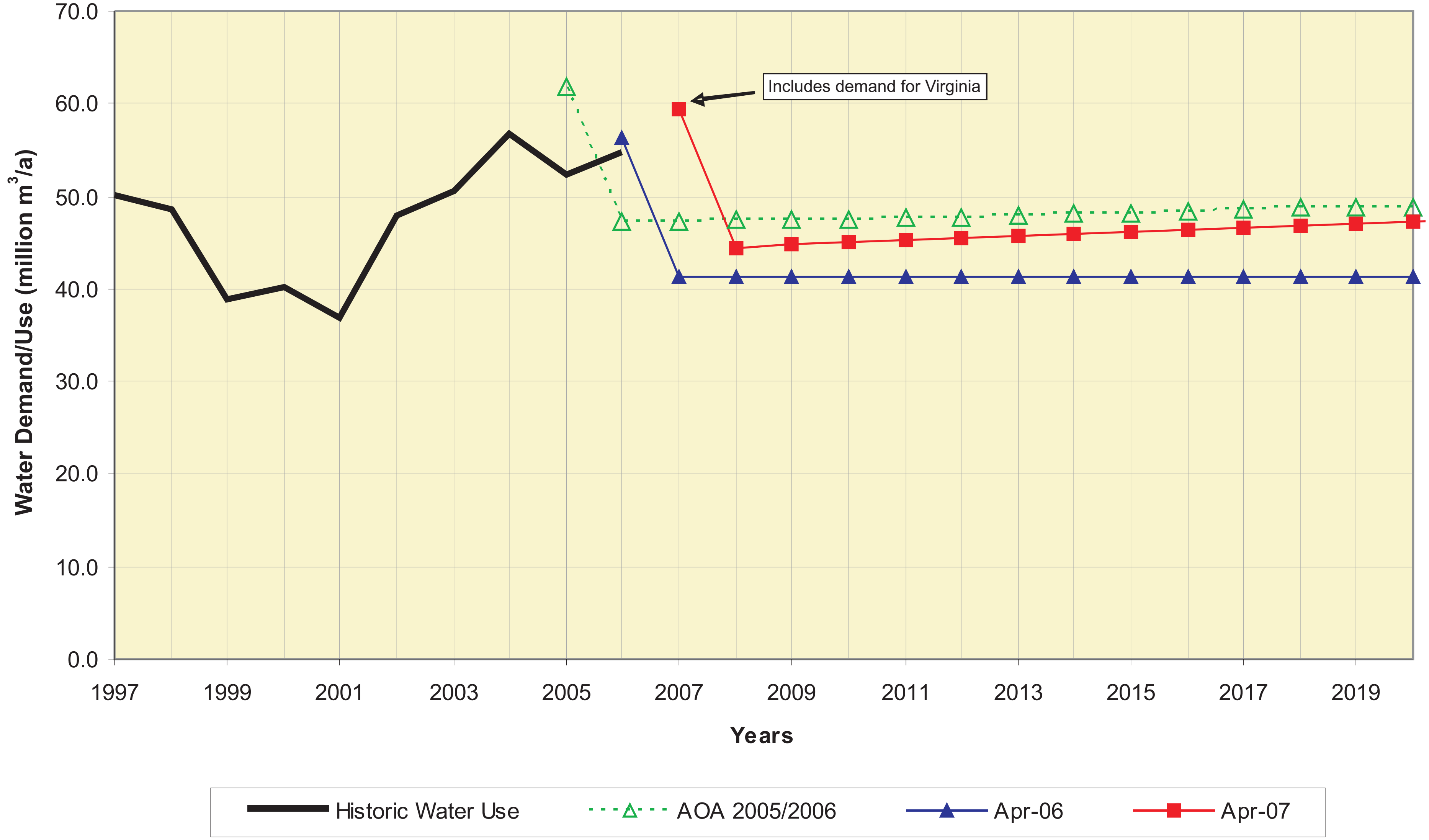


WRP_ P0138_Vaal Recon Study_Graphics_Fig43.cdr

VAAL RIVER SYSTEM: LARGE BULK WATER SUPPLY RECONCILIATION STRATEGIES AND WATER CONSERVATION AND DEMAND MANAGEMENT

Rand Water Demand Projections (This Study & 2004 Proj adopted for 2006/2007 AOA)

L-6

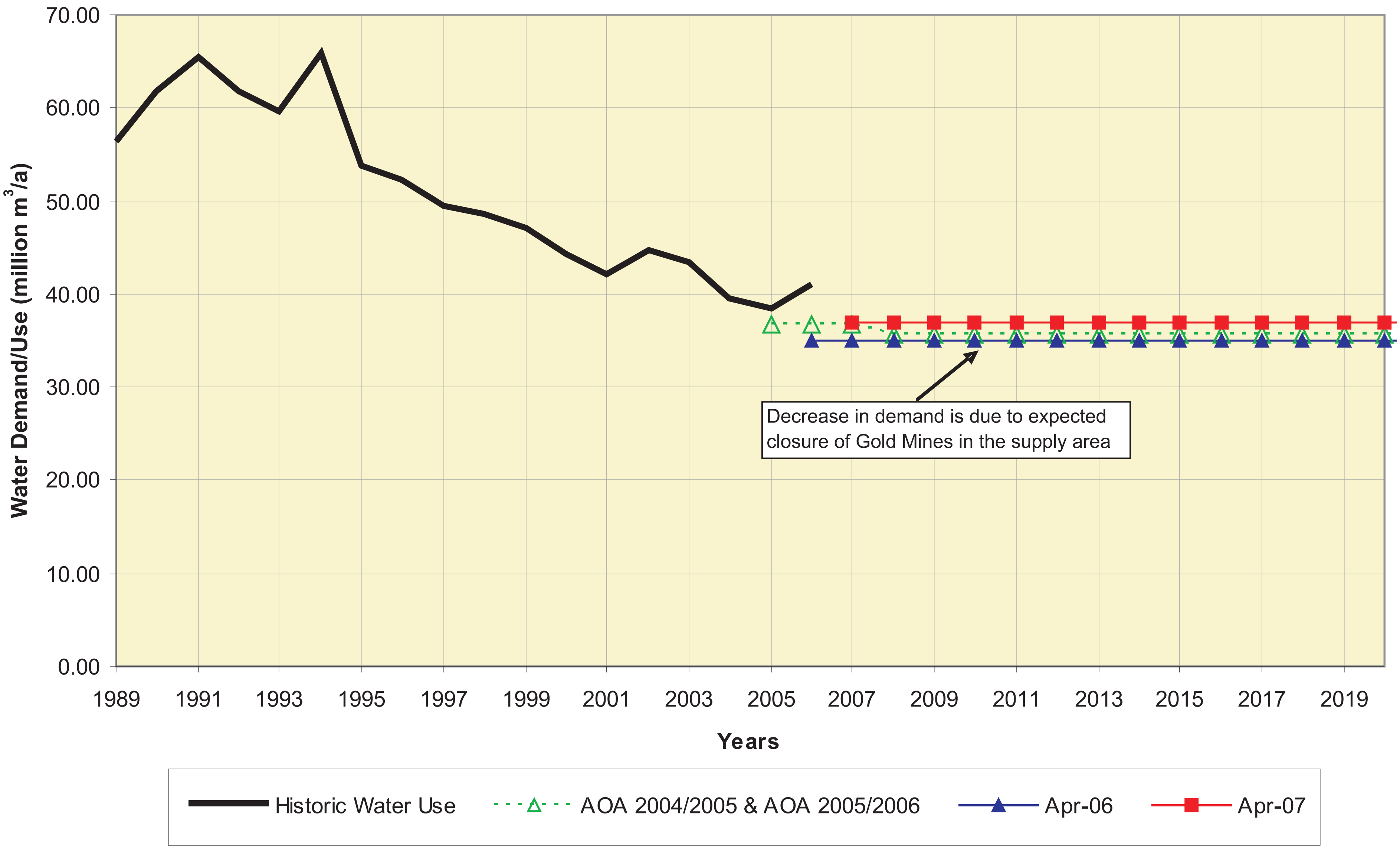


WRP_ P0138_Vaal Recon Study_Graphics_Fig43.cdr

VAAL RIVER SYSTEM: LARGE BULK WATER SUPPLY RECONCILIATION STRATEGIES AND WATER CONSERVATION AND DEMAND MANAGEMENT

Sedibeng Water :Comparison Actual Water Use and April 2006 Water Demand Projections (Balkfontein only except for the year 2007 which includes demand for Virginia)

L-7



WRP_ P0138_Vaal Recon Study_Graphics_Fig43.cdr

Midvaal Water : Comparison of Actual Water Use and 2006 Water Demand Projections

Table L-1: **Scenario B2 water demand and return flow projections for the Integrated Vaal River System as adopted for the Second Stage Vaal Reconciliation Strategy**
Based on Rand Water Scenario B (DWAF High Demographics projections excluding WDM), Midvaal and Sedibeng Water April 2007 projections, Eskom April 2007 Base Demands
Sasol Secunda Oct 2007 projections, 2006 projections for Sasol Sasolburg and Mittal Steel and the NWRS demand projections (Ratio Method) for smaller demand centres.

DESCRIPTION		Projected Demands and Return Flows (million m^3/a)														Extrapolated									
		2007	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
DEMANDS:	Rand Water [1]	1338.61	1355.92	1373.50	1390.12	1410.94	1432.32	1454.03	1476.08	1498.47	1514.81	1531.34	1548.05	1564.96	1582.06	1598.35	1614.81	1631.44	1648.25	1665.23	1682.37	1699.70	1717.20	1734.89	1752.76
	Magalies Water (Vaalkop Scheme) [11]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Mittal Steel [10]	17.17	16.98	16.80	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62
	ESKOM [8]	354.21	377.55	397.88	407.60	411.48	411.04	410.95	414.03	417.42	414.67	412.74	413.65	414.44	414.97	415.95	416.02	415.47	415.24	413.64	411.35	411.35	411.35	411.35	411.35
	SASOL Sasolburg (Raw water req) [9]	24.76	25.38	25.68	26.74	27.07	28.64	28.96	29.54	30.13	30.74	31.35	31.98	32.62	33.27	33.94	34.62	35.31	36.01	36.73	37.47	38.22	38.98	39.76	40.56
	SASOL Secunda	91.01	90.13	89.93	94.74	95.78	95.97	100.69	106.07	107.32	108.54	110.08	111.64	113.21	114.78	116.34	117.91	119.48	121.04	122.61	124.18	125.74	127.31	128.88	130.45
	Midvaal Water Company	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00
	Sedibeng Water (Balkfontein only)	59.09	44.43	44.70	44.95	45.19	45.41	45.62	45.84	46.05	46.27	46.52	46.79	47.05	47.31	47.57	47.76	47.94	48.12	48.30	48.47	48.65	48.83	49.00	49.18
	Other towns and industries (Vaal)	168.07	183.89	184.51	185.12	185.76	186.40	187.05	187.69	188.33	188.39	188.45	188.51	188.57	188.63	188.73	188.83	188.92	189.02	189.11	189.30	189.49	189.67	189.86	190.04
	Other towns and industries(Zaai)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Vaalharts/Lower Vaal irrigation [2]	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53
	Diffuse Irrig and Aff (Vaal)	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31
	Diffuse Irrig and AFF (Sup systems)	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30
	Other irrigation in Vaal [3]	646.22	685.75	587.01	488.28	389.54	389.54	389.54	389.54	389.54	389.54	389.54	389.54	389.54	389.54	389.54	389.54	389.54	389.54	389.54	389.54	389.54	389.54	389.54	389.54
	Other irrigation in sup subsystems [3]	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10
	Wetland losses [4]	44.35	44.60	44.86	45.11	45.36	45.62	45.88	46.14	46.40	46.66	46.91	47.17	47.43	47.70	47.95	48.21	48.47	48.73	48.99	49.24	49.48	49.73	49.98	50.24
	Bed losses [5]	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20
	Mooi River (net losses) [6]	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80
RETURN FLOWS:	Southern Gauteng (Rand Water)	-341.87	-348.43	-355.13	-361.95	-367.69	-373.53	-379.46	-385.49	-391.63	-396.80	-402.05	-407.37	-412.76	-418.23	-422.11	-426.03	-429.99	-433.99	-438.02	-442.10	-446.21	-450.37	-454.56	-458.80
	Midvaal Water Company	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.91	-0.91	-0.91	-0.91	-0.91	-0.91	-0.91	-0.91	-0.91	-0.91	-0.91
	Sedibeng Water	-2.36	-1.78	-1.79	-1.80	-1.81	-1.82	-1.82	-1.83	-1.84	-1.85	-1.86	-1.87	-1.88	-1.89	-1.90	-1.91	-1.92	-1.92	-1.93	-1.94	-1.95	-1.95	-1.96	-1.97
	Other towns and industries	-62.64	-63.47	-63.97	-65.24	-65.80	-67.21	-67.77	-68.52	-69.43	-70.07	-70.71	-71.37	-72.03	-72.81	-73.53	-74.25	-74.99	-75.73	-76.55	-77.36	-78.18	-79.01	-79.85	-80.72
	Irrigation [7]	-67.59	-71.37	-61.91	-52.45	-42.99	-42.99	-42.99	-42.99	-42.99	-42.99	-42.99	-42.99	-42.99	-42.99	-42.99	-42.99	-42.99	-42.99	-42.99	-42.99	-42.99	-42.99	-42.99	-42.99
	Mine dewatering	-116.31	-114.02	-111.74	-109.46	-109.01	-108.55	-108.55	-117.68	-125.71	-127.54	-127.54	-127.54	-127.54	-127.54	-127.54	-127.54	-127.54	-125.71	-125.71	-125.71	-125.71	-125.71	-125.71	-125.71
	Increased urban runoff	-101.49	-102.06	-102.64	-103.24	-103.86	-104.49	-105.14	-105.82	-106.51	-107.81	-109.14	-110.50	-111.89	-113.32	-114.78	-116.27	-117.80	-119.36	-120.97	-122.56	-124.20	-125.88	-127.61	-129.39
OVERALL GROSS SYSTEM DEMAND:		3707.74	3788.89	3729.11	3663.51	3591.97	3615.79	3643.58	3675.78	3704.53	3720.47	3737.79	3758.19	3778.68	3799.12	3819.23	3838.55	3857.43	3876.81	3895.01	3912.78	3933.03	3953.48	3974.13	3994.98
OVERALL NET SYSTEM DEMAND:		3014.58	3086.86	3031.03	2968.47	2899.92	2916.30	2936.94	2952.55	2965.52	2972.50	2982.59	2995.65	3008.67	3021.43	3035.48	3048.65	3061.30	3076.19	3087.93	3099.21	3112.88	3126.65	3140.53	3154.49

Notes :

(1): Rand Water's total raw water abstraction includes Sasolburg but excludes Authorised Users (i.e. ESKOM, ISCOR, Sasol Sasolburg , Mittal Steel and Small Users (Mining & Industrial)).
(2): Includes distribution losses within Vaalharts canal system and mainstream irrigation along Vaal River from Bloemhof Dam down to Douglas Weir.
(3): "Other irrigation" excludes diffuse irrigation
(4): Includes evaporation losses associated with wetlands as well as bed losses occuring within the Suikerbosrand and Klip rivers
(5): Vaal River bed losses include evaporation and operating losses associated with releases made from Bloemhof Dam
(6): Mooi River (Wonderfonteinspruit catchment) : Net effect of bed losses and decanting from dolomitic eyes resulting from WQT calibration
(7): Includes flow contribution resulting from the tailwater component at Erfenis Dam
(8): Includes DWAF 3rd Party Users
(9): It is assumed that Sasol's raw water requirements are not supplied through Rand Water, but that the projections of Rand Water include the potable water allocation of 6Ml/day.
(10): Represents Mittal Steel's total water requirements (i.e. includes the portion of the demand obtained from Rand Water)
(11): Represents portion of Rand Water's demand supplied by Magalies Water (drawn through the Vaalkop Scheme)

Table L-2: **Scenario D2 water demand and return flow projections for the Integrated Vaal River System as adopted for the Second Stage Vaal Reconciliation Strategy**
Based on Rand Water Scenario C (DWAF 2005 High Population projections including 5yr Loss Management), Midvaal and Sedibeng Water April 2007 projections, Eskom April 2007 Base Demands
Sasol Secunda Oct 2007 projections, 2006 projections for Sasol Sasolburg and Mittal Steel and the NWRS demand projections (Ratio Method) for smaller demand centres.

DESCRIPTION		Projected Demands and Return Flows (million m³/a)													
		2007	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
DEMANDS:	Rand Water (1)	1255.01	1239.67	1224.99	1209.71	1228.39	1247.61	1267.15	1287.00	1307.17	1321.71	1336.42	1351.29	1366.34	1381.56
	Magalies Water (Vaalkop Scheme) (11)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Mittal Steel (10)	17.17	16.98	16.80	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62
	ESKOM (8)	354.21	377.55	397.88	407.60	411.48	411.04	410.95	414.03	417.42	414.67	412.74	413.65	414.44	414.97
	SASOL Sasolburg (Raw water req) (9)	24.76	25.38	25.68	26.74	27.07	28.64	28.96	29.54	30.13	30.74	31.35	31.98	32.62	33.27
	SASOL Secunda	91.01	90.13	89.93	94.74	95.78	95.97	100.69	106.07	107.32	108.54	110.08	111.64	113.21	114.78
	Midvaal Water Company	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00
	Sedibeng Water (Balkfontein only)	59.09	44.43	44.70	44.95	45.19	45.41	45.62	45.84	46.05	46.27	46.52	46.79	47.05	47.31
	Other towns and industries (Vaal)	168.07	183.89	184.51	185.12	185.76	186.40	187.05	187.69	188.33	188.39	188.45	188.51	188.57	188.63
	Other towns and industries(Zaai)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Vaalharts/Lower Vaal irrigation (2)	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53
	Diffuse Irrig and Aff (Vaal)	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31
	Diffuse Irrig and AFF (Sup systems)	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30
	Other irrigation in Vaal (3)	646.22	685.75	587.01	488.28	389.54	389.54	389.54	389.54	389.54	389.54	389.54	389.54	389.54	389.54
	Other irrigation in sup subsystems (3)	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10
	Wetland losses (4)	44.35	44.60	44.86	45.11	45.36	45.62	45.88	46.14	46.40	46.66	46.91	47.17	47.43	47.70
	Bed losses (5)	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20
	Mooi River (net losses) (6)	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80
RETURN FLOWS:	Southern Gauteng (Rand Water)	-314.22	-307.14	-300.30	-293.67	-298.19	-302.78	-307.45	-312.19	-317.01	-321.00	-325.04	-329.14	-333.29	-337.49
	Midvaal Water Company	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.91
	Sedibeng Water	-2.36	-1.78	-1.79	-1.80	-1.81	-1.82	-1.82	-1.83	-1.84	-1.85	-1.86	-1.87	-1.88	-1.89
	Other towns and industries	-62.64	-63.47	-63.97	-65.24	-65.80	-67.21	-67.77	-68.52	-69.43	-70.07	-70.71	-71.37	-72.03	-72.81
	Irrigation (7)	-67.59	-71.37	-61.91	-52.45	-42.99	-42.99	-42.99	-42.99	-42.99	-42.99	-42.99	-42.99	-42.99	-42.99
	Mine dewatering	-116.31	-114.02	-111.74	-109.46	-109.01	-108.55	-108.55	-117.68	-125.71	-127.54	-127.54	-127.54	-127.54	-127.54
	Increased urban runoff	-101.49	-102.06	-102.64	-103.24	-103.86	-104.49	-105.14	-105.82	-106.51	-107.81	-109.14	-110.50	-111.89	-113.32
OVERALL GROSS SYSTEM DEMAND:		3624.14	3672.63	3580.60	3483.10	3409.42	3431.09	3456.70	3486.70	3513.23	3527.37	3542.87	3561.43	3580.06	3598.62
OVERALL NET SYSTEM DEMAND:		2958.63	3011.90	2937.35	2856.34	2786.88	2802.34	2822.07	2836.77	2848.83	2855.20	2864.67	2877.11	2889.53	2901.67

DESCRIPTION		Extrapolated									
		2021	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
DEMANDS:	Rand Water (1)	1395.35	1409.27	1423.33	1437.54	1451.90	1469.03	1486.37	1503.92	1521.67	1539.64
	Magalies Water (Vaalkop Scheme) (11)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Mittal Steel (10)	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62
	ESKOM (8)	415.95	416.02	415.47	415.24	413.64	411.35	411.35	411.35	411.35	411.35
	SASOL Sasolburg (Raw water req) (9)	33.94	34.62	35.31	36.01	36.73	37.47	38.22	38.98	39.76	40.56
	SASOL Secunda	116.34	117.91	119.48	121.04	122.61	124.18	125.74	127.31	128.88	130.45
	Midvaal Water Company	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00
	Sedibeng Water (Balkfontein only)	47.57	47.76	47.94	48.12	48.30	48.47	48.65	48.83	49.00	49.18
	Other towns and industries (Vaal)	188.73	188.83	188.92	189.02	189.11	189.30	189.49	189.67	189.86	190.04
	Other towns and industries(Zaai)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Vaalharts/Lower Vaal irrigation (2)	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53
	Diffuse Irrig and Aff (Vaal)	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31
	Diffuse Irrig and AFF (Sup systems)	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30
	Other irrigation in Vaal (3)	389.54	389.54	389.54	389.54	389.54	389.54	389.54	389.54	389.54	389.54
	Other irrigation in sup subsystems (3)	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10
	Wetland losses (4)	47.95	48.21	48.47	48.73	48.99	49.24	49.48	49.73	49.98	50.24
	Bed losses (5)	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20
	Mooi River (net losses) (6)	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80
RETURN FLOWS:	Southern Gauteng (Rand Water)	-340.09	-342.73	-345.38	-348.05	-350.75	-353.69	-356.66	-359.66	-362.69	-365.74
	Midvaal Water Company	-0.91	-0.91	-0.91	-0.91	-0.91	-0.91	-0.91	-0.91	-0.91	-0.91
	Sedibeng Water	-1.90	-1.91	-1.92	-1.92	-1.93	-1.94	-1.95	-1.95	-1.96	-1.97
	Other towns and industries	-73.53	-74.25	-74.99	-75.73	-76.55	-77.36	-78.18	-79.01	-79.85	-80.72
	Irrigation (7)	-42.99	-42.99	-42.99	-42.99	-42.99	-42.99	-42.99	-42.99	-42.99	-42.99
	Mine dewatering	-127.54	-127.54	-127.54	-125.71	-125.71	-125.71	-125.71	-125.71	-125.71	-125.71
	Increased urban runoff	-114.78	-116.27	-117.80	-119.36	-120.97	-122.56	-124.20	-125.88	-127.61	-129.39
OVERALL GROSS SYSTEM DEMAND:		3616.22	3633.01	3649.32	3666.10	3681.67	3699.44	3719.71	3740.20	3760.91	3781.85
OVERALL NET SYSTEM DEMAND:		2914.49	2926.41	2937.80	2951.42	2961.86	2974.28	2989.11	3004.08	3019.19	3034.42

Notes :

(1): Rand Water's total raw water abstraction includes Sasolburg but excludes Authorised Users (i.e. ESKOM, ISCOR, Sasol Sasolburg , Mittal Steel and Small Users (Mining & Industrial)).
(2): Includes distribution losses within Vaalharts canal system and mainstream irrigation along Vaal River from Bloemhof Dam down to Douglas Weir.
(3): "Other irrigation" excludes diffuse irrigation
(4): Includes evaporation losses associated with wetlands as well as bed losses occuring within the Suikerbosrand and Klip rivers
(5): Vaal River bed losses include evaporation and operating losses associated with releases made from Bloemhof Dam
(6): Mooi River (Wonderfonteinspruit catchment) : Net effect of bed losses and decanting from dolomitic eyes resulting from WQT calibration
(7): Includes flow contribution resulting from the tailwater component at Erfenis Dam
(8): Includes DWAF 3rd Party Users
(9): It is assumed that Sasol's raw water requirements are not supplied through Rand Water, but that the projections of Rand Water include the potable water allocation of 6Ml/day.
(10): Represents Mittal Steel's total water requirements (i.e. includes the portion of the demand obtained from Rand Water)
(11): Represents portion of Rand Water's demand supplied by Magalies Water (drawn through the Vaalkop Scheme)

Table L-3: **Scenario H2 water demand and return flow projections for the Integrated Vaal River System as adopted for the Second Stage Vaal Reconciliation Strategy**
Based on Rand Water Scenario B (DWAF High Demographics projections excluding WDM), Midvaal and Sedibeng Water April 2007 projections, Eskom April 2007 High Projections
Sasol Secunda Oct 2007 projections + Mafutha, 2006 projections for Sasol Sasolburg and Mittal Steel and the NWRS demand projections (Ratio Method) for smaller demand centres.

