DWA REPORT NUMBER: P RSA D000/00/18312/4

water affairs
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DEVELOPMENT OF RECONCILIATION STRATEGIES FOR LARGE BULK WATER SUPPLY SYSTEMS: ORANGE RIVER

CURRENT AND FUTURE URBAN INDUSTRIAL WATER REQUIREMENTS

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Prepared by:

WRP Consulting Engineers, Aurecon, Golder Associates Africa, and Zitholele Consulting.

Report No. P RSA D000/00/18312/4

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LIST OF REPORTS

The following reports form part of this study:

Report Title	Report number
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Literature Review Report	P RSA D000/00/18312/2
International obligations	P RSA D000/00/18312/3
Current and future Water Requirements	**P RSA D000/00/18312/4**
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DEVELOPMENT OF RECONCILIATION STRATEGIES FOR LARGE BULK WATER SUPPLY SYSTEMS: ORANGE RIVER

Current and Future Urban/Industrial Water Requirements

EXECUTIVE SUMMARY

The Department of Water Affairs (DWA) has identified the need for detailed water resource management strategies as part of their Internal Strategic Perspective (ISP) planning initiative, which recommended studies to identify and formulate intervention measures that will ensure enough water can be made available to supply the water requirements for the next three to four decades.

As part of this process the need for the Reconciliation Strategy Study for the Large Bulk Water Supply Systems in the Orange River was also defined. Given the location of the Orange River System and its interdependencies with other WMAs as well as other countries, various water resource planning and management initiatives compiled during the past few years as well as those currently in progress will form an integral part of the strategy development process.

Since 1994, a significant driver of change in the water balance of the Orange River System was brought about by the storing of water in Katse Dam as the first component of the multi-phase Lesotho Highlands Water Project (LHWP). Currently Phase 1 of the LHWP (consisting of Katse, and Mohale dams, Matsoku Weir and associated conveyance tunnels) transfers 780 million cubic metres per annum via the Liebenbergsvlei River into the Vaal Dam to augment the continuously growing water needs of the Gauteng Province. Phase 2 of the LWHP comprising of Polihali Dam and connecting tunnel to Katse Dam is already in its planning stages. Polihali Dam is expected to be in place by around 2022. Flows that are currently still entering into Gariep and Vanderkloof dams wil then be captured by Polohali Dam, thus reducing the inflow to Gariep and Vanderkloof dams. This will result in a reduction in yield of the Orange River Project (Gariep and Vanderkloof dams) to such an extent that shortages will be experienced in the ORP system. Some sort of yield replacement is then required in the Orange River to correct the yield versus demand imbalance in the ORP system.The objective of the study is to develop a reconciliation strategy for the bulk water resources of the Orange River System, to ensure that sufficient water can be made available to supply the current and future water needs for a 25 year planning horison. This Strategy must be flexible to accommodate future changes in the actual water requirements and transfers, with the result that the Strategy will evolve over time as part of an on-going planning process.

Appropriate integration with other planning and management processes as well as cooperation among stakeholders will be key success factors in formulating coherent recommendations and action plans.

Purpose

The purpose of this report is to document and describe the current urban/industrial and mining demands as well as the projected future demands. A comprehensive record of historical water usage and return flows will be determined and documented in the report. The methodology followed to develop different growth demand scenarios will be explained and results included in this report. The water demand information will take cognisance of the supply from groundwater since some of the areas are supplied from groundwater and opportunities to further develop and utilise groundwater exist in the study area.

Although not the main focus of this report, information on water requirements for a few other components or sectors will also be included in this report such as river and operational requirements and main system transfers. A section will be included in the report providing a summary on the current and possible future environmental requirements as obtained from the current Environmental Flows project by ORASECOM UNDP-GEF. Reference will also be included on the current hydro-power generation requirements. Irrigation requirements will be addressed in a separate report (Irrigation Demands and Water Conservation/Water Demand management Report no. P RSA D000/00/18312/6).

Methodology

All data sources and information from past studies were reviewed. The Development of Reconciliation Strategies for All Towns in the Central Region was used as the main resource for urban water requirements and projections in the Orange River Basin and compared to the latest data releases. Selected All Town strategies (DWA, 2011) within the Northern and Southern regions were also used. Discussions were held with relevant district and local municipalities when required.

The All Towns Study developed three scenarios for water requirement projections according to each of the town's population projections. Scenario lll was used in the All Towns Study for Planning Purposes and was also adopted for use in this study. Scenario lll entails the following:

> *Scenario III: The level of service was assumed to be at a minimum of Residential (Low Income) by 2015, with a 5% growth in Residential (Medium Income) by 2015 and a further 15% growth in Residential (Medium Income) by 2030 (total growth in Residential (Medium Income) of 20%)*

The base information for the current and future mining water requirements were sourced from the Lower Orange Management Study (DWAF, 2004). Discussions were as part of this study held with mining managers and water user associations where possible. The information was processed and validated by comparison with information in previous reports.