DESCRIPTION		Projected Demands and Return Flows (million m^3/a)													
		2007	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
DEMANDS:	Rand Water [1]	1338.61	1355.92	1373.50	1390.12	1410.94	1432.32	1454.03	1476.08	1498.47	1514.81	1531.34	1548.05	1564.96	1582.06
	Magalies Water (Vaalkop Scheme) [11]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Mittal Steel [10]	17.17	16.98	16.80	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62
	ESKOM [8]	354.27	378.34	401.82	415.41	419.62	419.85	420.02	423.79	427.79	425.80	424.74	426.32	427.53	428.44
	SASOL Sasolburg (Raw water req) [9]	24.76	25.38	25.68	26.74	27.07	28.64	28.96	29.54	30.13	30.74	31.35	31.98	32.62	33.27
	SASOL Secunda	91.01	90.13	89.93	94.74	95.78	95.97	100.69	106.07	107.32	108.54	110.08	111.64	113.21	114.78
	Sasol Mafutha	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	40.00	40.00	40.00	40.00	40.00	80.00
	Midvaal Water Company	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00
	Sedibeng Water (Balkfontein only)	59.09	44.43	44.70	44.95	45.19	45.41	45.62	45.84	46.05	46.27	46.52	46.79	47.05	47.31
	Other towns and industries (Vaal)	168.07	183.89	184.51	185.12	185.76	186.40	187.05	187.69	188.33	188.39	188.45	188.51	188.57	188.63
	Other towns and industries(Zaai)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Vaalharts/Lower Vaal irrigation [2]	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53
	Diffuse Irrig and Aff (Vaal)	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31
	Diffuse Irrig and AFF (Sup systems)	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30
	Other irrigation in Vaal [3]	646.22	685.75	587.01	488.28	389.54	389.54	389.54	389.54	389.54	389.54	389.54	389.54	389.54	389.54
	Other irrigation in sup subsystems [3]	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10
	Wetland losses [4]	44.35	44.60	44.86	45.11	45.36	45.62	45.88	46.14	46.40	46.66	46.91	47.17	47.43	47.70
	Bed losses [5]	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20
	Mooi River (net losses) [6]	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80
RETURN FLOWS:	Southern Gauteng (Rand Water)	-341.87	-348.43	-355.13	-361.95	-367.69	-373.53	-379.46	-385.49	-391.63	-396.80	-402.05	-407.37	-412.76	-418.23
	Midvaal Water Company	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.91
	Sedibeng Water	-2.36	-1.78	-1.79	-1.80	-1.81	-1.82	-1.82	-1.83	-1.84	-1.85	-1.86	-1.87	-1.88	-1.89
	Other towns and industries	-62.64	-63.47	-63.97	-65.24	-65.80	-67.21	-67.77	-68.52	-69.43	-70.07	-70.71	-71.37	-72.03	-72.81
	Irrigation [7]	-67.59	-71.37	-61.91	-52.45	-42.99	-42.99	-42.99	-42.99	-42.99	-42.99	-42.99	-42.99	-42.99	-42.99
	Mine dewatering	-116.31	-114.02	-111.74	-109.46	-109.01	-108.55	-108.55	-117.68	-125.71	-127.54	-127.54	-127.54	-127.54	-127.54
	Increased urban runoff	-101.49	-102.06	-102.64	-103.24	-103.86	-104.49	-105.14	-105.82	-106.51	-107.81	-109.14	-110.50	-111.89	-113.32
OVERALL GROSS SYSTEM DEMAND:		3707.80	3789.67	3733.04	3671.32	3600.11	3624.60	3652.65	3685.55	3754.90	3771.61	3789.79	3810.86	3831.77	3892.59
OVERALL NET SYSTEM DEMAND:		3014.64	3087.65	3034.97	2976.28	2908.07	2925.11	2946.00	2962.32	3015.89	3023.64	3034.59	3048.32	3061.76	3114.90

DESCRIPTION		Extrapolated									
		2021	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
DEMANDS:	Rand Water [1]	1598.35	1614.81	1631.44	1648.25	1665.23	1682.37	1699.70	1717.20	1734.89	1752.76
	Magalies Water (Vaalkop Scheme) [11]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Mittal Steel [10]	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62
	ESKOM [8]	429.91	430.27	429.72	429.49	427.88	425.60	425.60	425.60	425.60	425.60
	SASOL Sasolburg (Raw water req) [9]	33.94	34.62	35.31	36.01	36.73	37.47	38.22	38.98	39.76	40.56
	SASOL Secunda	116.34	117.91	119.48	121.04	122.61	124.18	125.74	127.31	128.88	130.45
	Sasol Mafutha	80.00	80.00	80.00	80.00	80.00	80.00	80.00	80.00	80.00	80.00
	Midvaal Water Company	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00
	Sedibeng Water (Balkfontein only)	47.57	47.76	47.94	48.12	48.30	48.47	48.65	48.83	49.00	49.18
	Other towns and industries (Vaal)	188.73	188.83	188.92	189.02	189.11	189.30	189.49	189.67	189.86	190.04
	Other towns and industries(Zaai)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Vaalharts/Lower Vaal irrigation [2]	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53
	Diffuse Irrig and Aff (Vaal)	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31
	Diffuse Irrig and AFF (Sup systems)	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30
	Other irrigation in Vaal [3]	389.54	389.54	389.54	389.54	389.54	389.54	389.54	389.54	389.54	389.54
	Other irrigation in sup subsystems [3]	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10
	Wetland losses [4]	47.95	48.21	48.47	48.73	48.99	49.24	49.48	49.73	49.98	50.24
	Bed losses [5]	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20
	Mooi River (net losses) [6]	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80
RETURN FLOWS:	Southern Gauteng (Rand Water)	-422.11	-426.03	-429.99	-433.99	-438.02	-442.10	-446.21	-450.37	-454.56	-458.80
	Midvaal Water Company	-0.91	-0.91	-0.91	-0.91	-0.91	-0.91	-0.91	-0.91	-0.91	-0.91
	Sedibeng Water	-1.90	-1.91	-1.92	-1.92	-1.93	-1.94	-1.95	-1.95	-1.96	-1.97
	Other towns and industries	-73.53	-74.25	-74.99	-75.73	-76.55	-77.36	-78.18	-79.01	-79.85	-80.72
	Irrigation [7]	-42.99	-42.99	-42.99	-42.99	-42.99	-42.99	-42.99	-42.99	-42.99	-42.99
	Mine dewatering	-127.54	-127.54	-127.54	-125.71	-125.71	-125.71	-125.71	-125.71	-125.71	-125.71
	Increased urban runoff	-114.78	-116.27	-117.80	-119.36	-120.97	-122.56	-124.20	-125.88	-127.61	-129.39
OVERALL GROSS SYSTEM DEMAND:		3913.19	3932.80	3951.68	3971.06	3989.25	4007.03	4027.28	4047.73	4068.37	4089.22
OVERALL NET SYSTEM DEMAND:		3129.44	3142.90	3155.55	3170.44	3182.17	3193.46	3207.13	3220.90	3234.77	3248.73

Notes :

(1): Rand Water's total raw water abstraction includes Sasolburg but excludes Authorised Users (i.e. ESKOM, ISCOR, Sasol Sasolburg , Mittal Steel and Small Users (Mining & Industrial)).
(2): Includes distribution losses within Vaalharts canal system and mainstream irrigation along Vaal River from Bloemhof Dam down to Douglas Weir.
(3): "Other irrigation" excludes diffuse irrigation
(4): Includes evaporation losses associated with wetlands as well as bed losses occuring within the Suikerbosrand and Klip rivers
(5): Vaal River bed losses include evaporation and operating losses associated with releases made from Bloemhof Dam
(6): Mooi River (Wonderfonteinspruit catchment) : Net effect of bed losses and decanting from dolomitic eyes resulting from WQT calibration
(7): Includes flow contribution resulting from the tailwater component at Erfenis Dam
(8): Includes DWAF 3rd Party Users
(9): It is assumed that Sasol's raw water requirements are not supplied through Rand Water, but that the projections of Rand Water include the potable water allocation of 6Ml/day.
(10): Represents Mittal Steel's total water requirements (i.e. includes the portion of the demand obtained from Rand Water)
(11): Represents portion of Rand Water's demand supplied by Magalies Water (drawn through the Vaalkop Scheme)

Table L-4: **Scenario I2 water demand and return flow projections for the Integrated Vaal River System as adopted for the Second Stage Vaal Reconciliation Strategy**
Based on Rand Water Scenario 2004 (2003 Questionnaire), Midvaal and Sedibeng Water April 2007 projections, Eskom April 2007 High Projections
Sasol Secunda Oct 2007 projections + Mafutha, 2006 projections for Sasol Sasolburg and Mittal Steel and the NWRS demand projections (Ratio Method) for smaller demand centres.

		Projected Demands and Return Flows (million m^3/a)														Extrapolated									
DESCRIPTION		**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
DEMANDS:	Rand Water [1]	1358.76	1397.00	1436.31	1475.51	1508.33	1541.33	1575.04	1609.48	1644.68	1677.28	1709.86	1743.06	1776.90	1811.40	1846.61	1882.52	1919.11	1956.41	1994.43	2033.19	2072.69	2112.96	2154.00	2195.84
	Magalies Water (Vaalkop Scheme) [11]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Mittal Steel [10]	17.17	16.98	16.80	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62
	ESKOM [8]	354.27	378.34	401.82	415.41	419.62	419.85	420.02	423.79	427.79	425.80	424.74	426.32	427.53	428.44	429.91	430.27	429.72	429.49	427.88	425.60	425.60	425.60	425.60	425.60
	SASOL Sasolburg (Raw water req) [9]	24.76	25.38	25.68	26.74	27.07	28.64	28.96	29.54	30.13	30.74	31.35	31.98	32.62	33.27	33.94	34.62	35.31	36.01	36.73	37.47	38.22	38.98	39.76	40.56
	SASOL Secunda	91.01	90.13	89.93	94.74	95.78	95.97	100.69	106.07	107.32	108.54	110.08	111.64	113.21	114.78	116.34	117.91	119.48	121.04	122.61	124.18	125.74	127.31	128.88	130.45
	Sasol Mafutha	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	40.00	40.00	40.00	40.00	40.00	80.00	80.00	80.00	80.00	80.00	80.00	80.00	80.00	80.00	80.00	80.00
	Midvaal Water Company	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00
	Sedibeng Water (Balkfontein only)	59.09	44.43	44.70	44.95	45.19	45.41	45.62	45.84	46.05	46.27	46.52	46.79	47.05	47.31	47.57	47.76	47.94	48.12	48.30	48.47	48.65	48.83	49.00	49.18
	Other towns and industries (Vaal)	168.07	183.89	184.51	185.12	185.76	186.40	187.05	187.69	188.33	188.39	188.45	188.51	188.57	188.63	188.73	188.83	188.92	189.02	189.11	189.30	189.49	189.67	189.86	190.04
	Other towns and industries(Zaai)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Vaalharts/Lower Vaal irrigation [2]	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53
	Diffuse Irrig and Aff (Vaal)	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31
	Diffuse Irrig and AFF (Sup systems)	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30
	Other irrigation in Vaal [3]	646.22	685.75	587.01	488.28	389.54	389.54	389.54	389.54	389.54	389.54	389.54	389.54	389.54	389.54	389.54	389.54	389.54	389.54	389.54	389.54	389.54	389.54	389.54	389.54
	Other irrigation in sup subsystems [3]	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10
	Wetland losses [4]	44.35	44.60	44.86	45.11	45.36	45.62	45.88	46.14	46.40	46.66	46.91	47.17	47.43	47.70	47.95	48.21	48.47	48.73	48.99	49.24	49.48	49.73	49.98	50.24
	Bed losses [5]	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20
	Mooi River (net losses) [6]	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80
RETURN FLOWS:	Southern Gauteng (Rand Water)	-346.97	-358.89	-371.22	-383.97	-392.83	-401.69	-410.75	-420.02	-429.49	-438.98	-448.51	-458.24	-468.18	-478.34	-487.12	-496.07	-505.18	-514.46	-523.91	-533.55	-543.36	-553.35	-563.52	-573.88
	Midvaal Water Company	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.91	-0.91	-0.91	-0.91	-0.91	-0.91	-0.91	-0.91	-0.91	-0.91	-0.91
	Sedibeng Water	-2.36	-1.78	-1.79	-1.80	-1.81	-1.82	-1.82	-1.83	-1.84	-1.85	-1.86	-1.87	-1.88	-1.89	-1.90	-1.91	-1.92	-1.92	-1.93	-1.94	-1.95	-1.95	-1.96	-1.97
	Other towns and industries	-62.64	-63.47	-63.97	-65.24	-65.80	-67.21	-67.77	-68.52	-69.43	-70.07	-70.71	-71.37	-72.03	-72.81	-73.53	-74.25	-74.99	-75.73	-76.55	-77.36	-78.18	-79.01	-79.85	-80.72
	Irrigation [7]	-67.59	-71.37	-61.91	-52.45	-42.99	-42.99	-42.99	-42.99	-42.99	-42.99	-42.99	-42.99	-42.99	-42.99	-42.99	-42.99	-42.99	-42.99	-42.99	-42.99	-42.99	-42.99	-42.99	-42.99
	Mine dewatering	-116.31	-114.02	-111.74	-109.46	-109.01	-108.55	-108.55	-117.68	-125.71	-127.54	-127.54	-127.54	-127.54	-127.54	-127.54	-127.54	-127.54	-125.71	-125.71	-125.71	-125.71	-125.71	-125.71	-125.71
	Increased urban runoff	-101.49	-102.06	-102.64	-103.24	-103.86	-104.49	-105.14	-105.82	-106.51	-107.81	-109.14	-110.50	-111.89	-113.32	-114.78	-116.27	-117.80	-119.36	-120.97	-122.56	-124.20	-125.88	-127.61	-129.39
OVERALL GROSS SYSTEM DEMAND:		3727.94	3830.75	3795.86	3756.71	3697.51	3733.61	3773.65	3818.95	3901.10	3934.08	3968.31	4005.87	4043.71	4121.92	4161.45	4200.50	4239.34	4279.22	4318.46	4357.84	4400.27	4443.48	4487.48	4532.30
OVERALL NET SYSTEM DEMAND:		3029.69	3118.26	3081.69	3039.65	2980.32	3005.95	3035.72	3061.20	3124.22	3143.93	3166.65	3192.46	3218.29	3284.13	3312.69	3340.57	3368.02	3398.13	3425.48	3452.82	3482.98	3513.68	3544.93	3576.72

Notes :

(1): Rand Water's total raw water abstraction includes Sasolburg but excludes Authorised Users (i.e. ESKOM, ISCOR, Sasol Sasolburg , Mittal Steel and Small Users (Mining & Industrial)).
(2): Includes distribution losses within Vaalharts canal system and mainstream irrigation along Vaal River from Bloemhof Dam down to Douglas Weir.
(3): "Other irrigation" excludes diffuse irrigation
(4): Includes evaporation losses associated with wetlands as well as bed losses occuring within the Suikerbosrand and Klip rivers
(5): Vaal River bed losses include evaporation and operating losses associated with releases made from Bloemhof Dam
(6): Mooi River (Wonderfonteinspruit catchment) : Net effect of bed losses and decanting from dolomitic eyes resulting from WQT calibration
(7): Includes flow contribution resulting from the tailwater component at Erfenis Dam
(8): Includes DWAF 3rd Party Users
(9): It is assumed that Sasol's raw water requirements are not supplied through Rand Water, but that the projections of Rand Water include the potable water allocation of 6Ml/day.
(10): Represents Mittal Steel's total water requirements (i.e. includes the portion of the demand obtained from Rand Water)
(11): Represents portion of Rand Water's demand supplied by Magalies Water (drawn through the Vaalkop Scheme)

Table L-5: **Scenario E2 water demand and return flow projections for the Integrated Vaal River System as adopted for the Second Stage Vaal Reconciliation Strategy**
Based on Rand Water Scenario E (DWAF High Demographics projections including 10yr loss Management Program), Midvaal and Sedibeng Water April 2007 projections, Eskom April 2007 Base Dem Proj
Sasol Secunda Oct 2007 projections, 2006 projections for Sasol Sasolburg and Mittal Steel and the NWRS demand projections (Ratio Method) for smaller demand centres.

DESCRIPTION		Projected Demands and Return Flows (million m^3/a)													
		2007	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
DEMANDS:	Rand Water [1]	1284.55	1283.32	1282.35	1280.42	1288.30	1296.56	1304.94	1313.46	1322.11	1335.27	1348.57	1362.02	1375.61	1389.35
	Magalies Water (Vaalkop Scheme) [11]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Mittal Steel [10]	17.17	16.98	16.80	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62
	ESKOM [8]	354.21	377.55	397.88	407.60	411.48	411.04	410.95	414.03	417.42	414.67	412.74	413.65	414.44	414.97
	SASOL Sasolburg (Raw water req) [9]	24.76	25.38	25.68	26.74	27.07	28.64	28.96	29.54	30.13	30.74	31.35	31.98	32.62	33.27
	SASOL Secunda	91.01	90.13	89.93	94.74	95.78	95.97	100.69	106.07	107.32	108.54	110.08	111.64	113.21	114.78
	Midvaal Water Company	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00
	Sedibeng Water (Balkfontein only)	59.09	44.43	44.70	44.95	45.19	45.41	45.62	45.84	46.05	46.27	46.52	46.79	47.05	47.31
	Other towns and industries (Vaal)	168.07	183.89	184.51	185.12	185.76	186.40	187.05	187.69	188.33	188.39	188.45	188.51	188.57	188.63
	Other towns and industries(Zaai)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Vaalharts/Lower Vaal irrigation [2]	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53
	Diffuse Irrig and Aff (Vaal)	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31
	Diffuse Irrig and AFF (Sup systems)	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30
	Other irrigation in Vaal [3]	646.22	685.75	587.01	488.28	389.54	389.54	389.54	389.54	389.54	389.54	389.54	389.54	389.54	389.54
	Other irrigation in sup subsystems [3]	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10
	Wetland losses [4]	44.35	44.60	44.86	45.11	45.36	45.62	45.88	46.14	46.40	46.66	46.91	47.17	47.43	47.70
	Bed losses [5]	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20
	Mooi River (net losses) [6]	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80
RETURN FLOWS:	Southern Gauteng (Rand Water)	-324.27	-321.93	-319.66	-317.45	-317.96	-318.49	-319.04	-319.60	-320.19	-324.19	-328.26	-332.37	-336.54	-340.76
	Midvaal Water Company	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.91
	Sedibeng Water	-2.36	-1.78	-1.79	-1.80	-1.81	-1.82	-1.82	-1.83	-1.84	-1.85	-1.86	-1.87	-1.88	-1.89
	Other towns and industries	-62.64	-63.47	-63.97	-65.24	-65.80	-67.21	-67.77	-68.52	-69.43	-70.07	-70.71	-71.37	-72.03	-72.81
	Irrigation [7]	-67.59	-71.37	-61.91	-52.45	-42.99	-42.99	-42.99	-42.99	-42.99	-42.99	-42.99	-42.99	-42.99	-42.99
	Mine dewatering	-116.31	-114.02	-111.74	-109.46	-109.01	-108.55	-108.55	-117.68	-125.71	-127.54	-127.54	-127.54	-127.54	-127.54
	Increased urban runoff	-101.49	-102.06	-102.64	-103.24	-103.86	-104.49	-105.14	-105.82	-106.51	-107.81	-109.14	-110.50	-111.89	-113.32
OVERALL GROSS SYSTEM DEMAND:		3653.68	3716.28	3637.96	3553.81	3469.33	3480.03	3494.49	3513.16	3528.17	3540.93	3555.03	3572.16	3589.33	3606.41
OVERALL NET SYSTEM DEMAND:		2978.13	3040.76	2975.35	2903.27	2827.02	2835.57	2848.27	2855.82	2860.60	2865.57	2873.62	2884.61	2895.55	2906.19

DESCRIPTION		Extrapolated									
		2021	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
DEMANDS:	Rand Water [1]	1403.07	1416.93	1430.92	1445.06	1459.34	1476.12	1493.10	1510.28	1527.65	1545.23
	Magalies Water (Vaalkop Scheme) [11]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Mittal Steel [10]	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62
	ESKOM [8]	415.95	416.02	415.47	415.24	413.64	411.35	411.35	411.35	411.35	411.35
	SASOL Sasolburg (Raw water req) [9]	33.94	34.62	35.31	36.01	36.73	37.47	38.22	38.98	39.76	40.56
	SASOL Secunda	116.34	117.91	119.48	121.04	122.61	124.18	125.74	127.31	128.88	130.45
	Midvaal Water Company	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00
	Sedibeng Water (Balkfontein only)	47.57	47.76	47.94	48.12	48.30	48.47	48.65	48.83	49.00	49.18
	Other towns and industries (Vaal)	188.73	188.83	188.92	189.02	189.11	189.30	189.49	189.67	189.86	190.04
	Other towns and industries(Zaai)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Vaalharts/Lower Vaal irrigation [2]	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53
	Diffuse Irrig and Aff (Vaal)	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31
	Diffuse Irrig and AFF (Sup systems)	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30
	Other irrigation in Vaal [3]	389.54	389.54	389.54	389.54	389.54	389.54	389.54	389.54	389.54	389.54
	Other irrigation in sup subsystems [3]	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10
	Wetland losses [4]	47.95	48.21	48.47	48.73	48.99	49.24	49.48	49.73	49.98	50.24
	Bed losses [5]	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20
	Mooi River (net losses) [6]	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80
RETURN FLOWS:	Southern Gauteng (Rand Water)	-343.38	-346.02	-348.68	-351.37	-354.08	-356.97	-359.88	-362.83	-365.80	-368.80
	Midvaal Water Company	-0.91	-0.91	-0.91	-0.91	-0.91	-0.91	-0.91	-0.91	-0.91	-0.91
	Sedibeng Water	-1.90	-1.91	-1.92	-1.92	-1.93	-1.94	-1.95	-1.95	-1.96	-1.97
	Other towns and industries	-73.53	-74.25	-74.99	-75.73	-76.55	-77.36	-78.18	-79.01	-79.85	-80.72
	Irrigation [7]	-42.99	-42.99	-42.99	-42.99	-42.99	-42.99	-42.99	-42.99	-42.99	-42.99
	Mine dewatering	-127.54	-127.54	-127.54	-125.71	-125.71	-125.71	-125.71	-125.71	-125.71	-125.71
	Increased urban runoff	-114.78	-116.27	-117.80	-119.36	-120.97	-122.56	-124.20	-125.88	-127.61	-129.39
OVERALL GROSS SYSTEM DEMAND:		3623.95	3640.67	3656.91	3673.62	3689.12	3706.53	3726.44	3746.56	3766.89	3787.44
OVERALL NET SYSTEM DEMAND:		2918.93	2930.78	2942.08	2955.62	2965.97	2978.09	2992.62	3007.27	3022.05	3036.95

Notes :

(1): Rand Water's total raw water abstraction includes Sasolburg but excludes Authorised Users (i.e. ESKOM, ISCOR, Sasol Sasolburg , Mittal Steel and Small Users (Mining & Industrial)).
(2): Includes distribution losses within Vaalharts canal system and mainstream irrigation along Vaal River from Bloemhof Dam down to Douglas Weir.
(3): "Other irrigation" excludes diffuse irrigation
(4): Includes evaporation losses associated with wetlands as well as bed losses occuring within the Suikerbosrand and Klip rivers
(5): Vaal River bed losses include evaporation and operating losses associated with releases made from Bloemhof Dam
(6): Mooi River (Wonderfonteinspruit catchment) : Net effect of bed losses and decanting from dolomitic eyes resulting from WQT calibration
(7): Includes flow contribution resulting from the tailwater component at Erfenis Dam
(8): Includes DWAF 3rd Party Users
(9): It is assumed that Sasol's raw water requirements are not supplied through Rand Water, but that the projections of Rand Water include the potable water allocation of 6Ml/day.
(10): Represents Mittal Steel's total water requirements (i.e. includes the portion of the demand obtained from Rand Water)
(11): Represents portion of Rand Water's demand supplied by Magalies Water (drawn through the Vaalkop Scheme)

Table L-6: **Scenario J water demand and return flow projections for the Integrated Vaal River System as adopted for the Second Stage Vaal Reconciliation Strategy:Trading of water rights**
Based on Rand Water Scenario B (DWAF High Demographics projections excluding WDM), Midvaal and Sedibeng Water April 2007 projections, Eskom April 2007 Base Demand Projections
Sasol Secunda Oct 2007 projections, 2006 projections for Sasol Sasolburg and Mittal Steel and the NWRS demand projections (Ratio Method) for smaller demand centres.

		Projected Demands and Return Flows (million m^3/a)														Extrapolated									
DESCRIPTION		**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
DEMANDS:	Rand Water [1]	1338.61	1355.92	1373.50	1390.12	1410.94	1432.32	1454.03	1476.08	1498.47	1514.81	1531.34	1548.05	1564.96	1582.06	1598.35	1614.81	1631.44	1648.25	1665.23	1682.37	1699.70	1717.20	1734.89	1752.76
	Magalies Water (Vaalkop Scheme) [11]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Mittal Steel [10]	17.17	16.98	16.80	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62
	ESKOM [8]	354.21	377.55	397.88	407.60	411.48	411.04	410.95	414.03	417.42	414.67	412.74	413.65	414.44	414.97	415.95	416.02	415.47	415.24	413.64	411.35	411.35	411.35	411.35	411.35
	SASOL Sasolburg (Raw water req) [9]	24.76	25.38	25.68	26.74	27.07	28.64	28.96	29.54	30.13	30.74	31.35	31.98	32.62	33.27	33.94	34.62	35.31	36.01	36.73	37.47	38.22	38.98	39.76	40.56
	SASOL Secunda	91.01	90.13	89.93	94.74	95.78	95.97	100.69	106.07	107.32	108.54	110.08	111.64	113.21	114.78	116.34	117.91	119.48	121.04	122.61	124.18	125.74	127.31	128.88	130.45
	Midvaal Water Company	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00
	Sedibeng Water (Balkfontein only)	59.09	44.43	44.70	44.95	45.19	45.41	45.62	45.84	46.05	46.27	46.52	46.79	47.05	47.31	47.57	47.76	47.94	48.12	48.30	48.47	48.65	48.83	49.00	49.18
	Other towns and industries (Vaal)	168.07	183.89	184.51	185.12	185.76	186.40	187.05	187.69	188.33	188.39	188.45	188.51	188.57	188.63	188.73	188.83	188.92	189.02	189.11	189.30	189.49	189.67	189.86	190.04
	Other towns and industries(Zaai)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Vaalharts/Lower Vaal irrigation [2]	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53	541.53
	Diffuse Irrig and Aff (Vaal)	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31
	Diffuse Irrig and AFF (Sup systems)	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30	68.30
	Other irrigation in Vaal [3]	646.22	653.94	523.39	392.85	294.11	294.11	294.11	294.11	294.11	294.11	294.11	294.11	294.11	294.11	294.11	294.11	294.11	294.11	294.11	294.11	294.11	294.11	294.11	294.11
	Other irrigation in sup subsystems [3]	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10	25.10
	Wetland losses [4]	44.35	44.60	44.86	45.11	45.36	45.62	45.88	46.14	46.40	46.66	46.91	47.17	47.43	47.70	47.95	48.21	48.47	48.73	48.99	49.24	49.48	49.73	49.98	50.24
	Bed losses [5]	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20	267.20
	Mooi River (net losses) [6]	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80	13.80
RETURN FLOWS:	Southern Gauteng (Rand Water)	-341.87	-348.43	-355.13	-361.95	-367.69	-373.53	-379.46	-385.49	-391.63	-396.80	-402.05	-407.37	-412.76	-418.23	-422.11	-426.03	-429.99	-433.99	-438.02	-442.10	-446.21	-450.37	-454.56	-458.80
	Midvaal Water Company	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.91	-0.91	-0.91	-0.91	-0.91	-0.91	-0.91	-0.91	-0.91	-0.91	-0.91
	Sedibeng Water	-2.36	-1.78	-1.79	-1.80	-1.81	-1.82	-1.82	-1.83	-1.84	-1.85	-1.86	-1.87	-1.88	-1.89	-1.90	-1.91	-1.92	-1.92	-1.93	-1.94	-1.95	-1.95	-1.96	-1.97
	Other towns and industries	-62.64	-63.47	-63.97	-65.24	-65.80	-67.21	-67.77	-68.52	-69.43	-70.07	-70.71	-71.37	-72.03	-72.81	-73.53	-74.25	-74.99	-75.73	-76.55	-77.36	-78.18	-79.01	-79.85	-80.72
	Irrigation [7]	-67.59	-64.28	-47.72	-31.16	-21.70	-21.70	-21.70	-21.70	-21.70	-21.70	-21.70	-21.70	-21.70	-21.70	-21.70	-21.70	-21.70	-21.70	-21.70	-21.70	-21.70	-21.70	-21.70	-21.70
	Mine dewatering	-116.31	-114.02	-111.74	-109.46	-109.01	-108.55	-108.55	-117.68	-125.71	-127.54	-127.54	-127.54	-127.54	-127.54	-127.54	-127.54	-127.54	-125.71	-125.71	-125.71	-125.71	-125.71	-125.71	-125.71
	Increased urban runoff	-101.49	-102.06	-102.64	-103.24	-103.86	-104.49	-105.14	-105.82	-106.51	-107.81	-109.14	-110.50	-111.89	-113.32	-114.78	-116.27	-117.80	-119.36	-120.97	-122.56	-124.20	-125.88	-127.61	-129.39
OVERALL GROSS SYSTEM DEMAND:		3707.74	3757.08	3665.49	3568.08	3496.54	3520.36	3548.15	3580.35	3609.10	3625.04	3642.36	3662.76	3683.25	3703.69	3723.80	3743.12	3762.00	3781.38	3799.58	3817.35	3837.60	3858.05	3878.70	3899.55
OVERALL NET SYSTEM DEMAND:		3014.58	3062.15	2981.61	2894.33	2825.78	2842.16	2862.80	2878.41	2891.38	2898.36	2908.45	2921.51	2934.53	2947.29	2961.34	2974.51	2987.16	3002.05	3013.79	3025.07	3038.74	3052.51	3066.39	3080.35

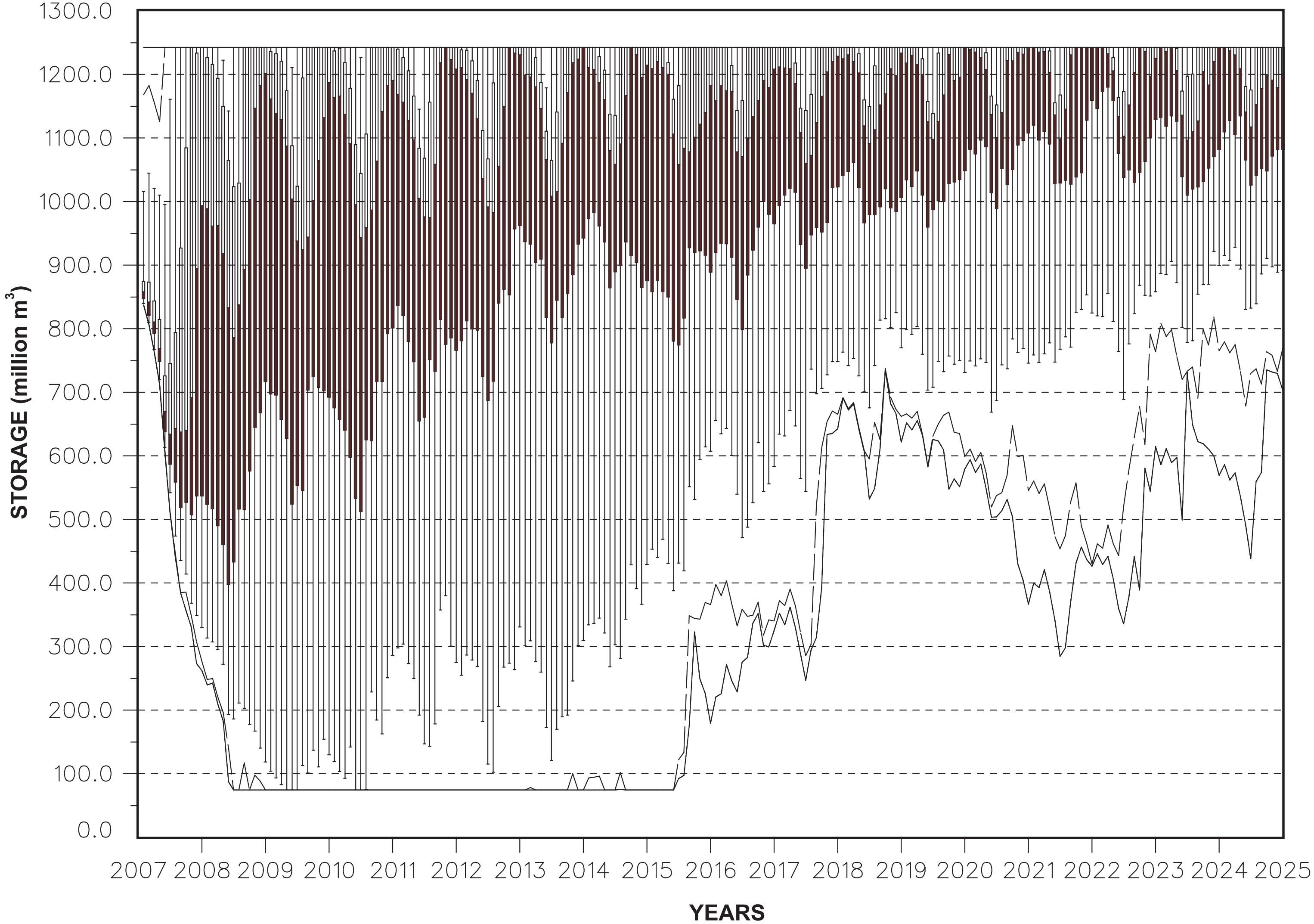
Purchase irrigation water rights upstream of Vaal Dam:		**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
	Irrigation demands bought out:	0.00	31.81	63.62	95.43	95.43	95.43	95.43	95.43	95.43	95.43	95.43	95.43	95.43	95.43	95.43	95.43	95.43	95.43	95.43	95.43	95.43	95.43	95.43	95.43
	Irrigation Return Flows terminated:	0.00	-7.10	-14.19	-21.29	-21.29	-21.29	-21.29	-21.29	-21.29	-21.29	-21.29	-21.29	-21.29	-21.29	-21.29	-21.29	-21.29	-21.29	-21.29	-21.29	-21.29	-21.29	-21.29	-21.29
Net effect of irrigation demands bought out:		0.00	24.71	49.43	74.14	74.14	74.14	74.14	74.14	74.14	74.14	74.14	74.14	74.14	74.14	74.14	74.14	74.14	74.14	74.14	74.14	74.14	74.14	74.14	74.14

Notes :

(1): Rand Water's total raw water abstraction includes Sasolburg but excludes Authorised Users (i.e. ESKOM, ISCOR, Sasol Sasolburg , Mittal Steel and Small Users (Mining & Industrial)).
(2): Includes distribution losses within Vaalharts canal system and mainstream irrigation along Vaal River from Bloemhof Dam down to Douglas Weir.
(3): "Other irrigation" excludes diffuse irrigation
(4): Includes evaporation losses associated with wetlands as well as bed losses occuring within the Suikerbosrand and Klip rivers
(5): Vaal River bed losses include evaporation and operating losses associated with releases made from Bloemhof Dam
(6): Mooi River (Wonderfonteinspruit catchment) : Net effect of bed losses and decanting from dolomitic eyes resulting from WQT calibration
(7): Includes flow contribution resulting from the tailwater component at Erfenis Dam
(8): Includes DWAF 3rd Party Users
(9): It is assumed that Sasol's raw water requirements are not supplied through Rand Water, but that the projections of Rand Water include the potable water allocation of 6Ml/day.
(10): Represents Mittal Steel's total water requirements (i.e. includes the portion of the demand obtained from Rand Water)
(11): Represents portion of Rand Water's demand supplied by Magalies Water (drawn through the Vaalkop Scheme)

Appendix M

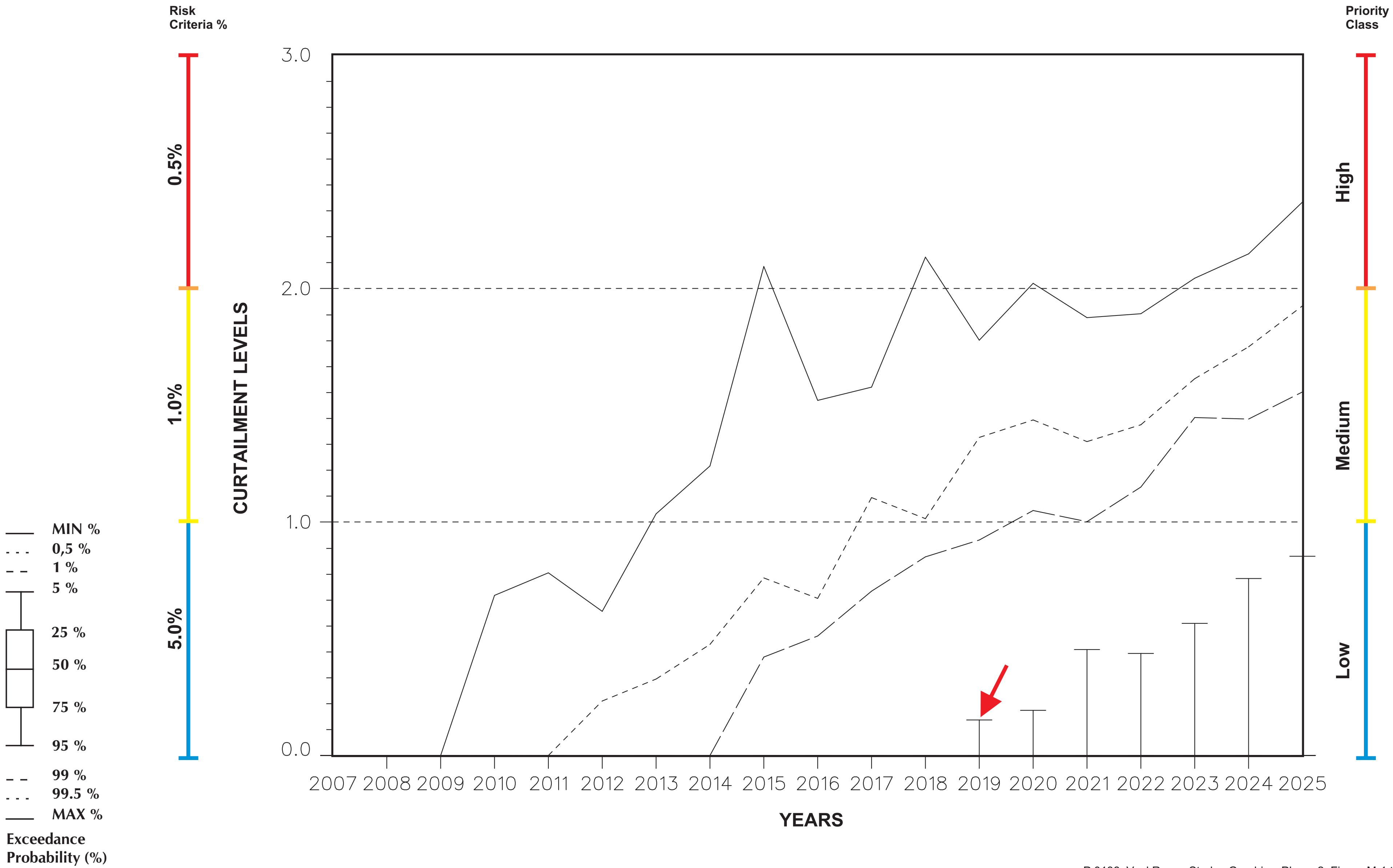
Graphical results: Scenario 1a



P 0138_Vaal Recon.Study_ Graphics_Phase 2_Figure M-1 to M-12.cdr

Scenario 1a: Bloemhof Dam (Excluding excess support)

M-1



P 0138_Vaal Recon.Study_ Graphics_Phase 2_Figure M-1 to M-12.cdr

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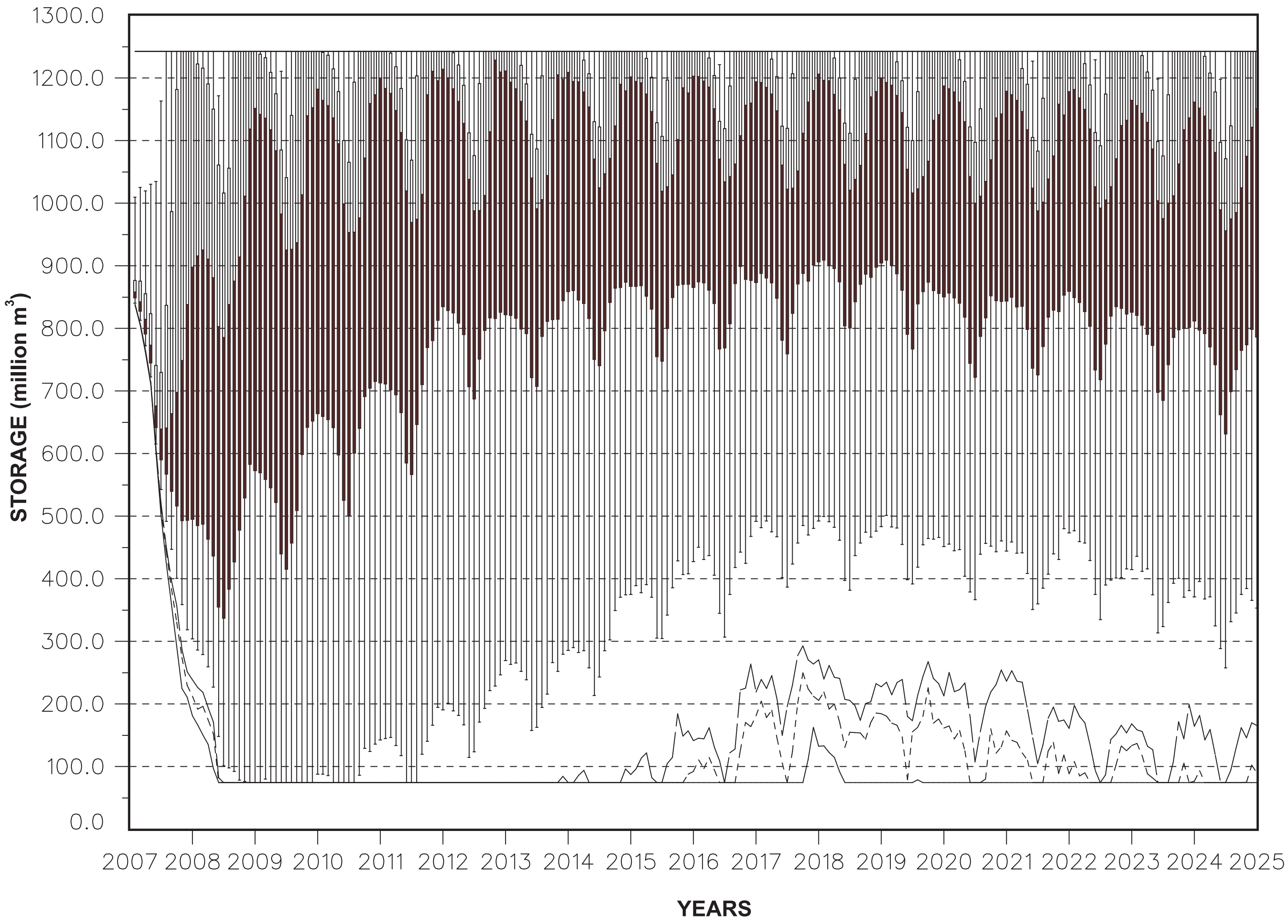
VAAL RIVER SYSTEM: LARGE BULK WATER
SUPPLY RECONCILIATION STRATEGIES AND
WATER CONSERVATION AND DEMAND MANAGEMENT

Scenario 1a: Curtailment Levels (Excluding LHFP)

M-2



P 0138_Vaal Recon.Study_ Graphics_Phase 2_Figure M-1 to M-12.cdr

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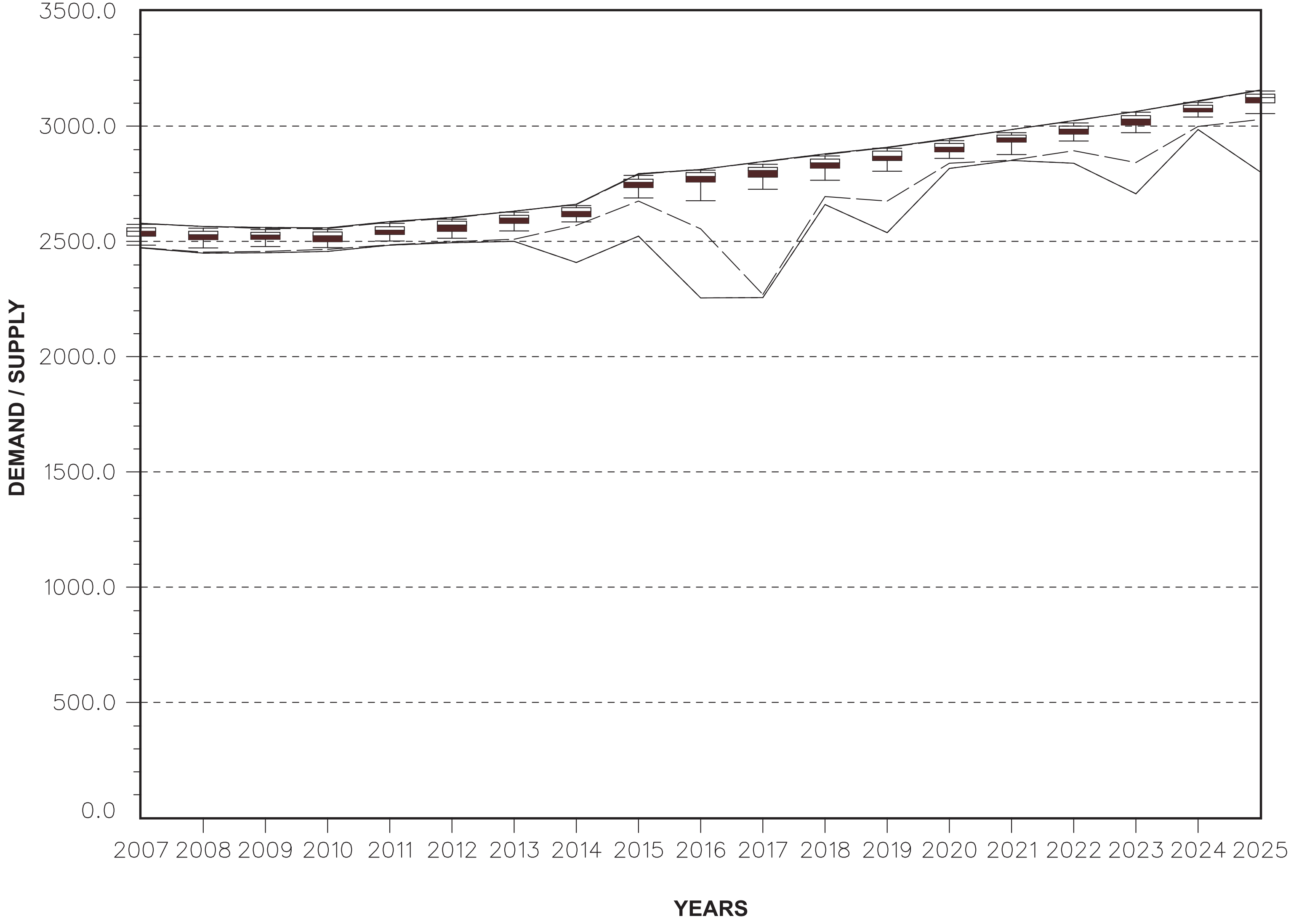
VAAL RIVER SYSTEM: LARGE BULK WATER SUPPLY RECONCILIATION STRATEGIES AND WATER CONSERVATION AND DEMAND MANAGEMENT

Scenario 1a: Bloemhof Dam (Including excess support)

M-3



P 0138_Vaal Recon.Study_ Graphics_Phase 2_Figure M-1 to M-12.cdr

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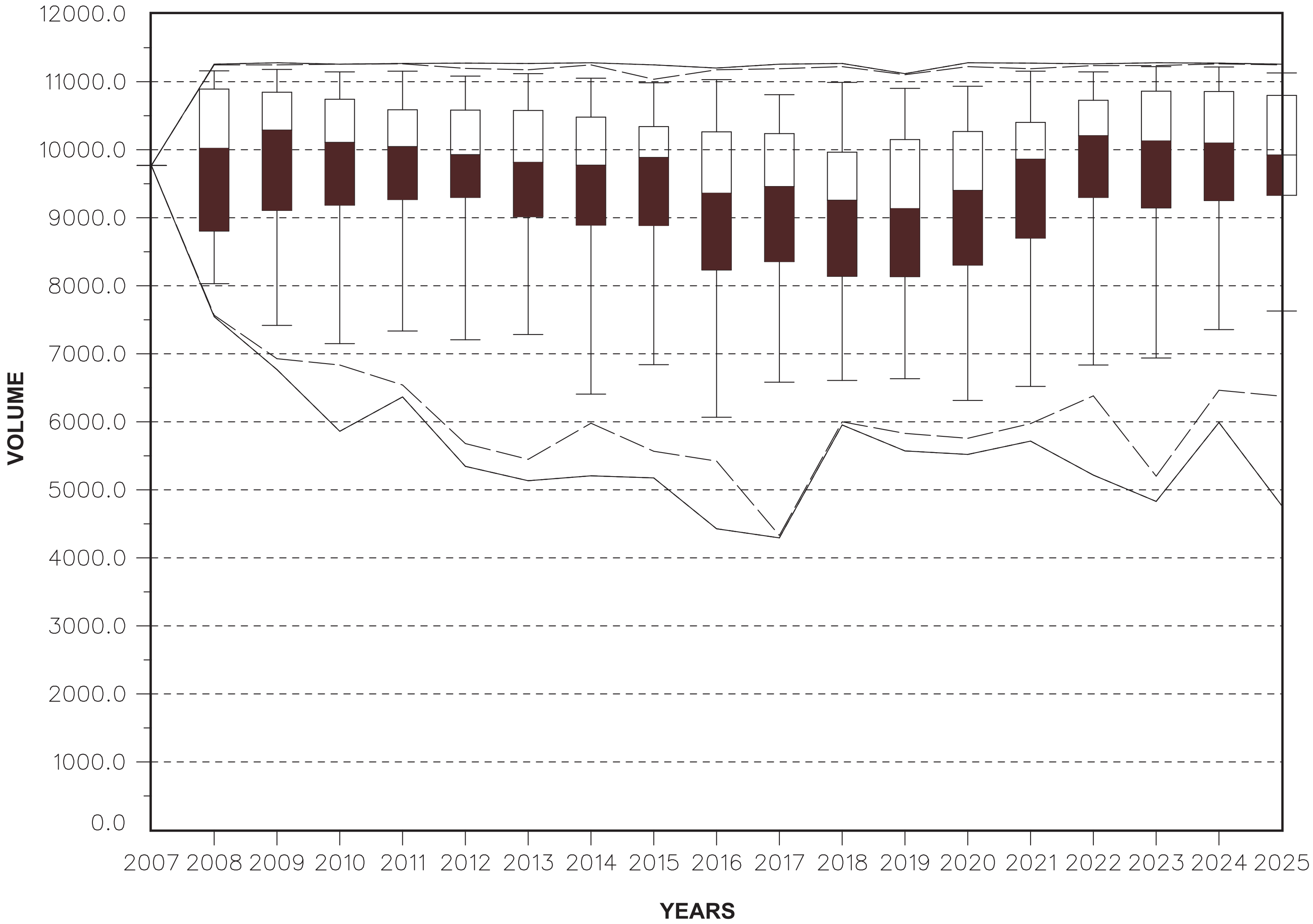
VAAL RIVER SYSTEM: LARGE BULK WATER
SUPPLY RECONCILIATION STRATEGIES AND
WATER CONSERVATION AND DEMAND MANAGEMENT

Scenario 1a: Demand / Supply

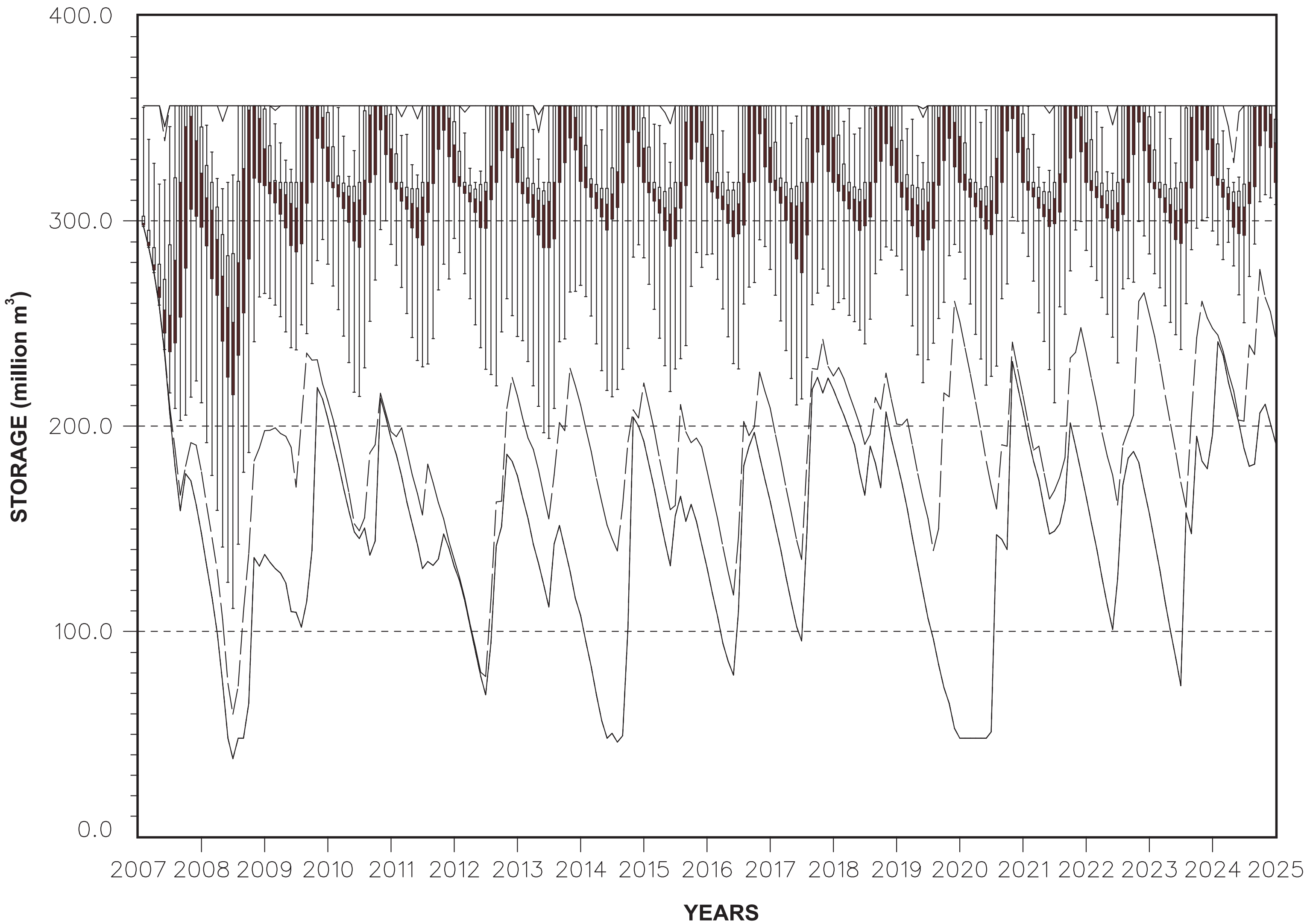
M-4



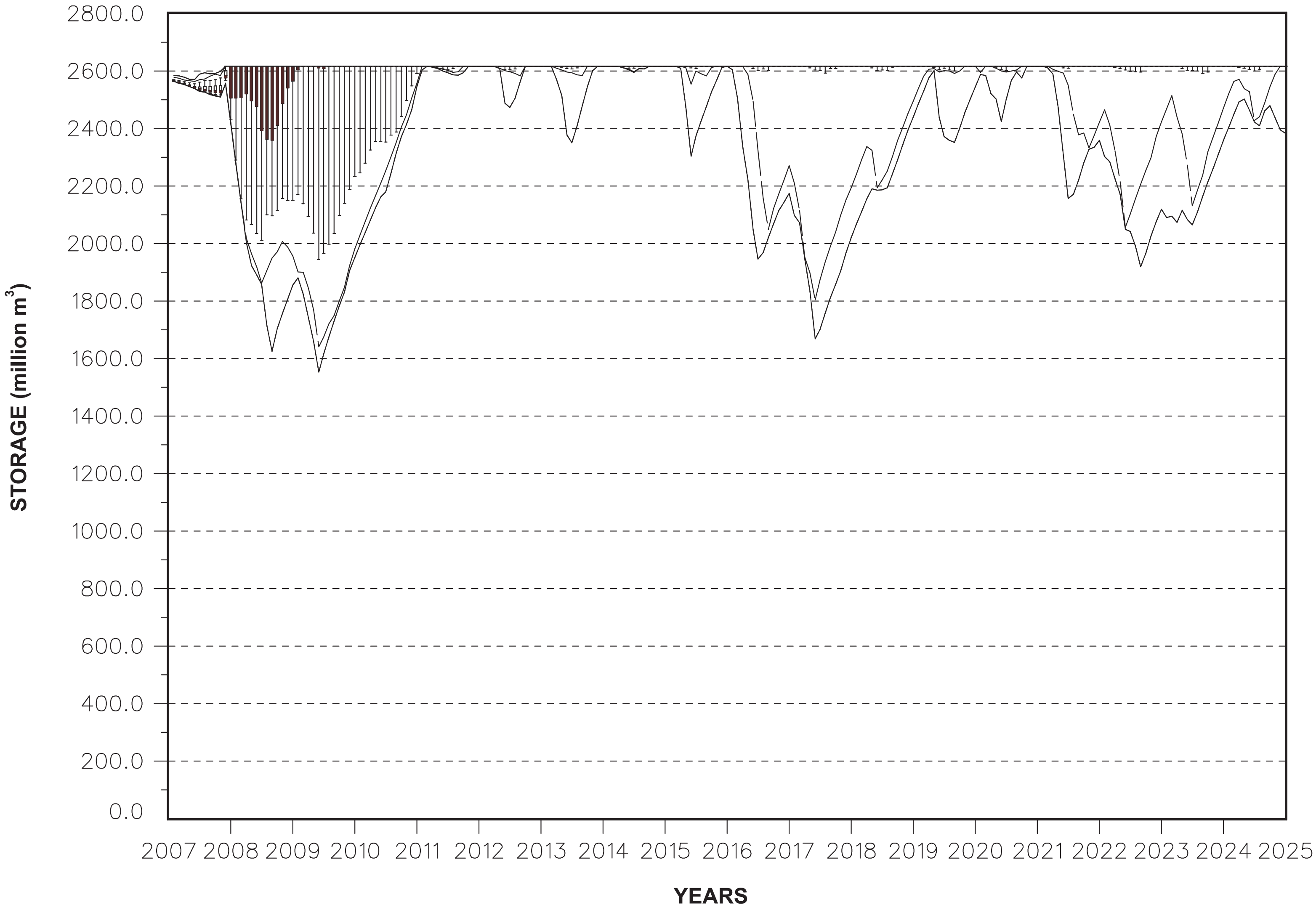
P 0138_Vaal Recon.Study_ Graphics_Phase 2_Figure M-1 to M-12.cdr

Scenario 1a: Total System Volume

M-5



P 0138_Vaal Recon.Study_ Graphics_Phase 2_Figure M-1 to M-12.cdr



P 0138_Vaal Recon.Study_ Graphics_Phase 2_Figure M-1 to M-12.cdr

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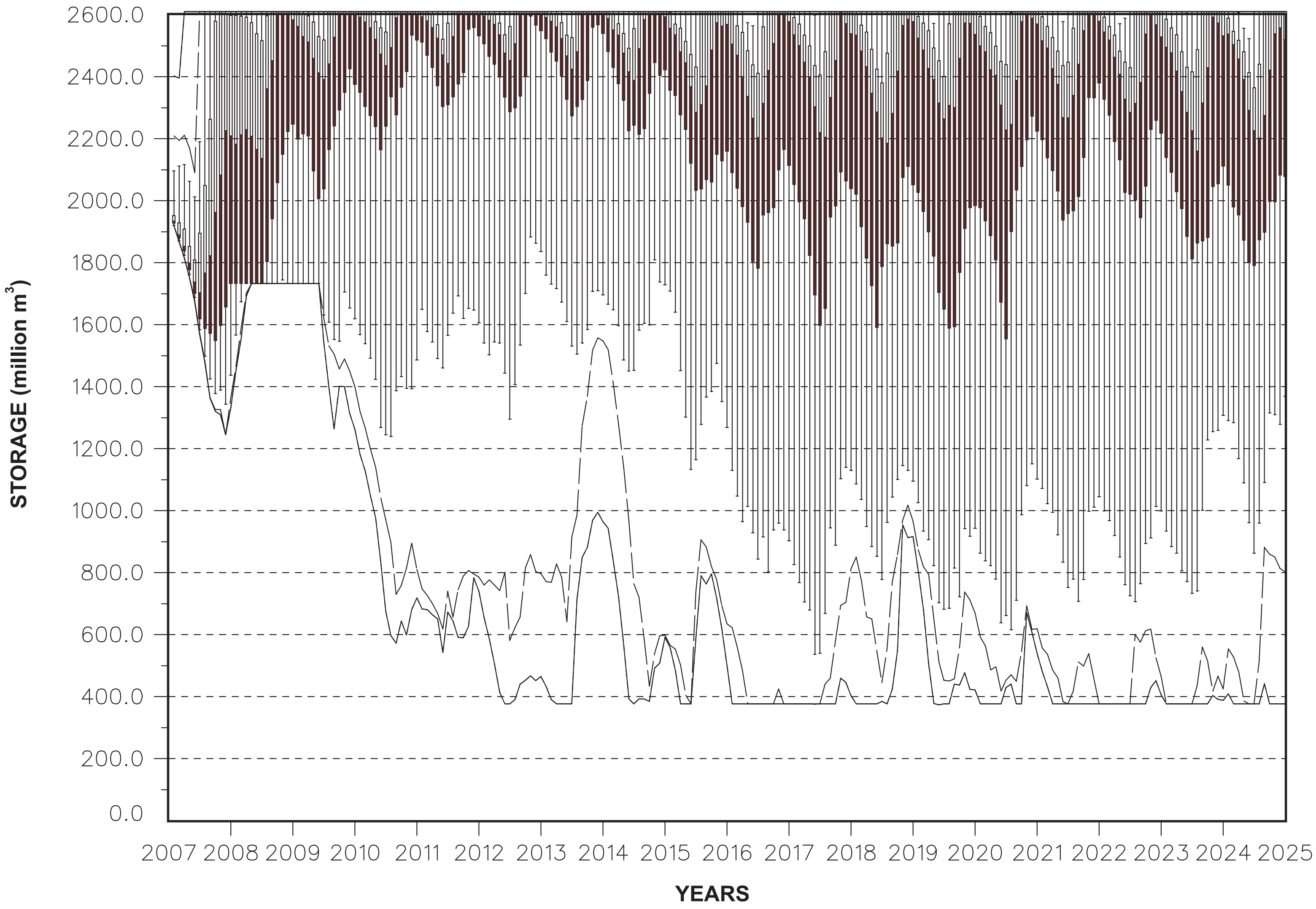
VAAL RIVER SYSTEM: LARGE BULK WATER SUPPLY RECONCILIATION STRATEGIES AND WATER CONSERVATION AND DEMAND MANAGEMENT

Scenario 1a: Sterkfontein Dam

M-7



P 0138_Vaal Recon.Study_ Graphics_Phase 2_Figure M-1 to M-12.cdr

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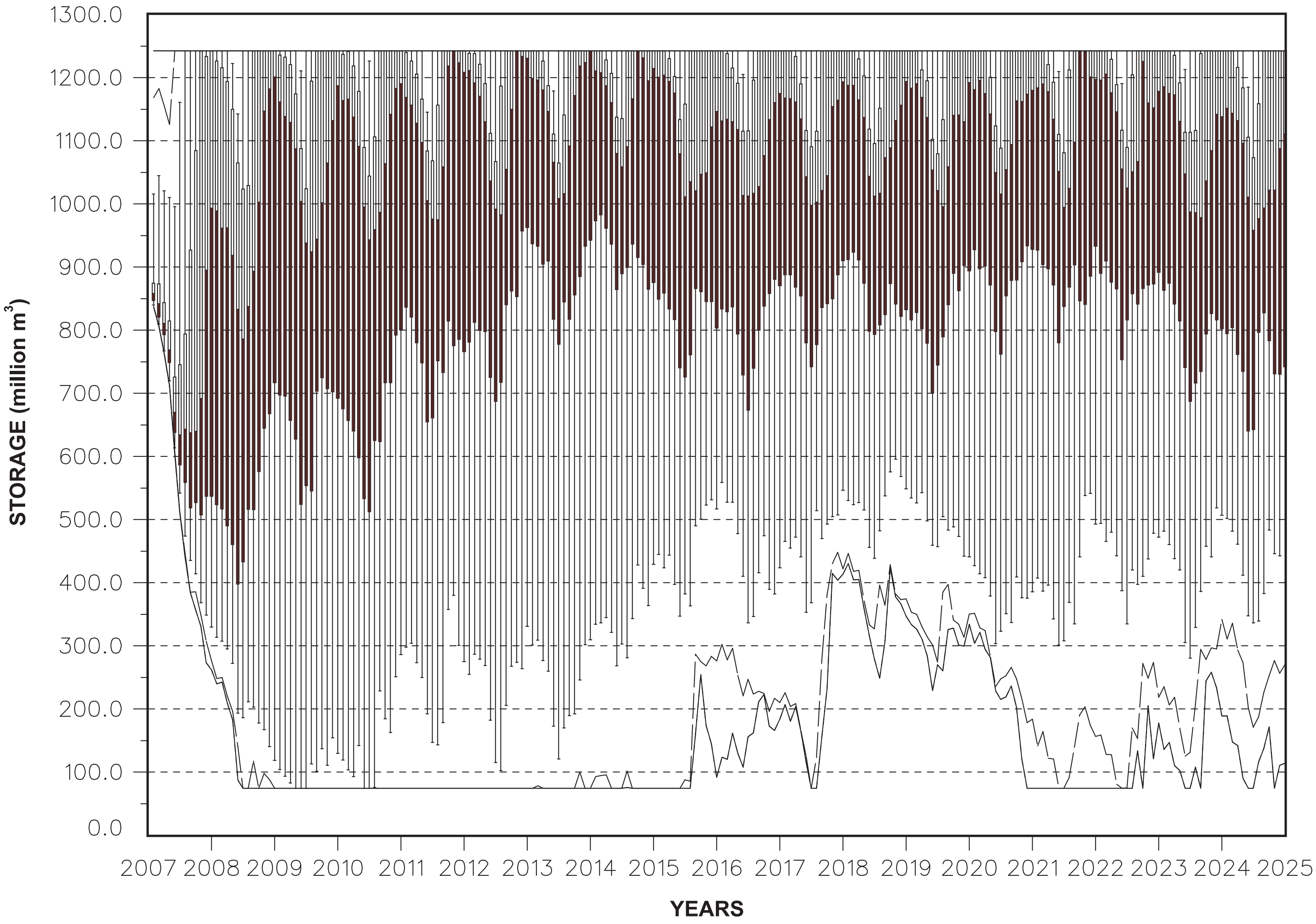
VAAL RIVER SYSTEM: LARGE BULK WATER SUPPLY RECONCILIATION STRATEGIES AND WATER CONSERVATION AND DEMAND MANAGEMENT

Scenario 1a: Vaal Dam

M-8



P 0138_Vaal Recon.Study_ Graphics_Phase 2_Figure M-1 to M-12.cdr

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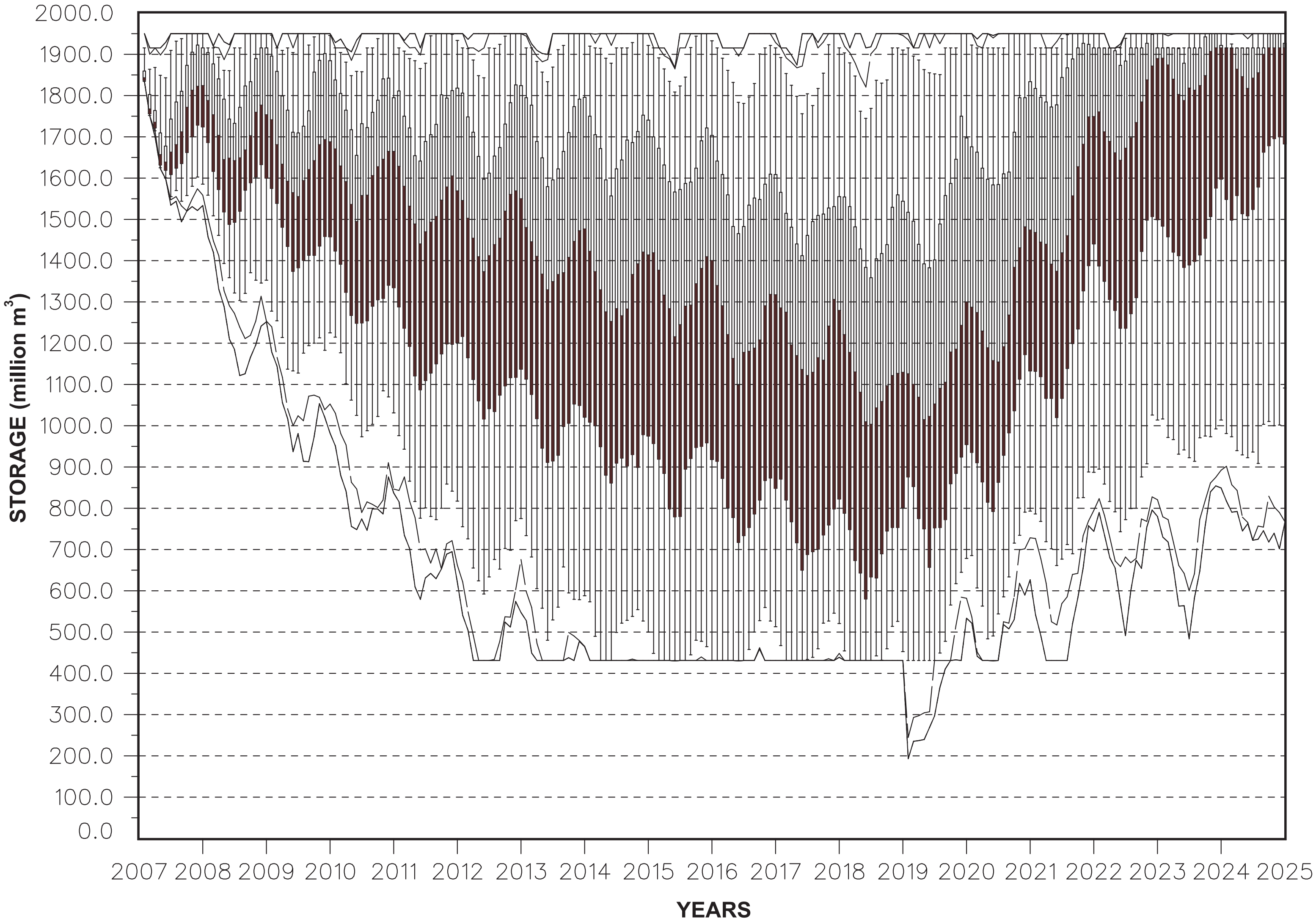
VAAL RIVER SYSTEM: LARGE BULK WATER
SUPPLY RECONCILIATION STRATEGIES AND
WATER CONSERVATION AND DEMAND MANAGEMENT

Scenario 1a: Bloemhof Dam

M-9



P 0138_Vaal Recon.Study_ Graphics_Phase 2_Figure M-1 to M-12.cdr

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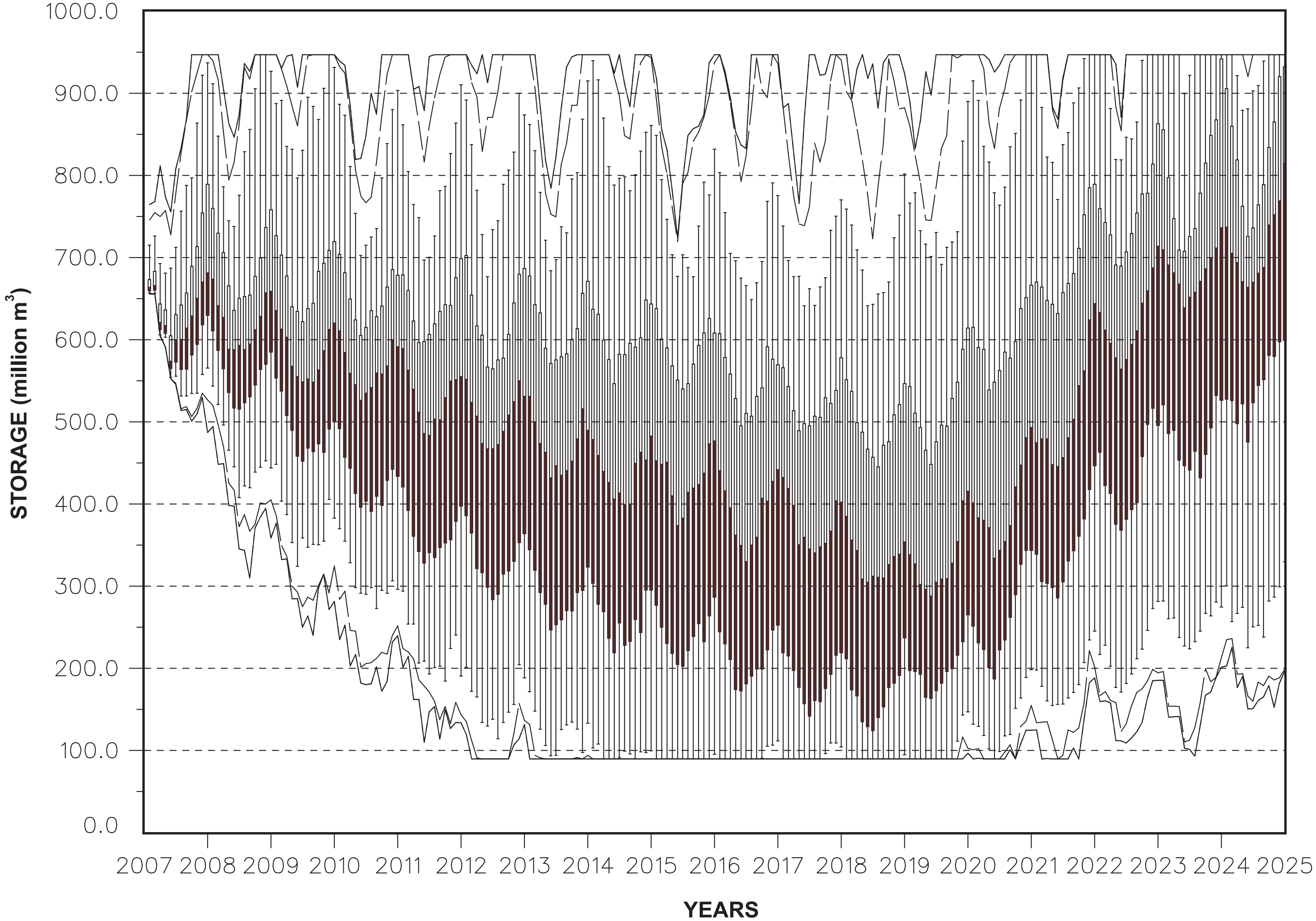
VAAL RIVER SYSTEM: LARGE BULK WATER SUPPLY RECONCILIATION STRATEGIES AND WATER CONSERVATION AND DEMAND MANAGEMENT

Scenario 1a: Katse Dam

M-10



P 0138_Vaal Recon.Study_ Graphics_Phase 2_Figure M-1 to M-12.cdr

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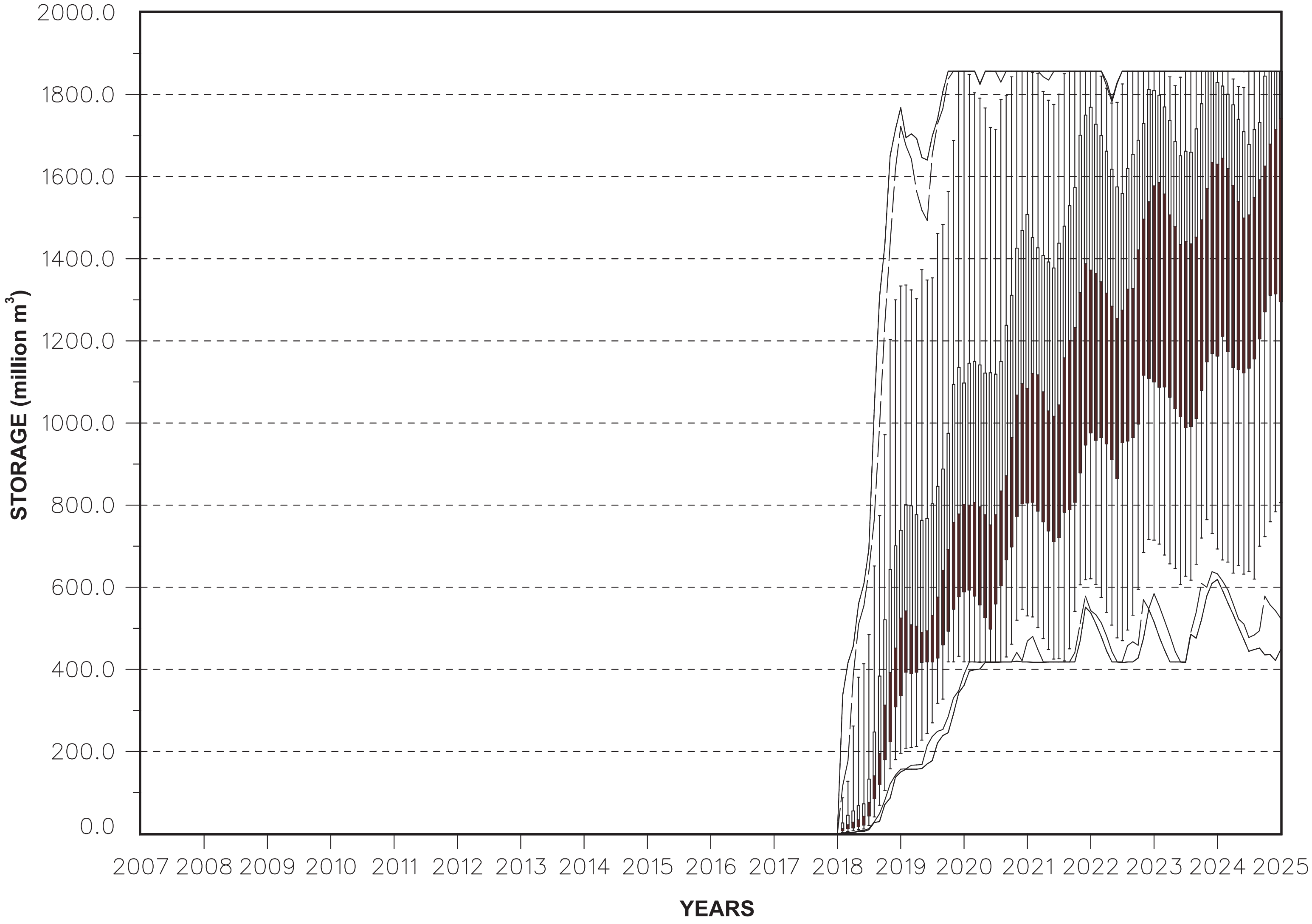
VAAL RIVER SYSTEM: LARGE BULK WATER SUPPLY RECONCILIATION STRATEGIES AND WATER CONSERVATION AND DEMAND MANAGEMENT

Scenario 1a: Mohale Dam

M-11



P 0138_Vaal Recon.Study_ Graphics_Phase 2_Figure M-1 to M-12.cdr

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VAAL RIVER SYSTEM: LARGE BULK WATER SUPPLY RECONCILIATION STRATEGIES AND WATER CONSERVATION AND DEMAND MANAGEMENT

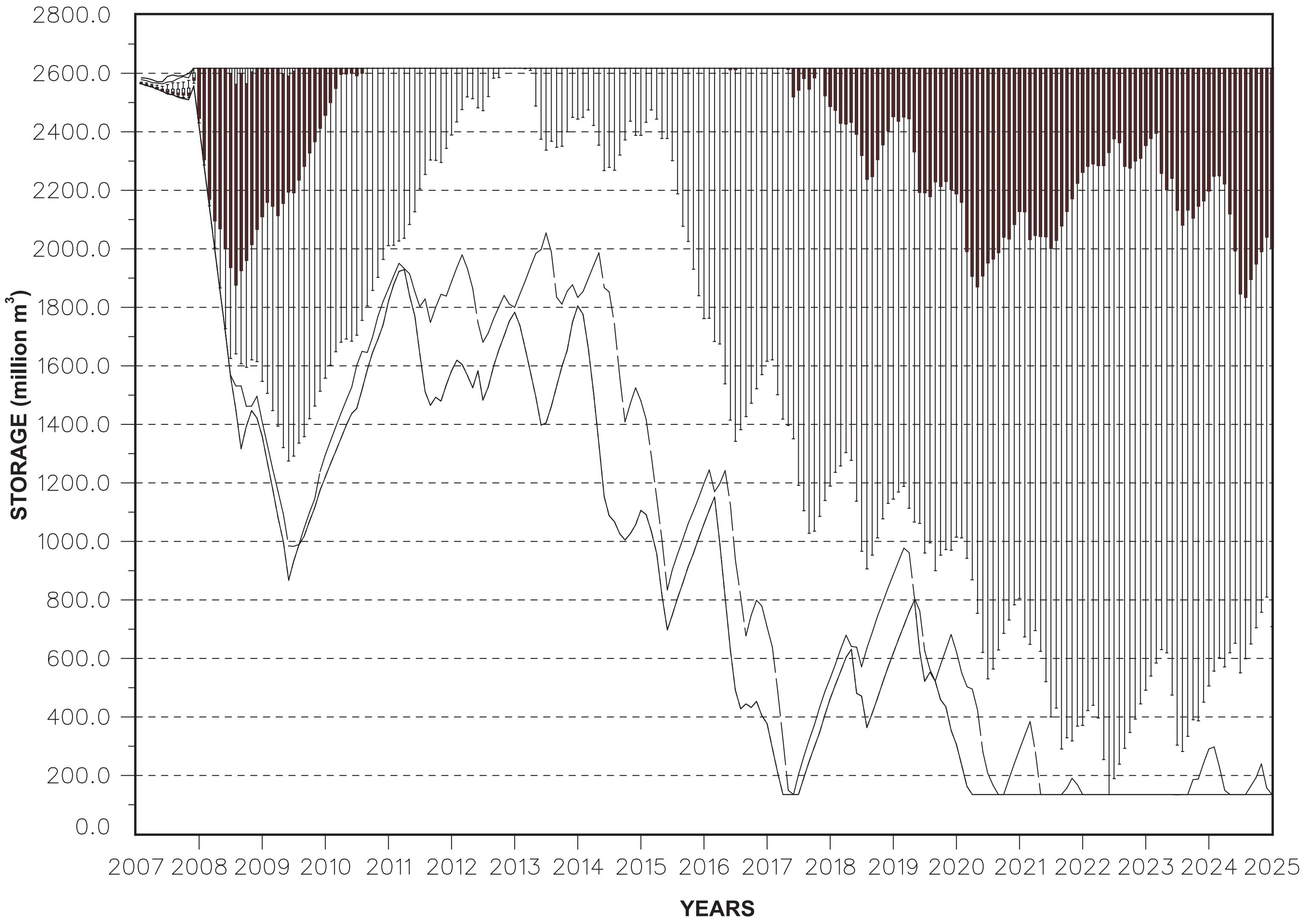
Scenario 1a: Proposed Polihali Dam

M-12

Appendix N

Graphical results: Scenario 1b

Figure No:	Description
N-1	Scenario 1b: Sterkfontein Dam
N-2	Scenario 1b: Vaal Dam
N-3	Scenario 1b: Bloemhof Dam



P 0138_Vaal Recon.Study_ Graphics_Phase 2_Figure N-1 to N-3.cdr

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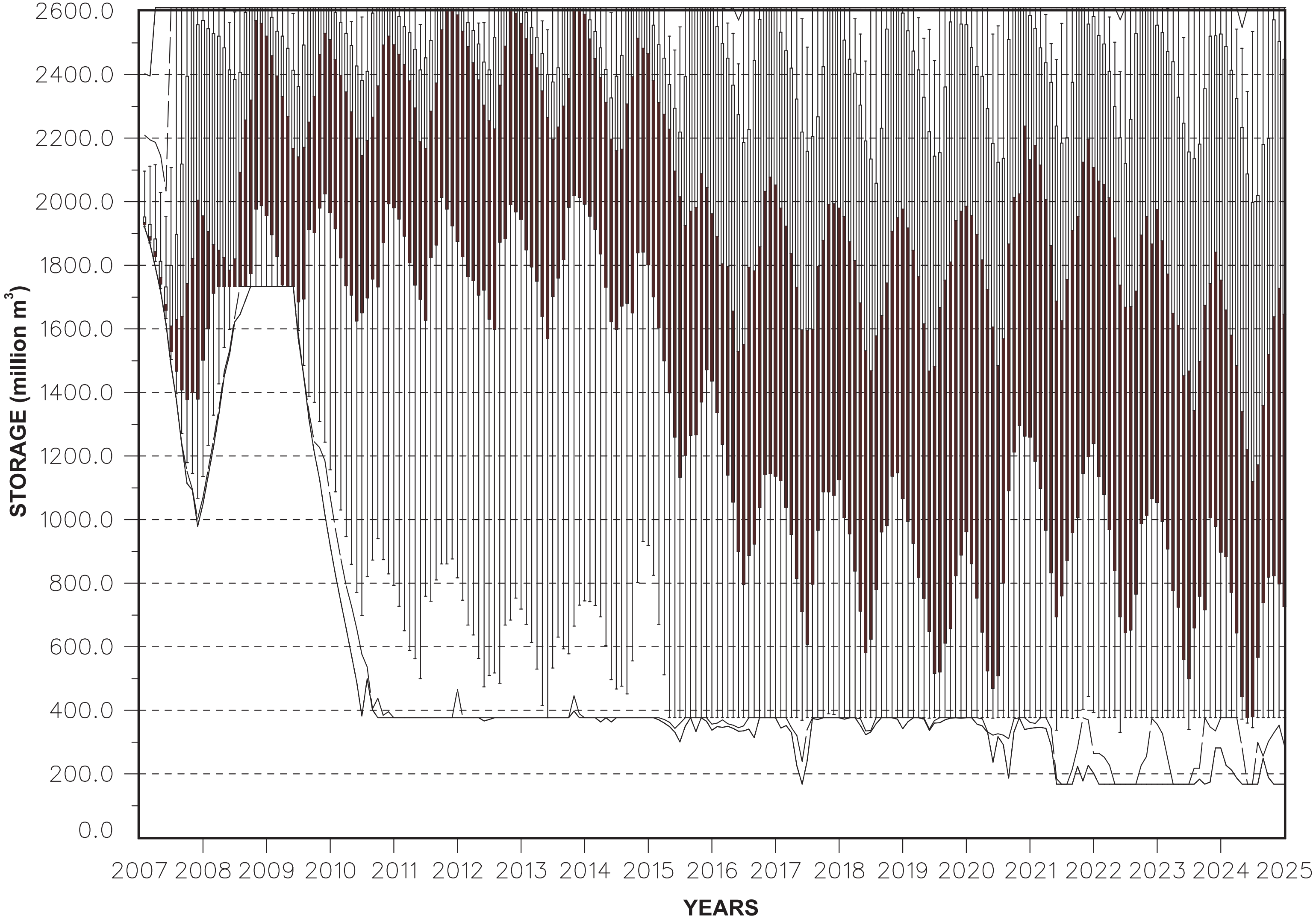
VAAL RIVER SYSTEM: LARGE BULK WATER SUPPLY RECONCILIATION STRATEGIES AND WATER CONSERVATION AND DEMAND MANAGEMENT

Scenario 1b: Sterkfontein Dam 1

N-1



P 0138_Vaal Recon.Study_ Graphics_Phase 2_Figure N-1 to N-3.cdr

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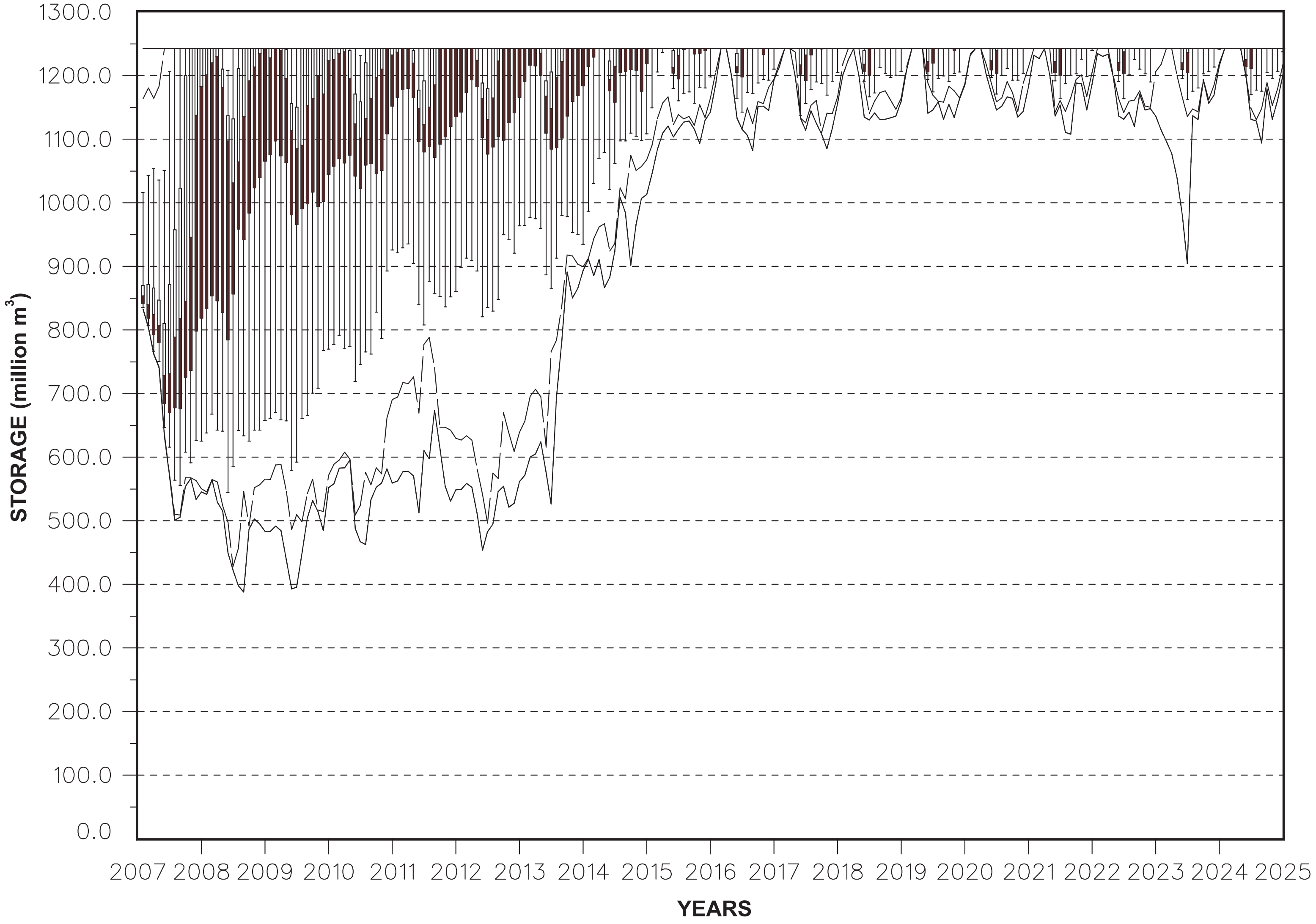
Scenario 1b: Vaal Dam 1

N-2



P 0138_Vaal Recon.Study_ Graphics_Phase 2_Figure N-1 to N-3.cdr

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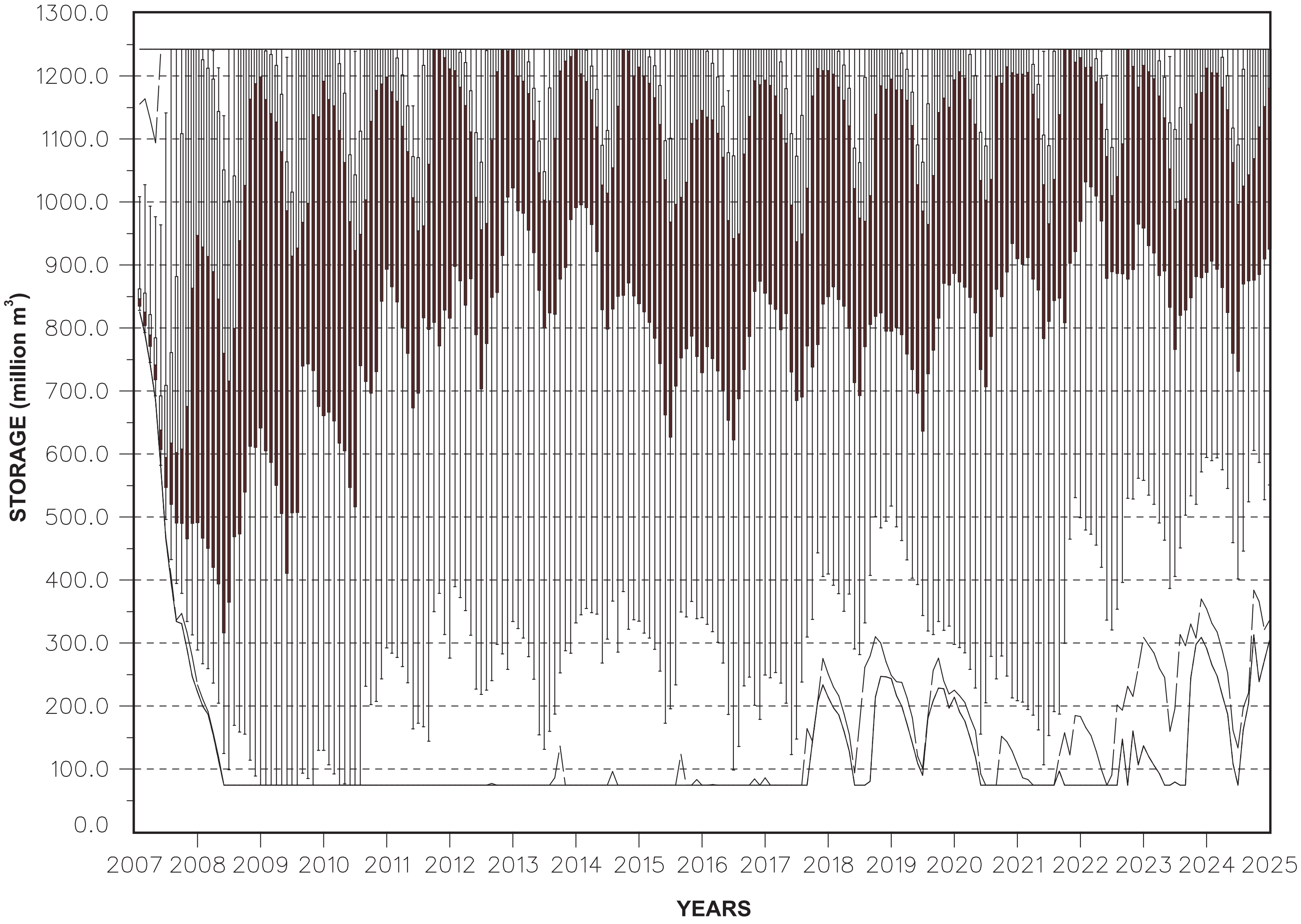
VAAL RIVER SYSTEM: LARGE BULK WATER SUPPLY RECONCILIATION STRATEGIES AND WATER CONSERVATION AND DEMAND MANAGEMENT

Scenario 1b: Bloemhof Dam 1

N-3

Appendix O

Graphical results: Scenario 1c



P 0138_Vaal Recon.Study_ Graphics_Phase 2_Figure O-1.cdr

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VAAL RIVER SYSTEM: LARGE BULK WATER SUPPLY RECONCILIATION STRATEGIES AND WATER CONSERVATION AND DEMAND MANAGEMENT

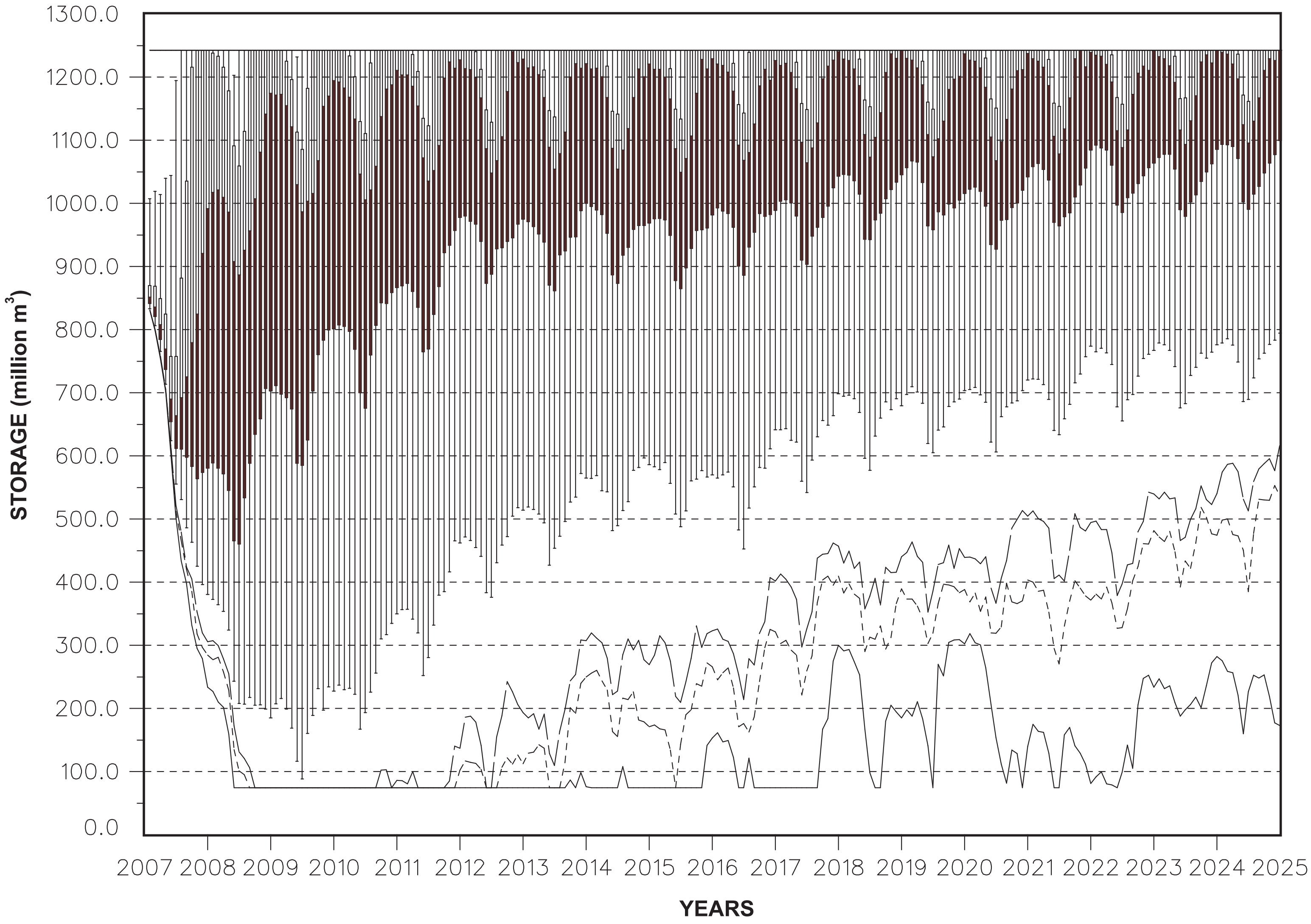
Scenario 1c: Bloemhof Dam

O-1

Appendix P

Graphical results: Scenario 1c1

Figure No:	Description
P-1	Scenario 1c1: Bloemhof Dam



P 0138_Vaal Recon.Study_ Graphics_Phase 2_Figure P-1.cdr

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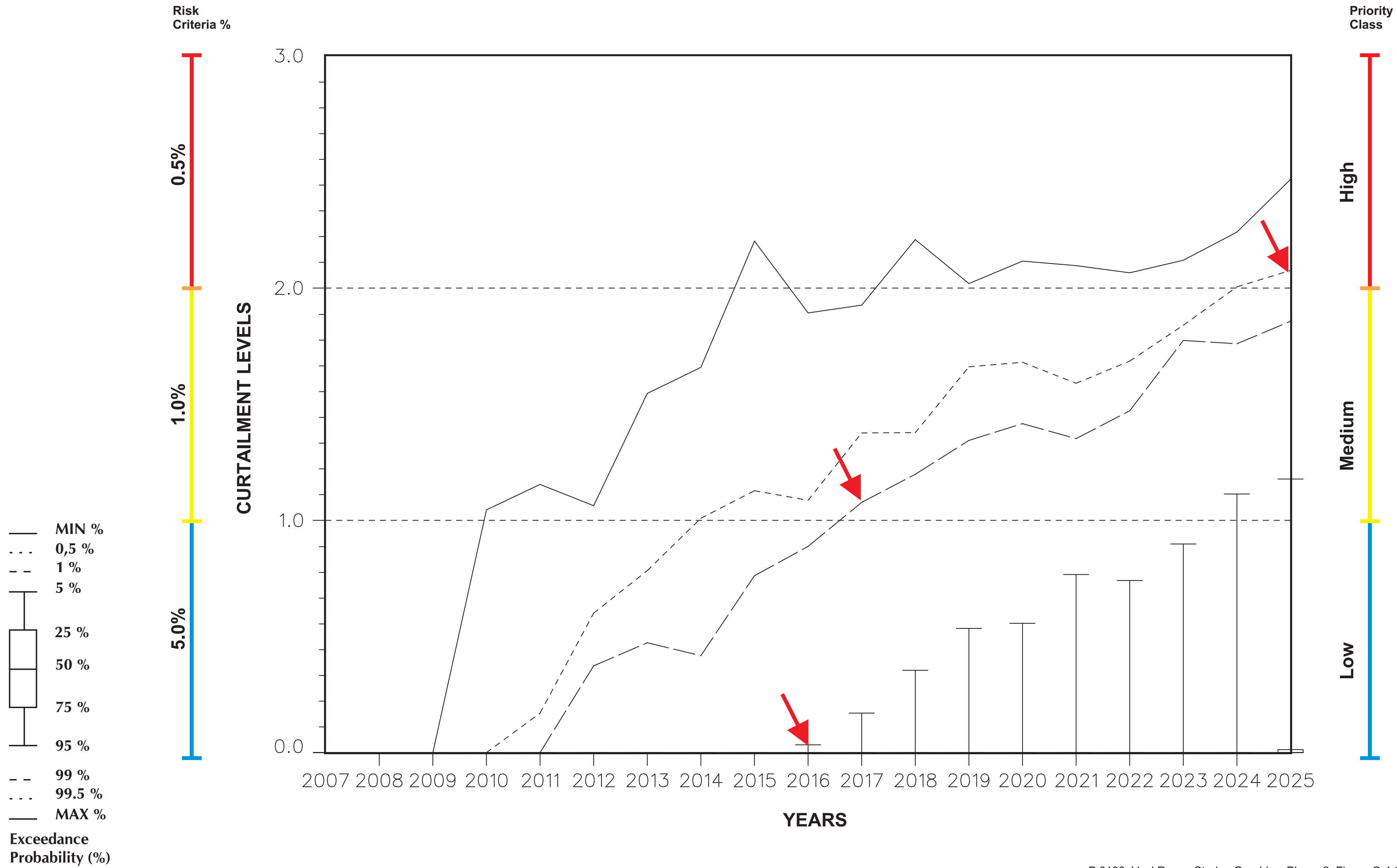
Scenario 1c1: Bloemhof Dam

P-1

Appendix Q

Graphical results: Scenario 2a



P 0138_Vaal Recon.Study_ Graphics_Phase 2_Figure Q-1 to Q-13.cdr

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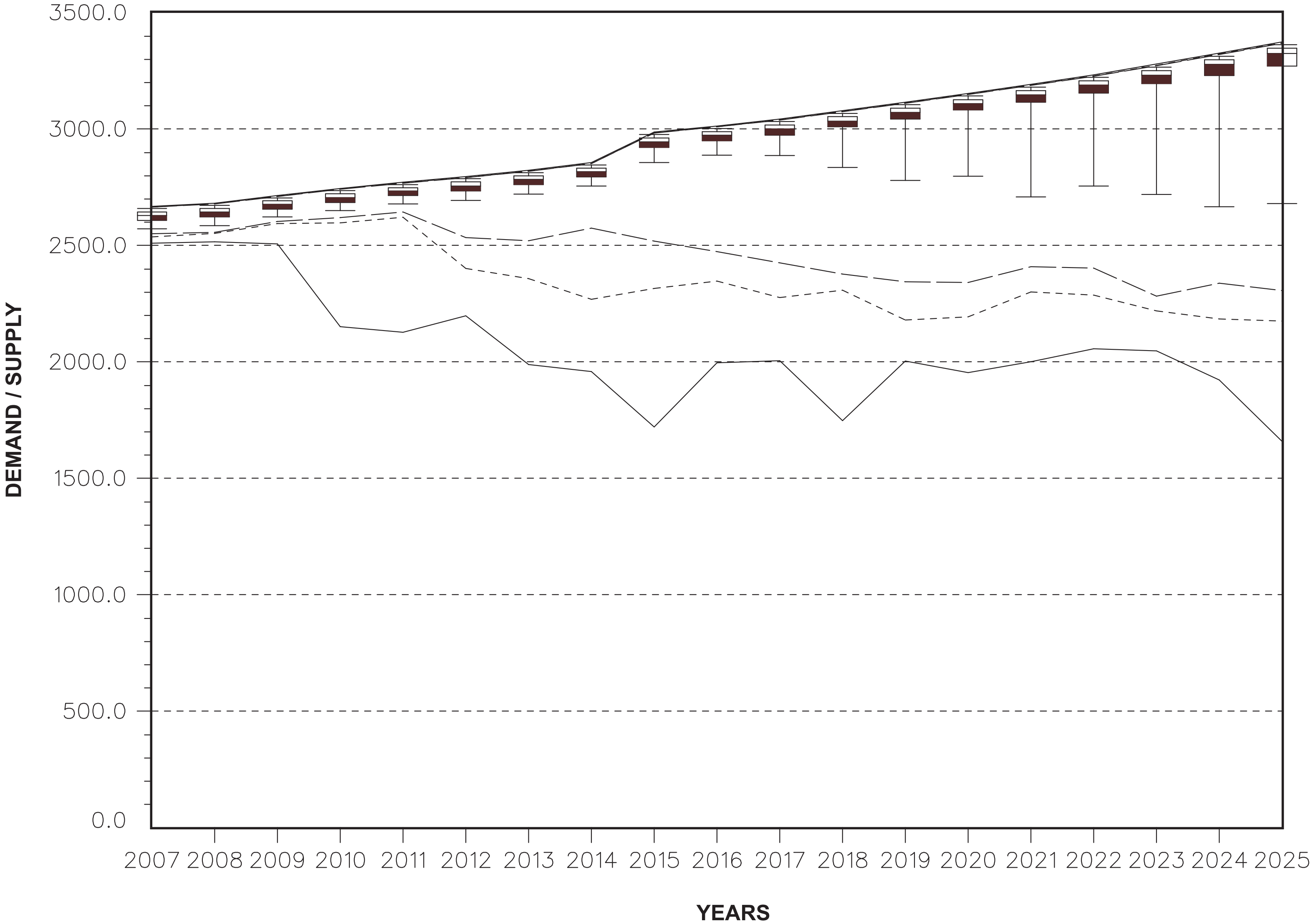
VAAL RIVER SYSTEM: LARGE BULK WATER SUPPLY RECONCILIATION STRATEGIES AND WATER CONSERVATION AND DEMAND MANAGEMENT

Scenario 2a: Curtailment Levels

Q-1



P 0138_Vaal Recon.Study_ Graphics_Phase 2_Figure Q-1 to Q-13.cdr

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VAAL RIVER SYSTEM: LARGE BULK WATER
SUPPLY RECONCILIATION STRATEGIES AND
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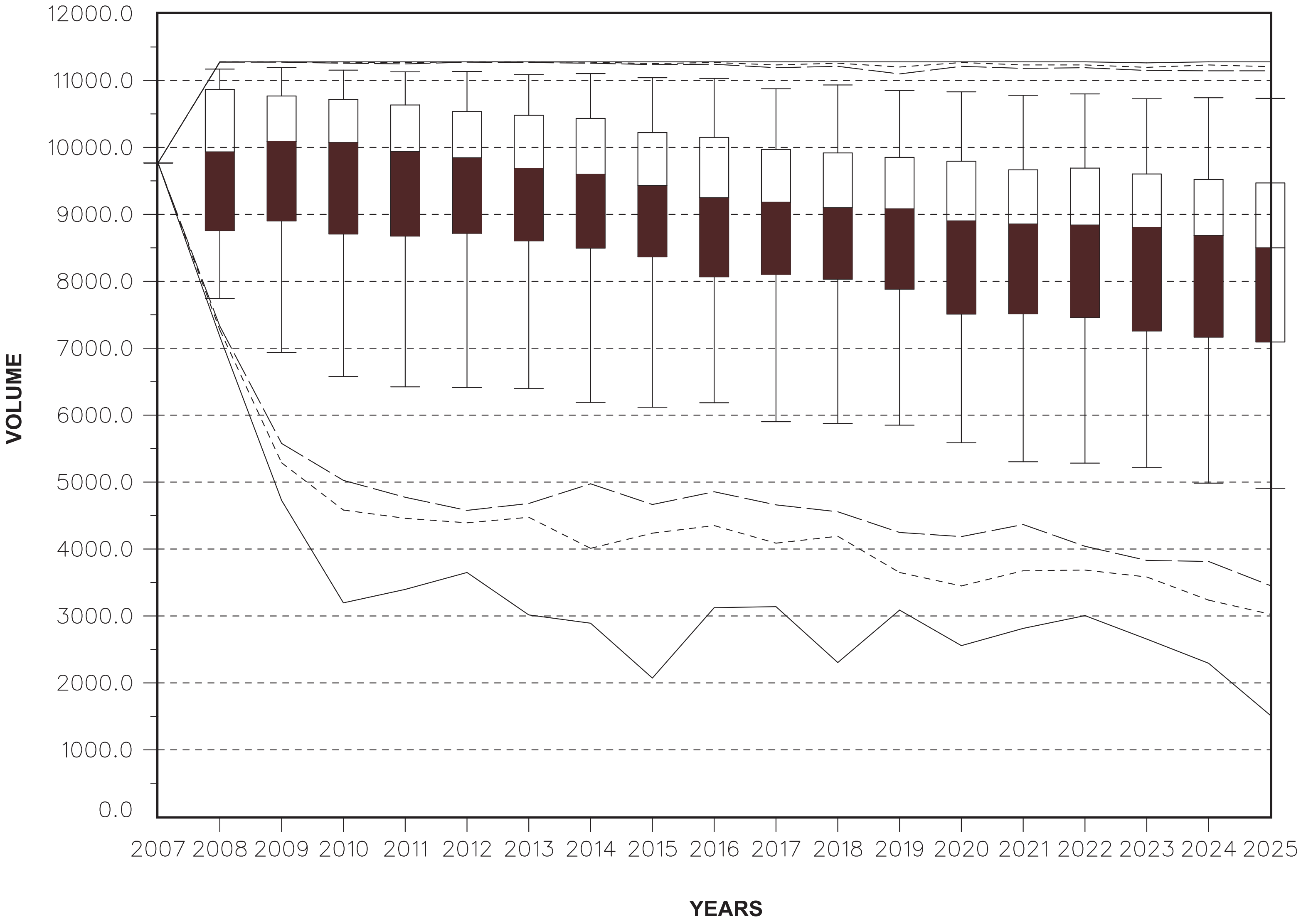
Scenario 2a: Demand/Supply

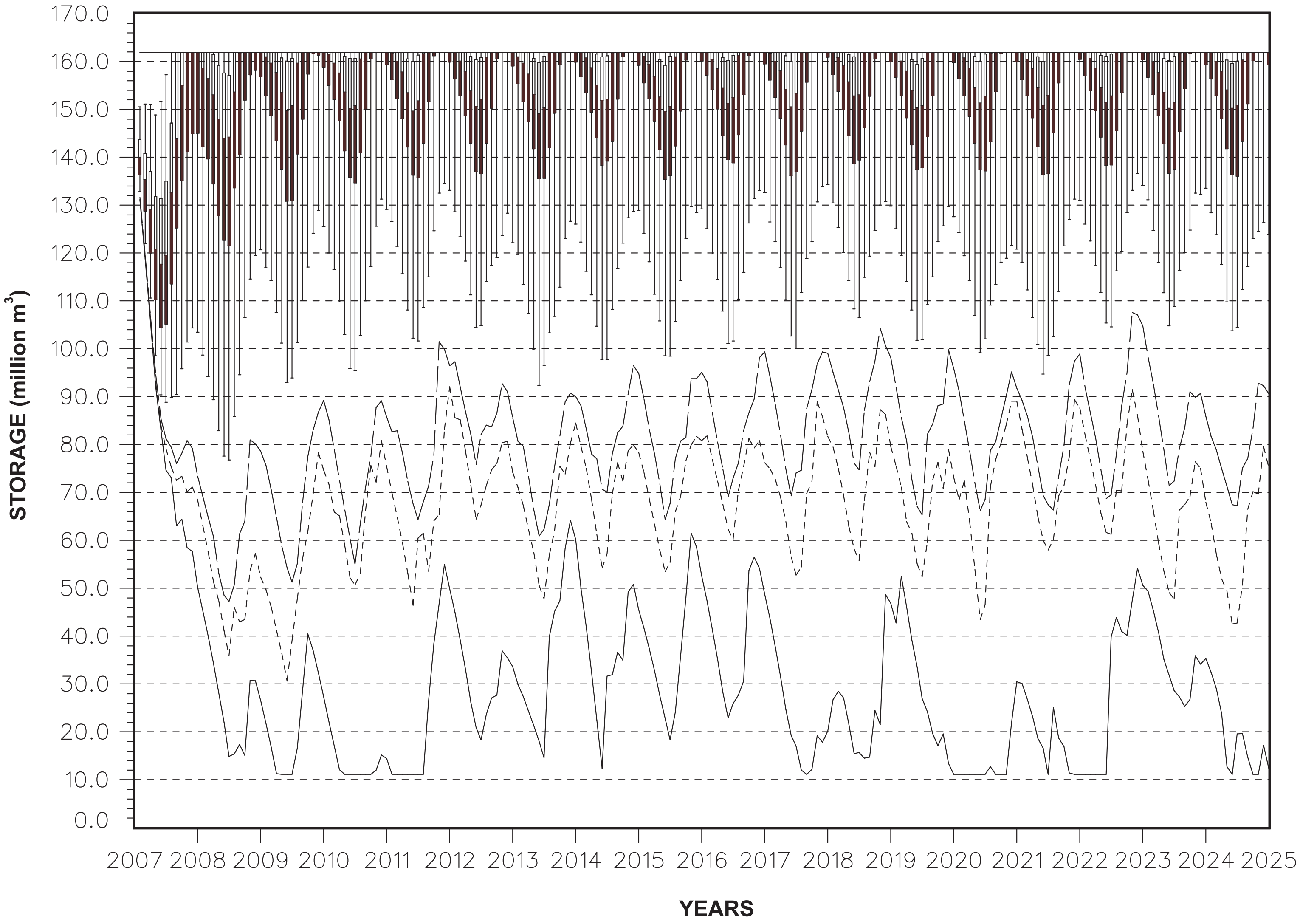
Q-2



P 0138_Vaal Recon.Study_ Graphics_Phase 2_Figure Q-1 to Q-13.cdr

Scenario 2a: Total System Volume

Q-3



P 0138_Vaal Recon.Study_ Graphics_Phase 2_Figure Q-1 to Q-13.cdr

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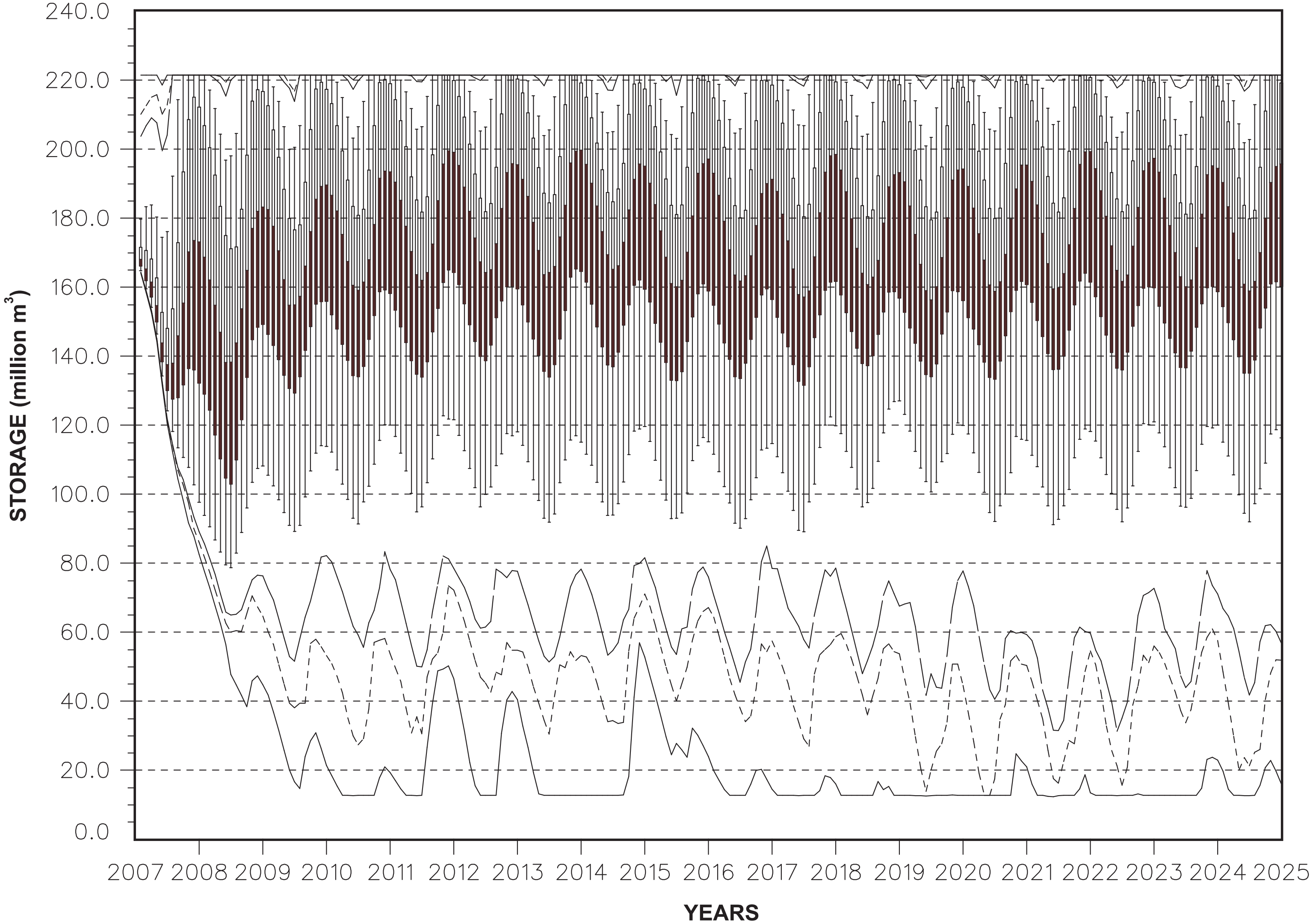
VAAL RIVER SYSTEM: LARGE BULK WATER SUPPLY RECONCILIATION STRATEGIES AND WATER CONSERVATION AND DEMAND MANAGEMENT

Scenario 2a: Komati Sub-system

Q-4



P 0138_Vaal Recon.Study_ Graphics_Phase 2_Figure Q-1 to Q-13.cdr

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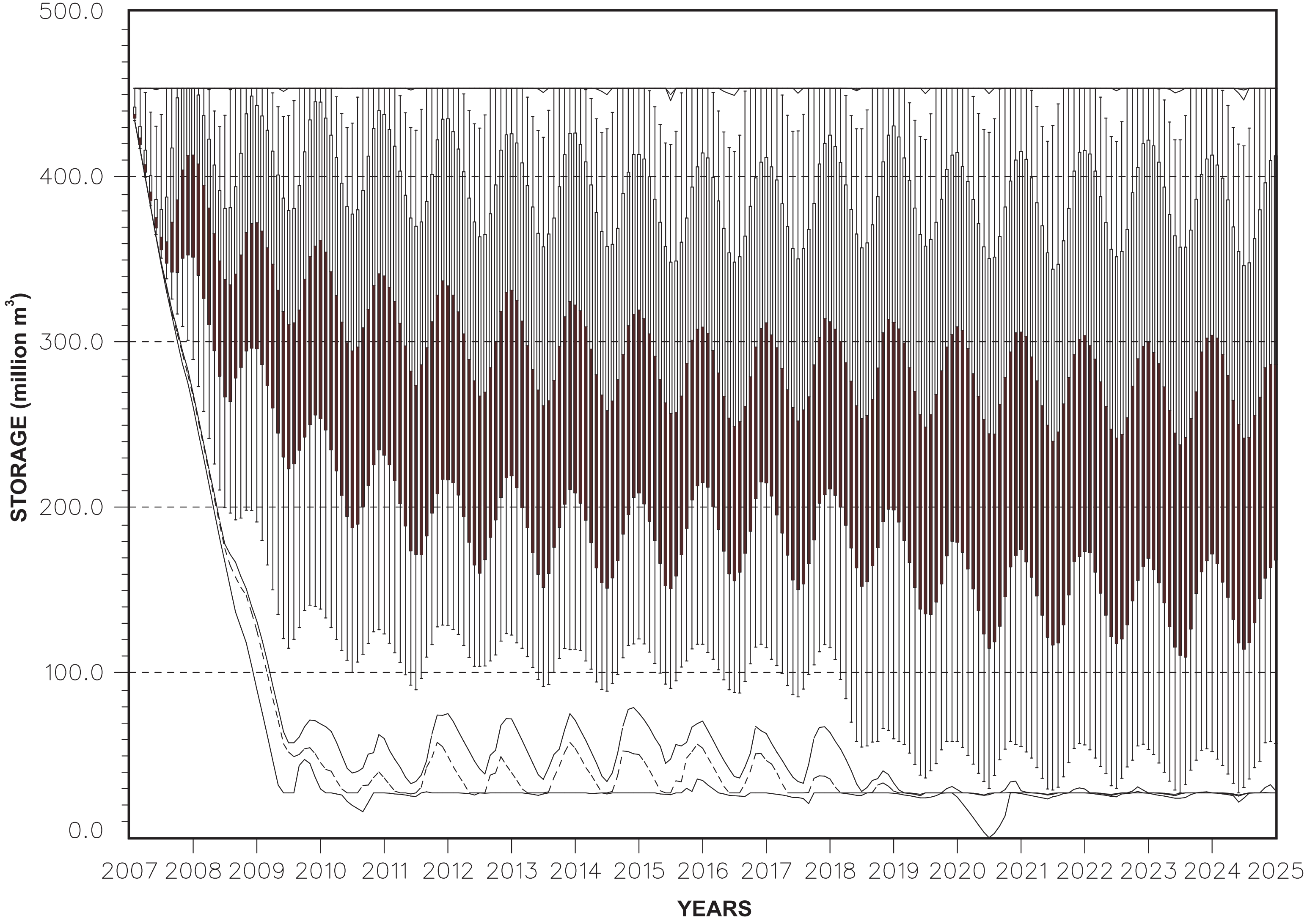
Scenario 2a: Usutu Sub-system

Q-5



P 0138_Vaal Recon.Study_ Graphics_Phase 2_Figure Q-1 to Q-13.cdr

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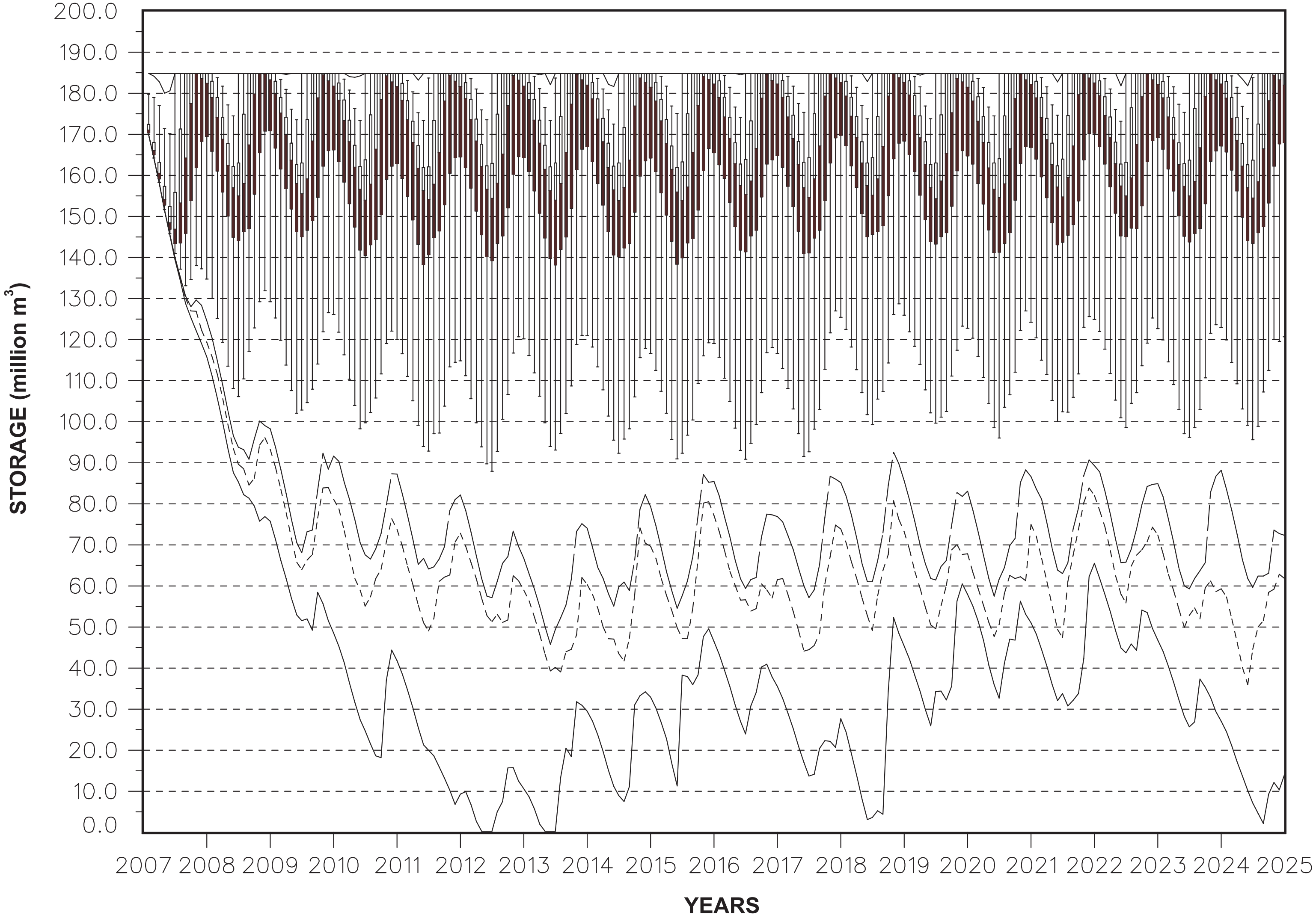
Scenario 2a: Heyshope Dam

Q-6



P 0138_Vaal Recon.Study_ Graphics_Phase 2_Figure Q-1 to Q-13.cdr

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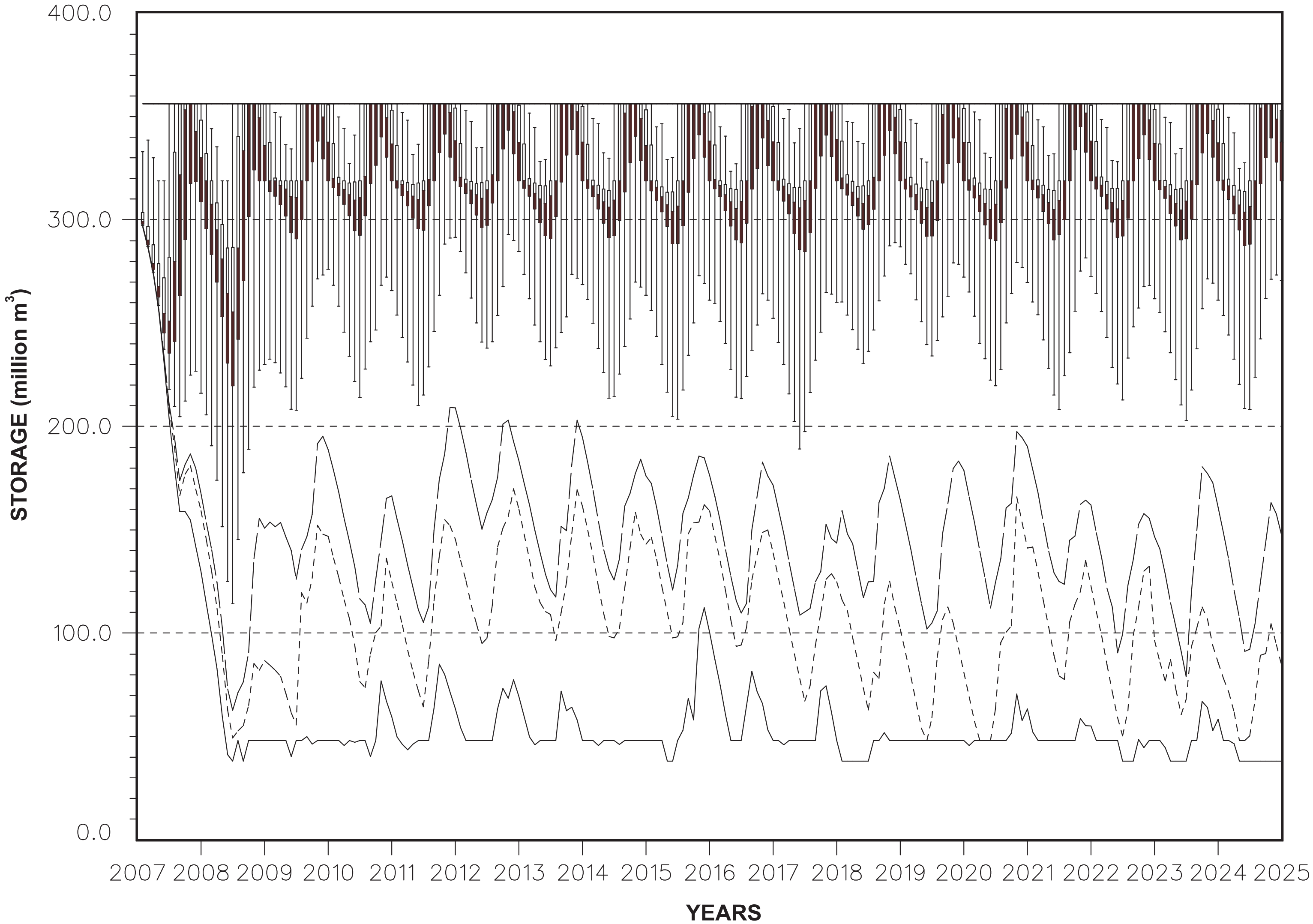
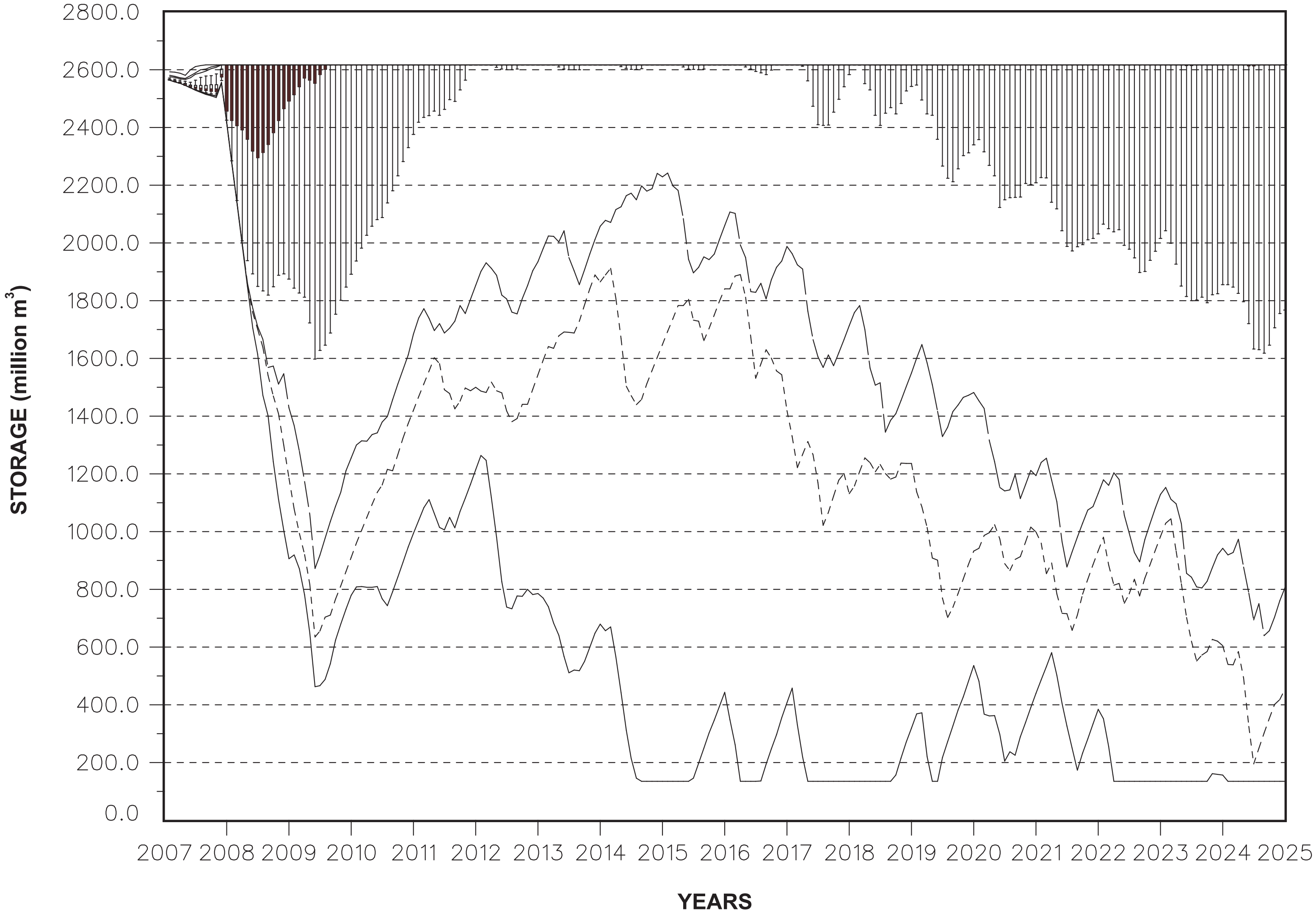
VAAL RIVER SYSTEM: LARGE BULK WATER
SUPPLY RECONCILIATION STRATEGIES AND
WATER CONSERVATION AND DEMAND MANAGEMENT

Scenario 2a: Zaaihoek Dam

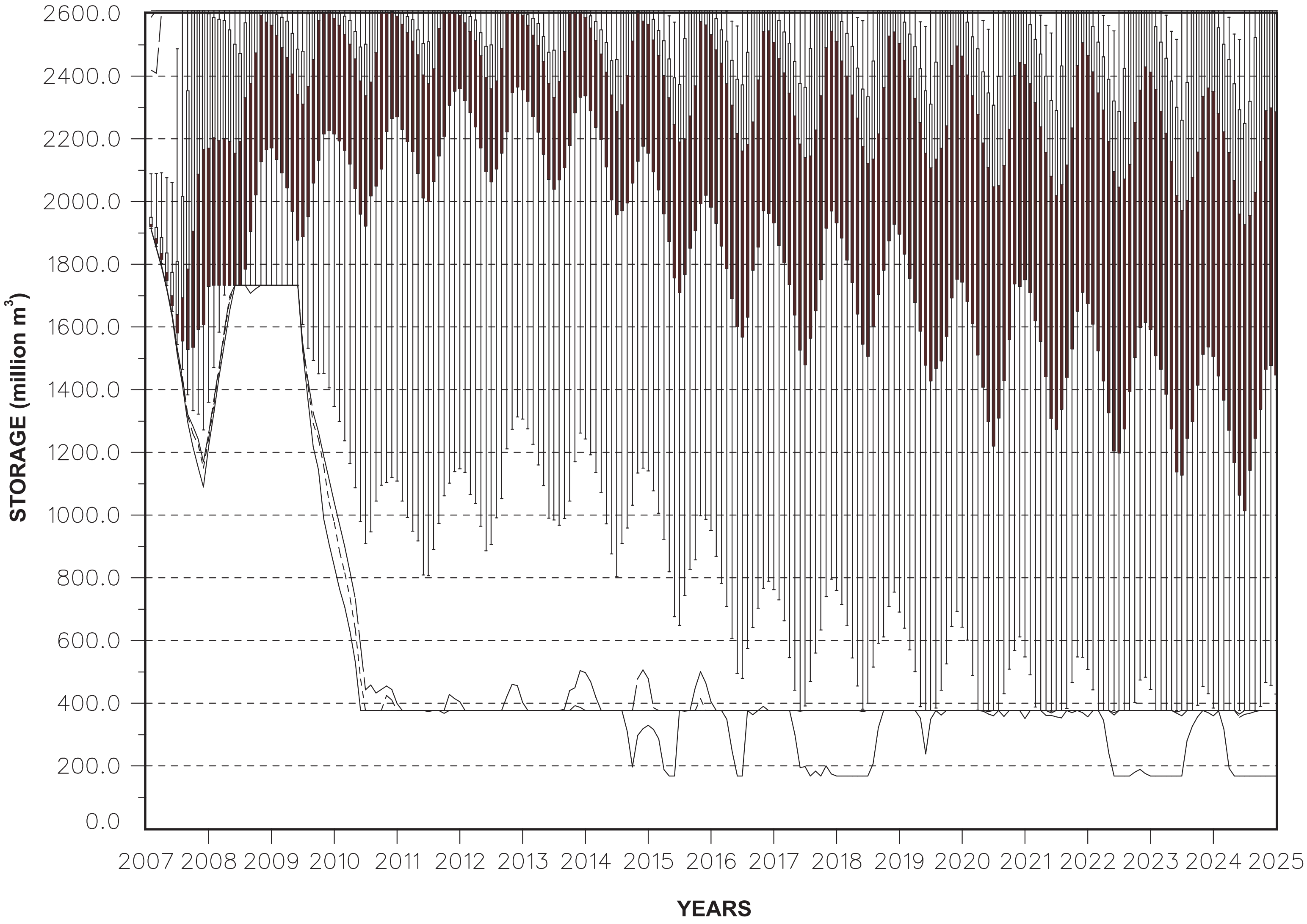
Q-7



P 0138_Vaal Recon.Study_ Graphics_Phase 2_Figure Q-1 to Q-13.cdr



P 0138_Vaal Recon.Study_ Graphics_Phase 2_Figure Q-1 to Q-13.cdr



P 0138_Vaal Recon.Study_ Graphics_Phase 2_Figure Q-1 to Q-13.cdr

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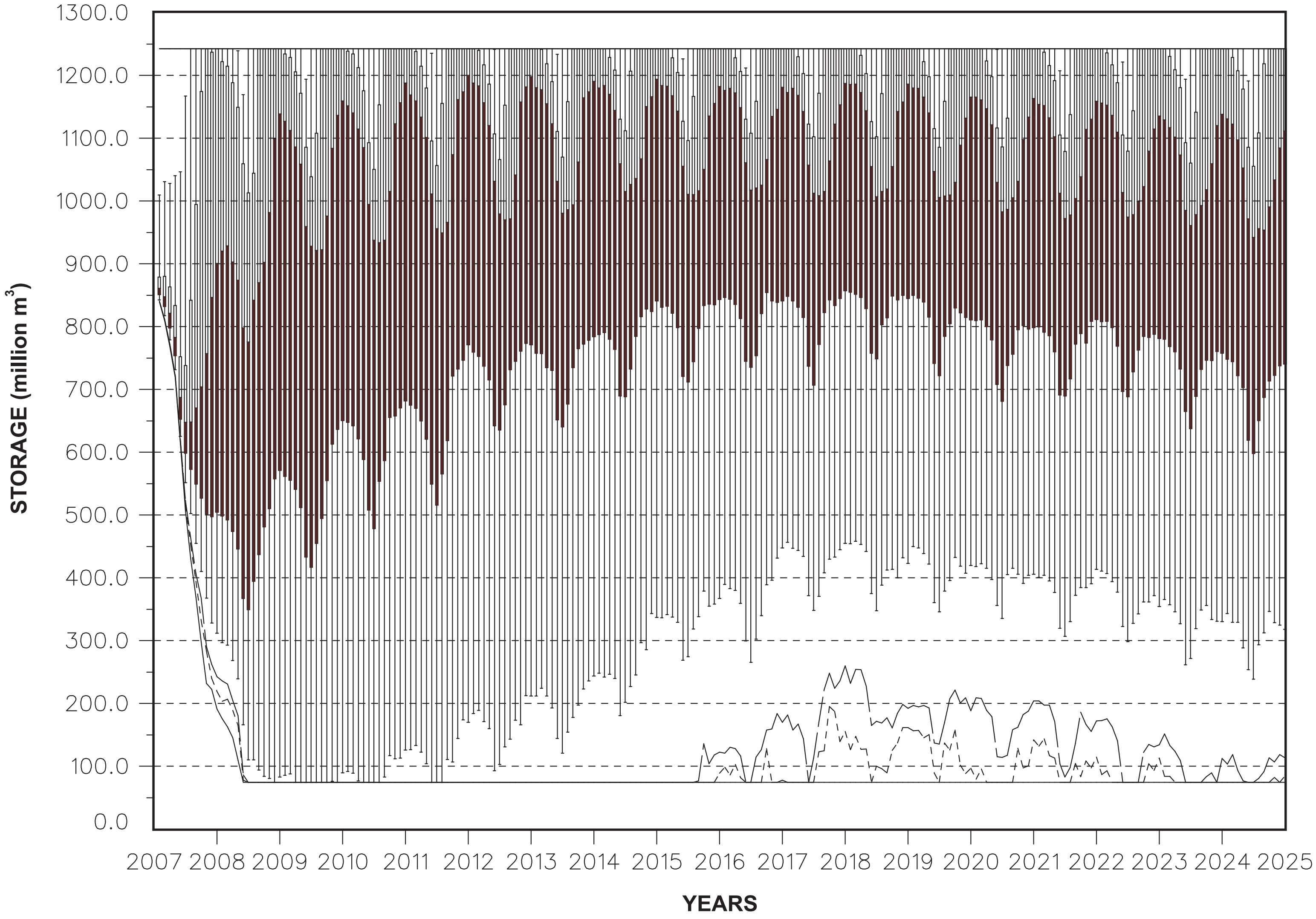
VAAL RIVER SYSTEM: LARGE BULK WATER SUPPLY RECONCILIATION STRATEGIES AND WATER CONSERVATION AND DEMAND MANAGEMENT

Scenario 2a: Vaal Dam

Q-10



P 0138_Vaal Recon.Study_ Graphics_Phase 2_Figure Q-1 to Q-13.cdr

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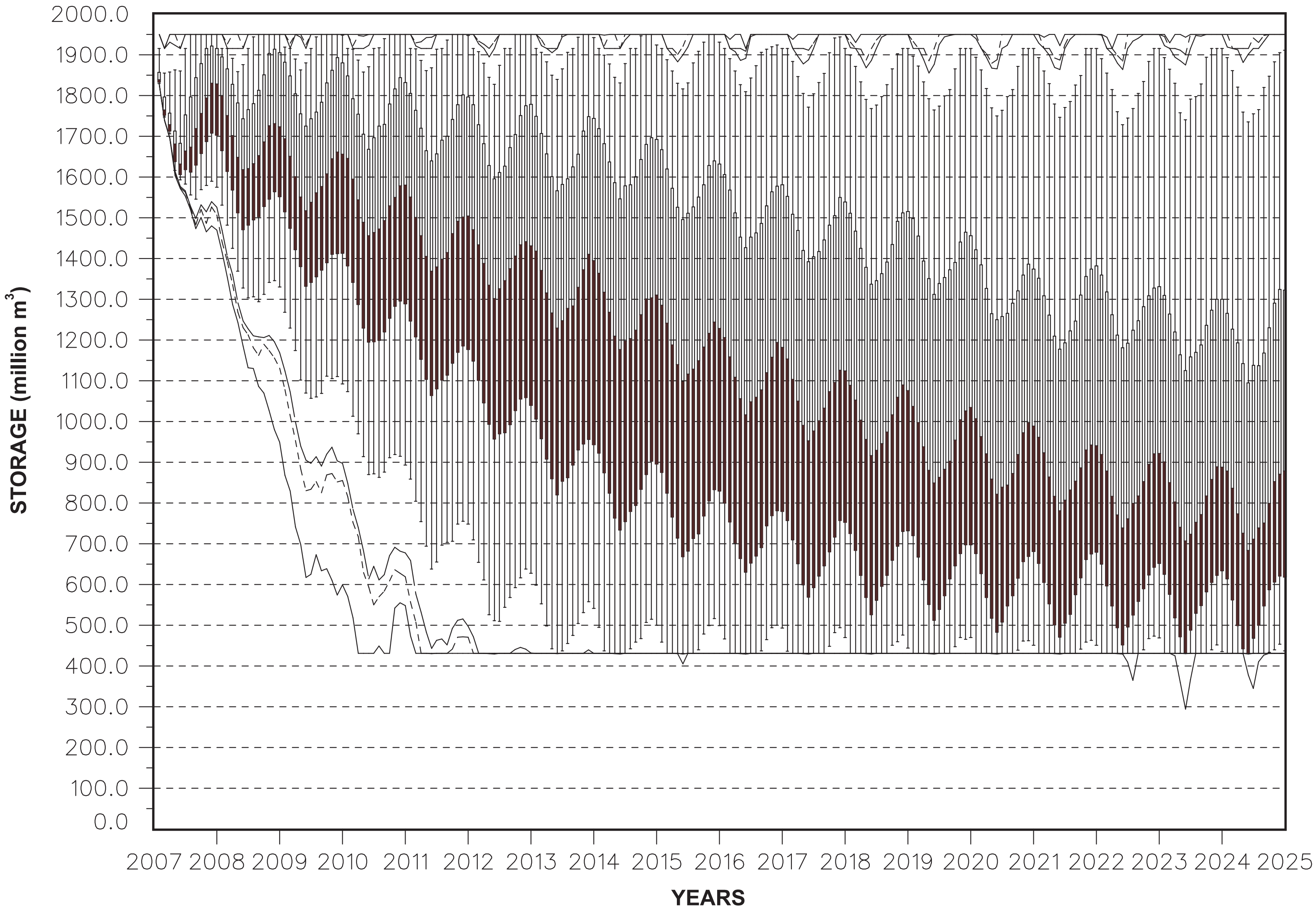
VAAL RIVER SYSTEM: LARGE BULK WATER SUPPLY RECONCILIATION STRATEGIES AND WATER CONSERVATION AND DEMAND MANAGEMENT

Scenario 2a: Bloemhof Dam

Q-11



P 0138_Vaal Recon.Study_ Graphics_Phase 2_Figure Q-1 to Q-13.cdr

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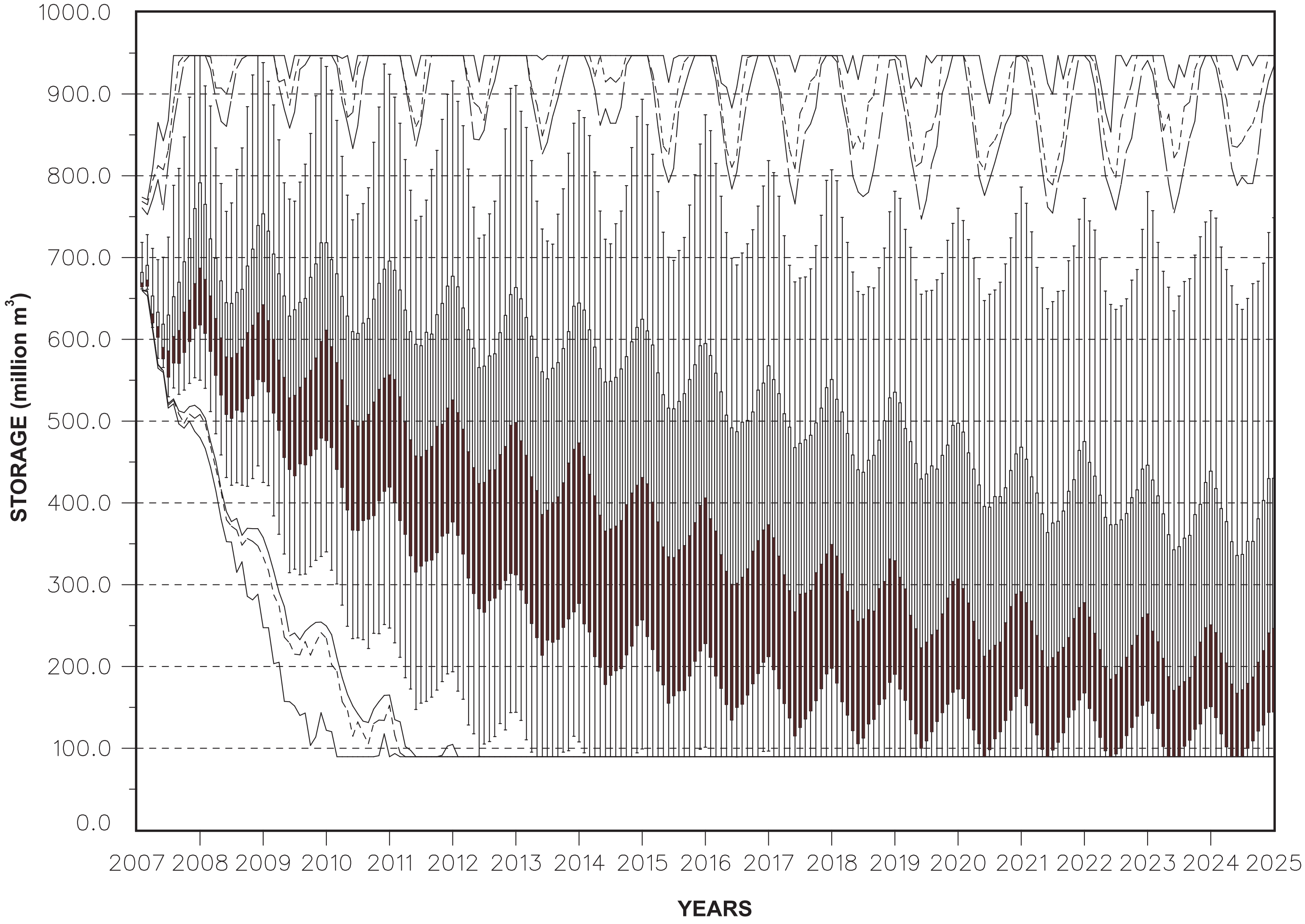
VAAL RIVER SYSTEM: LARGE BULK WATER
SUPPLY RECONCILIATION STRATEGIES AND
WATER CONSERVATION AND DEMAND MANAGEMENT

Scenario 2a: Katse Dam

Q-12



P 0138_Vaal Recon.Study_ Graphics_Phase 2_Figure Q-1 to Q-13.cdr

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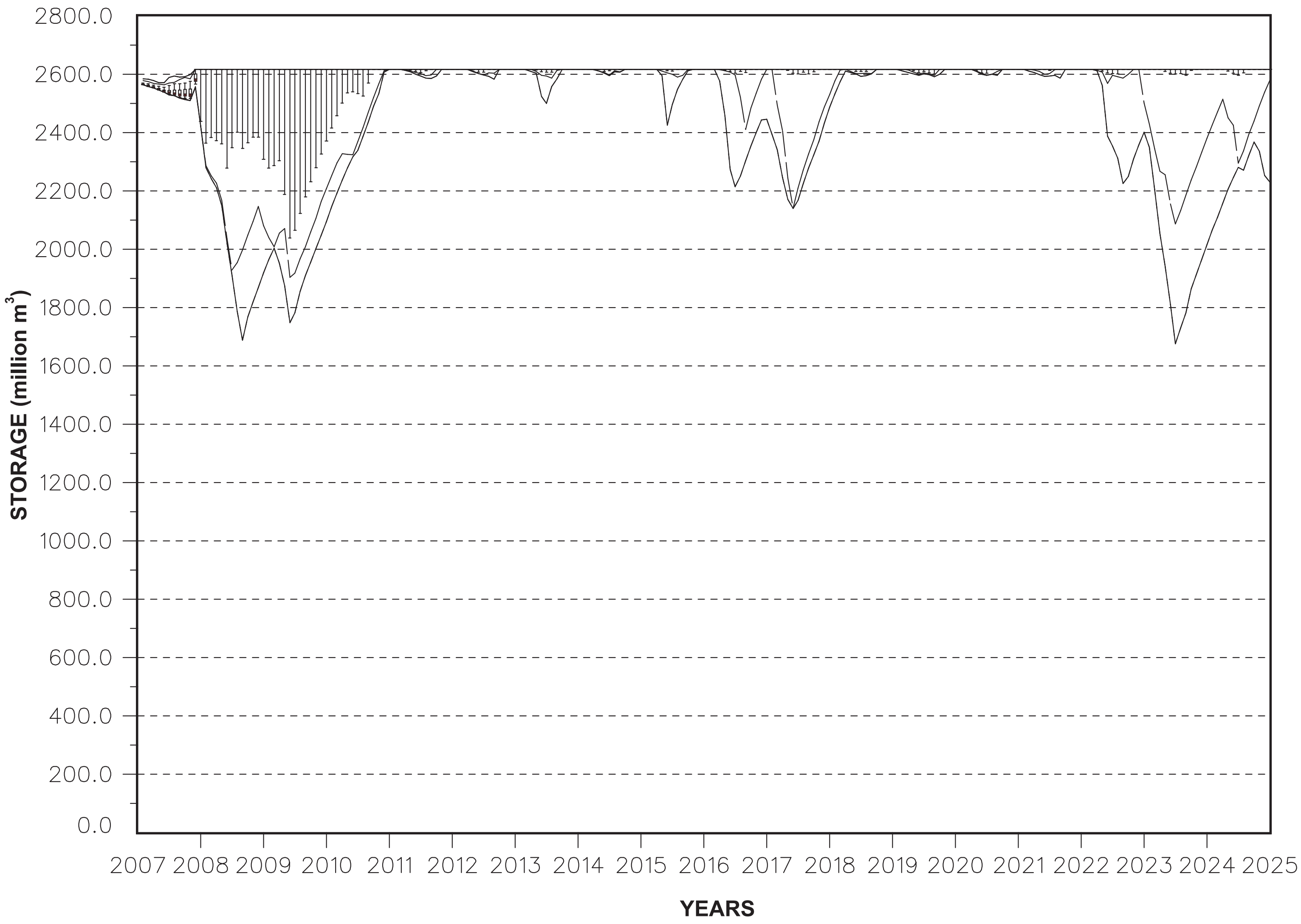
Scenario 2a: Mohale Dam

Q-13

Appendix R

Graphical results: Scenario 3

Figure No:	Description
R-1	Scenario 3: Sterkfontein Dam
R-2	Scenario 3: Vaal Dam
R-3	Scenario 3: Bloemhof Dam



P 0138_Vaal Recon.Study_ Graphics_Phase 2_Figure R-1 to R-3.cdr

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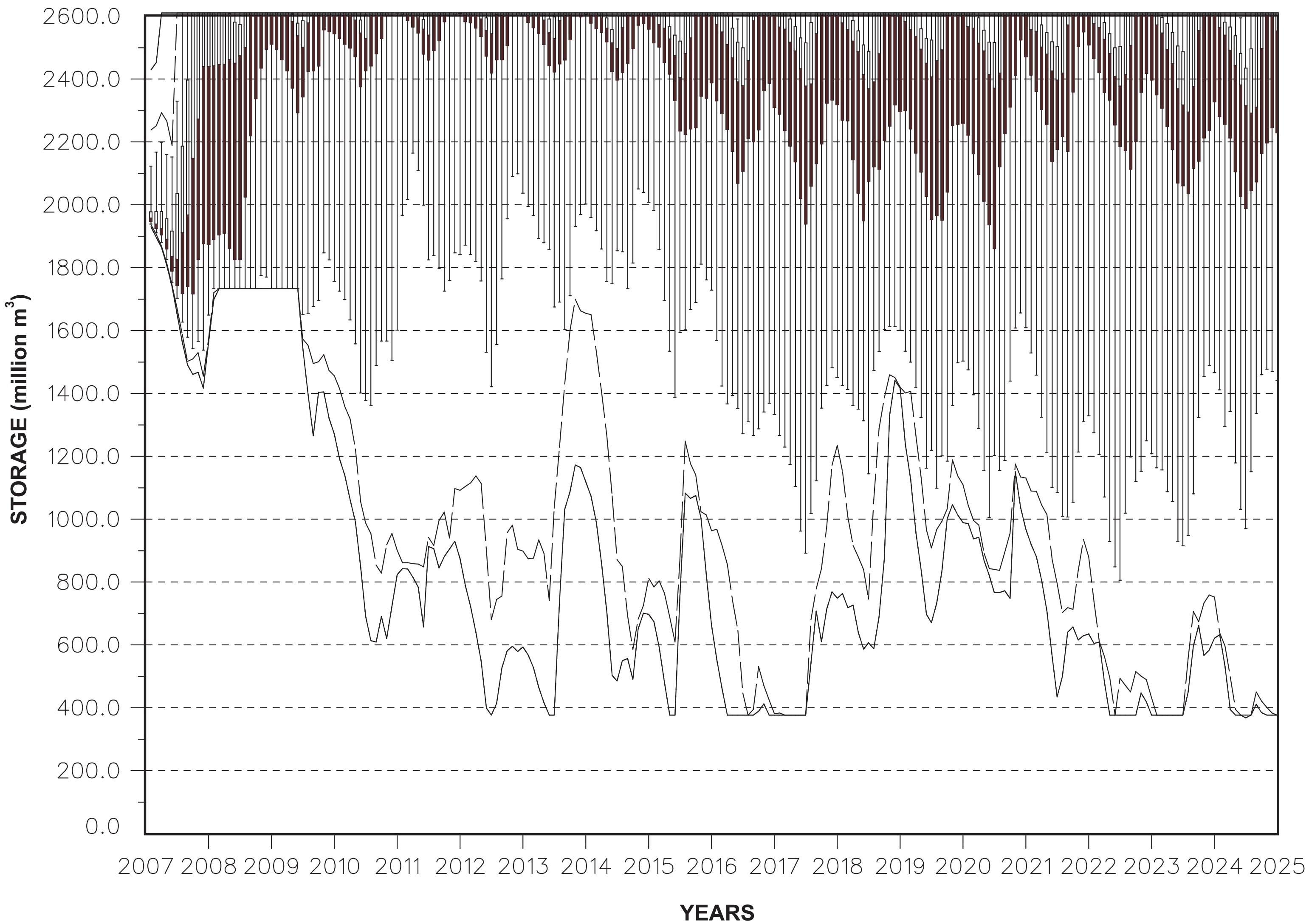
SUPPLY RECONCILIATION STRATEGIES AND
WATER CONSERVATION AND DEMAND MANAGEMENT

Scenario 3: Sterkfontein Dam

R-1



P 0138_Vaal Recon.Study_ Graphics_Phase 2_Figure R-1 to R-3.cdr

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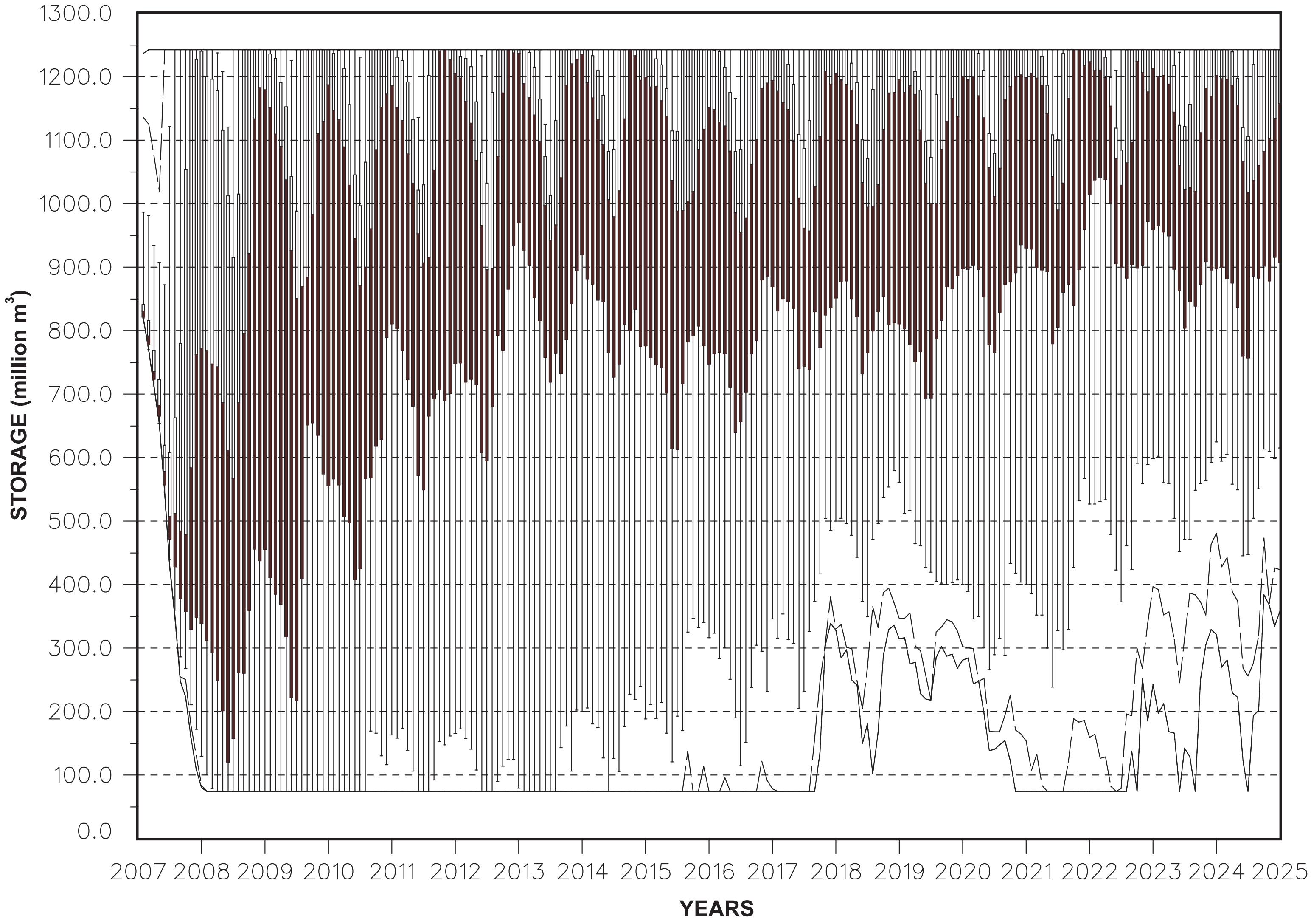
Scenario 3: Vaal Dam

R-2



P 0138_Vaal Recon.Study_ Graphics_Phase 2_Figure R-1 to R-3.cdr

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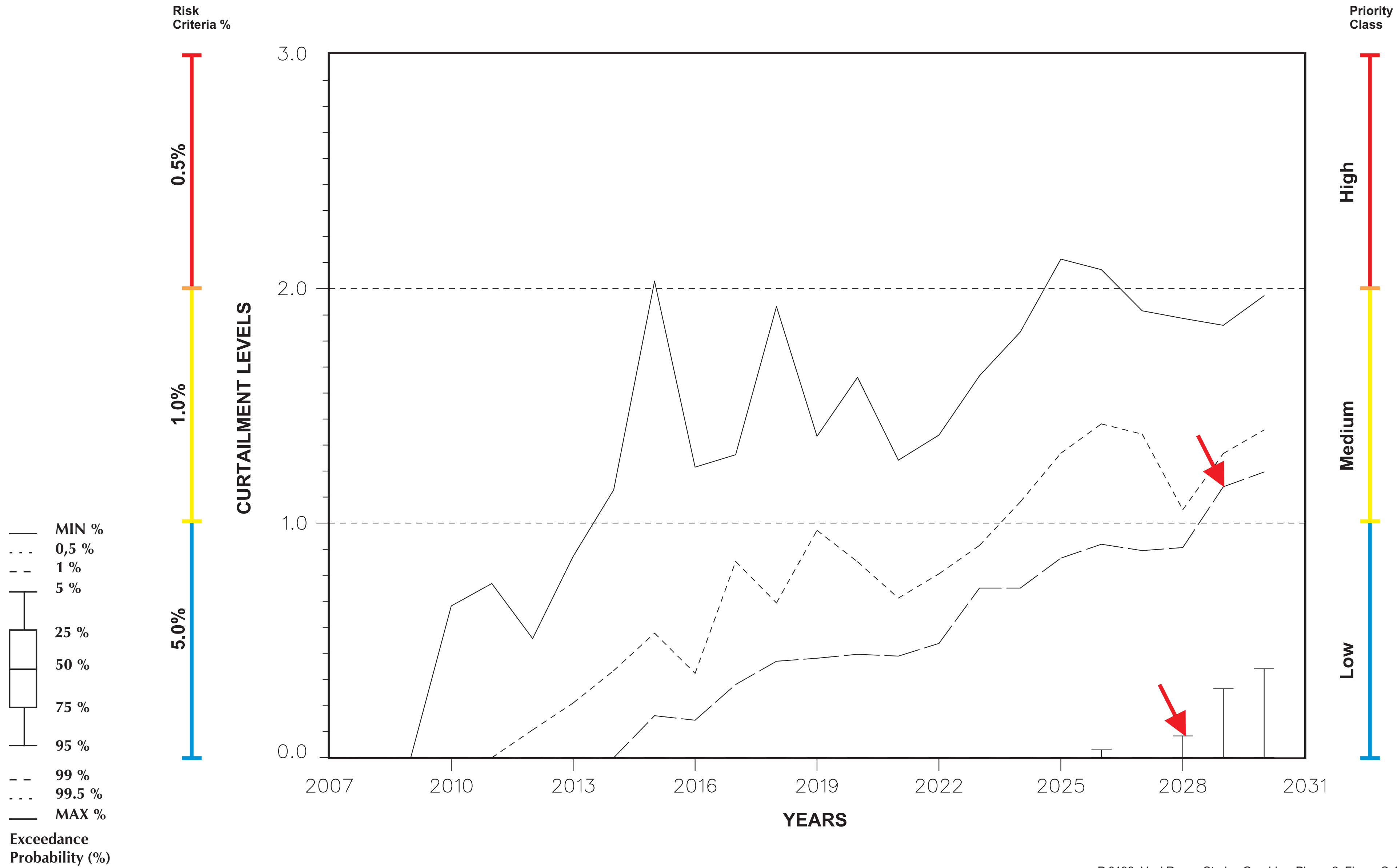
VAAL RIVER SYSTEM: LARGE BULK WATER SUPPLY RECONCILIATION STRATEGIES AND WATER CONSERVATION AND DEMAND MANAGEMENT

Scenario 3: Bloemhof Dam

R-3

Appendix S

Graphical results: Scenario 8a



P 0138_Vaal Recon.Study_ Graphics_Phase 2_Figure S-1 to S-5.cdr

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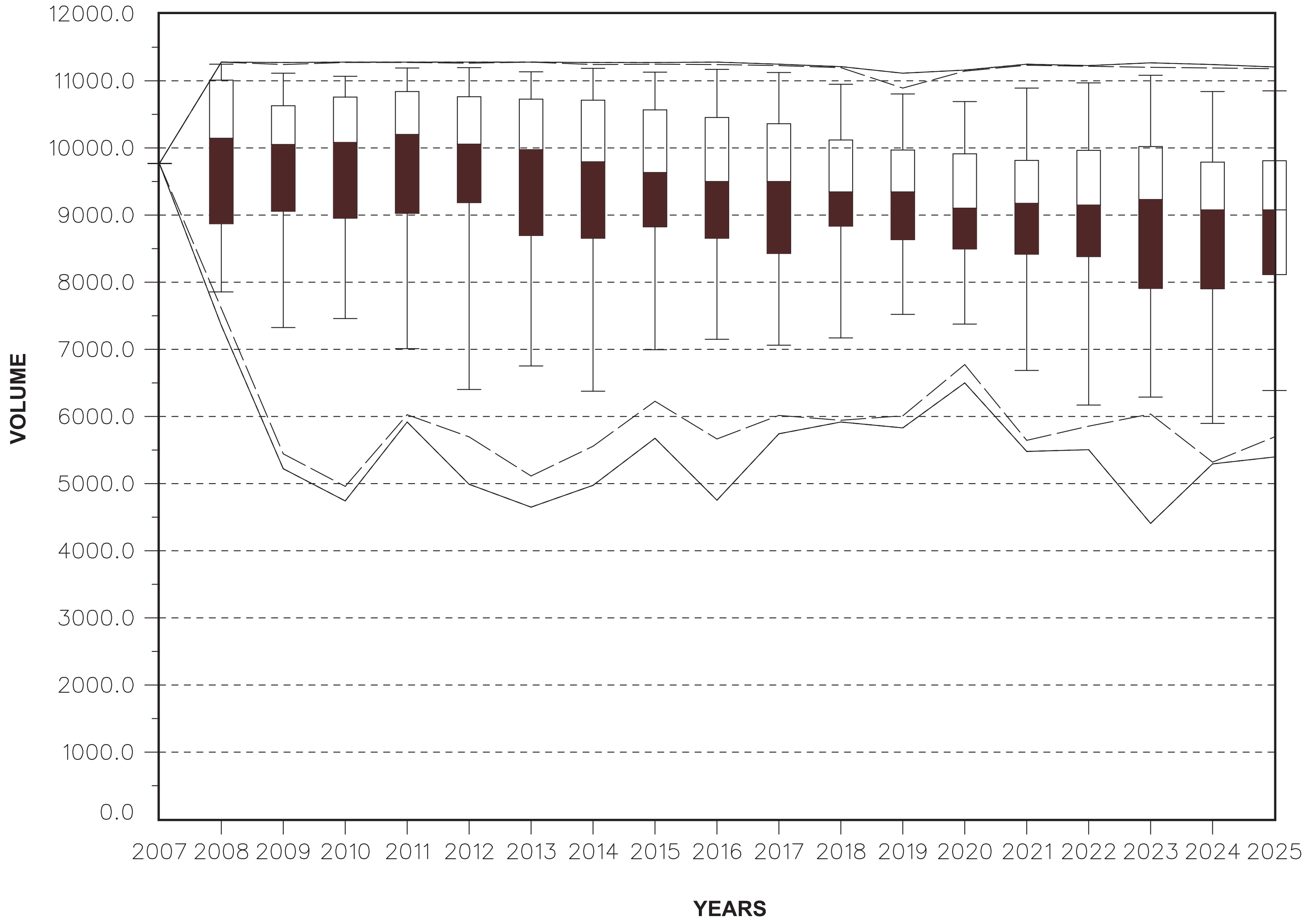
VAAL RIVER SYSTEM: LARGE BULK WATER SUPPLY RECONCILIATION STRATEGIES AND WATER CONSERVATION AND DEMAND MANAGEMENT

Scenario 8a: Curtailment Levels

S-1



P 0138_Vaal Recon.Study_ Graphics_Phase 2_Figure S-1 to S-5.cdr

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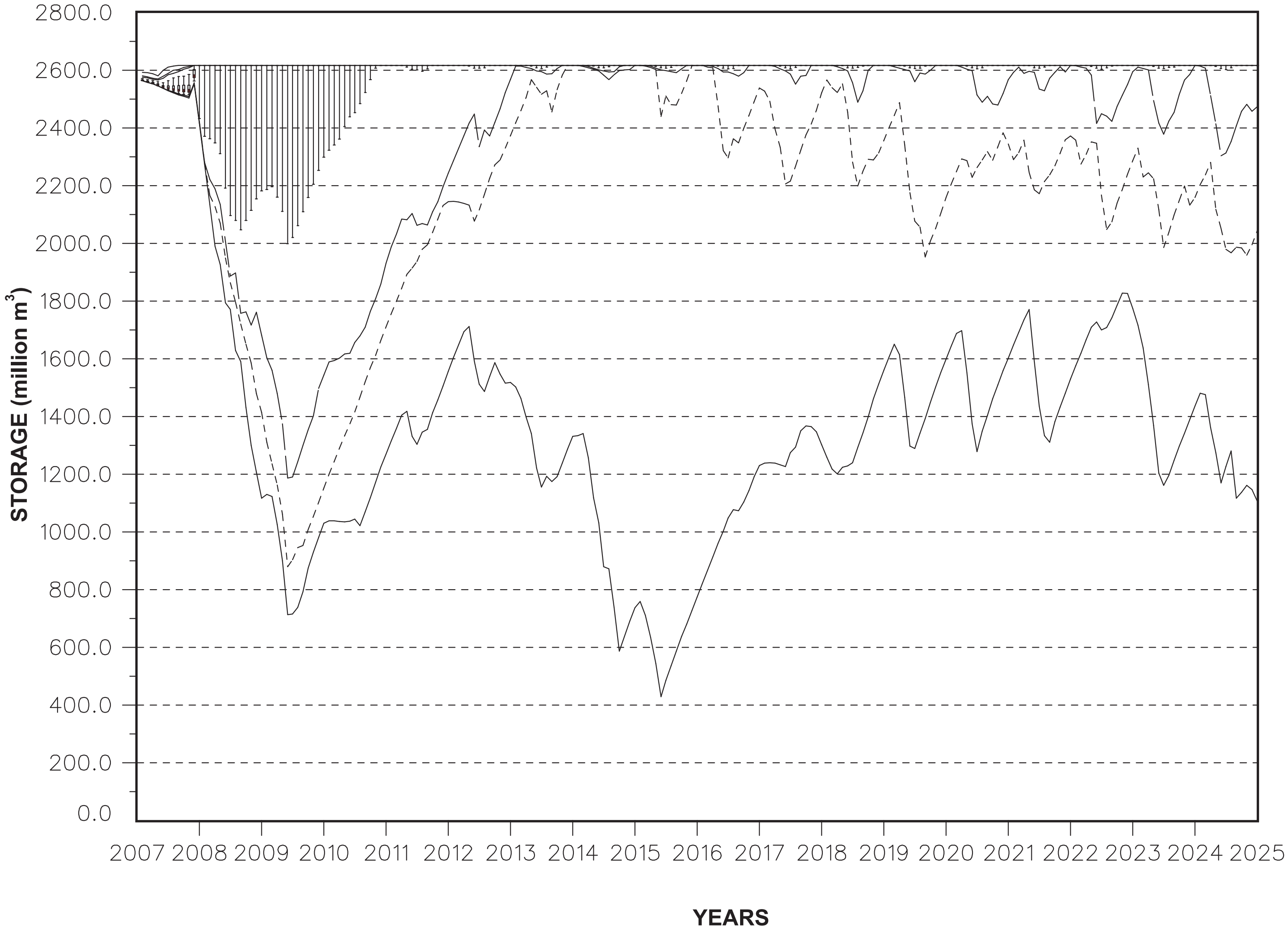
VAAL RIVER SYSTEM: LARGE BULK WATER SUPPLY RECONCILIATION STRATEGIES AND WATER CONSERVATION AND DEMAND MANAGEMENT

Scenario 8a: System Volume

S-2



P 0138_Vaal Recon.Study_ Graphics_Phase 2_Figure S-1 to S-5.cdr

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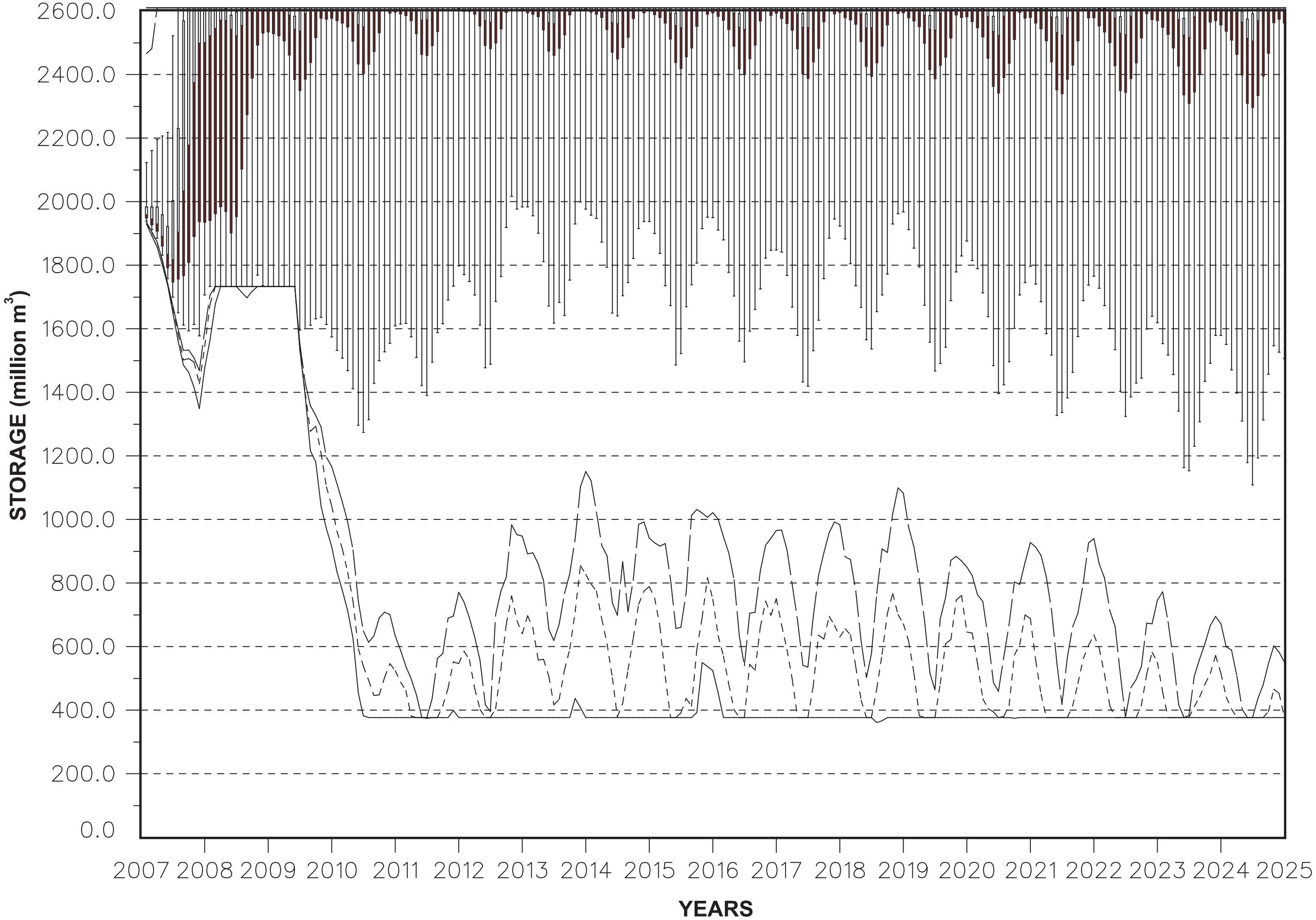
Scenario 8a: Sterkfontein Dam

S-3



P 0138_Vaal Recon.Study_ Graphics_Phase 2_Figure S-1 to S-5.cdr

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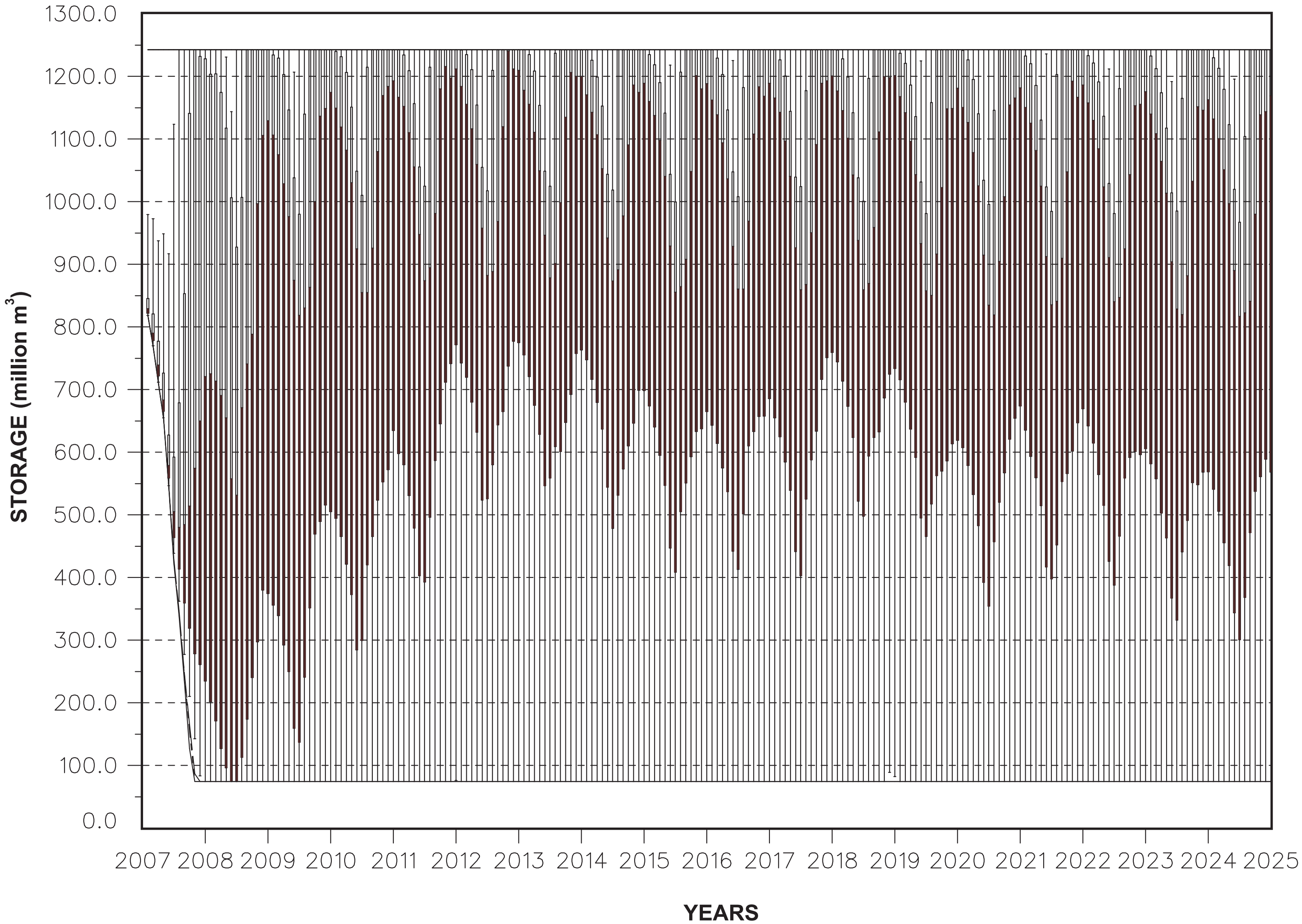
Scenario 8a: Vaal Dam

S-4



P 0138_Vaal Recon.Study_ Graphics_Phase 2_Figure S-1 to S-5.cdr

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Scenario 8a: Bloemhof Dam

S-5