Urban Industrial Demand Projections

The urban/industrial demand is expected to grow from the current 230 million m^3/a in 2012 to almost 450 million m^3/a by 2040. Bloemfontein/Mangaung, Botshabelo and Thaba N'Chu demand centre is the largest demand centre in the study area at 83.4 million m^3/a in 2012 followed by the Eastern Cape at 42.3 million m^3/a, Upington at 16.0 million m^3/a, Maseru at 14.3 million m^3/a and Namakwa Water Board at 10.3 million m^3/a. The bulk of the urban/industrial requirements, approximately 87%, are located in the RSA with 8% in Lesotho and 5% in Namibia at 2012 development level.

Table i: Urban Industrial Demand Projections within the study area (million m^3/a)

SUB-SYSTEM	2012	2015	2020	2025	2030	2035	2040
Caledon	10.527	11.834	13.256	14.681	16.122	17.563	19.004
Upper Orange (excluding Eastern Cape transfer)	18.121	20.399	21.453	22.357	23.564	24.767	25.970
Eastern Cape Urban	42.381	70.985	72.073	73.300	74.527	75.727	76.927
Riet Modder	92.629	95.178	111.107	130.189	152.190	177.575	204.002
Lower Vaal (Douglas)	2.120	2.422	2.729	3.004	3.258	3.512	3.766
Lower Orange	32.919	34.819	36.372	37.963	39.600	41.237	42.873
Total RSA	**198.698**	**235.637**	**256.990**	**281.494**	**309.262**	**340.381**	**372.543**
Senqu/Makaleng	1.029	1.205	1.564	2.033	2.650	3.469	4.288
Mohokare (Caledon)	17.773	21.484	27.702	34.981	42.315	49.711	57.108
Total Lesotho	**18.802**	**22.688**	**29.266**	**37.014**	**44.965**	**53.180**	**61.396**
Lower Orange	8.768	8.940	9.378	9.474	9.569	9.665	9.760
Fish River Namibia	2.902	2.902	2.902	2.902	2.902	2.902	2.902
Total Namibia	**11.670**	**11.842**	**12.280**	**12.375**	**12.471**	**12.566**	**12.662**
Total Urban Industrial	**229.170**	**270.167**	**298.537**	**330.884**	**366.697**	**406.127**	**446.600**

The mining water requirements are significantly less than the urban/industrial requirements at 16 million m^3/a in 2012 increasing to almost 33 million m^3/a by 2040. The decrease evident in the mine demands from 2015 to 2020 is as result of the closing down of the Trans Hex mine followed by opening up of other Trans Hex mining activities.

Table ii: Mining Demand Projections within the study area (million m^3/a)

SUB-SYSTEM	2012	2015	2020	2025	2030	2035	2040
Riet Modder	1.500	1.690	2.005	2.321	2.637	2.953	3.269
Lower Orange	6.963	19.131	16.786	16.943	17.100	17.258	17.416
Total RSA	**8.463**	**20.820**	**18.791**	**19.264**	**19.738**	**20.211**	**20.685**
Lower Orange	7.642	10.745	10.973	11.224	11.474	11.725	11.975
Total Namibia	**7.642**	**10.745**	**10.973**	**11.224**	**11.474**	**11.725**	**11.975**
Total Mining	**16.105**	**31.565**	**29.764**	**30.487**	**31.212**	**31.936**	**32.661**

The bulk of the return flows are generated from the Bloemfontein/Mangaung, Botshabelo, Thaba N'Chu demand centre of almost 42 million m^3/a in 2012 followed by 5.2 million m^3/a for Upington.

Table iii: Main Urban Return Flows within the study area

Sub-System	Description	2012 Gross Demand (million m^3/a)	2012 Return Flows (million m^3/a)	Percentage Return Flow (%)
Caledon	Maseru	14.264	1.820	12.8
	Ficksburg	2.932	1.466	50.0
Upper Orange	Aliwal North	1.838	0.919	50.0
Riet/Modder	Bloemfontein	68.946	35.321	51.23
	Botshabelo	9.625	4.139	43.00
	Thaba N'Chu	4.846	2.423	50.00
Lower Orange Main Stem	Upington	14.644	5.222	35.7
Total		121.189	52.546	43.4

***Riverine and operational requirements** from the lower Orange River System represent important "demands" that need to be taken into account. The riverine requirements are a natural phenomenon to both regulated and unregulated rivers. In the case of unregulated rivers the actual volume of these requirements is seldom quantified, as it is included in the hydrology process used to determine the natural runoff. In the event of the Orange River where water is released from Vanderkloof Dam and conveyed by means of the river to users as far as 1 380 km downstream from the point of release, it is of utmost importance to obtain a good estimation of the actual volume of the riverine requirements. These riverine requirements are mainly due to evaporation from the river surface area, but also include seepage losses and evapo-transpiration from the riparian vegetation. The riverine requirements for the Orange River downstream of Vanderkloof Dam was determined as 615 million m^3/a under normal operational conditions, based on findings from the WRC Report No 638/1/99, dated December 1998.*

Some of the demand centres are located along the Orange River over a length of approximately

1 380 km, which, together with riverine requirements and unpredictable heat waves, results in increased demands over the short-term. Unlawful abstractions as well as inflows from the Vaal and Fish rivers, further contribute to the complexity of operating the system and to be able to determine how much water need to be released from Vanderkloof Dam. A further complication concerns releases from Vanderkloof Dam to generate hydropower, which are sometimes in excess of the downstream demands. The large controlling structures (sluice gates, hydro-power turbines etc.), at Vanderkloof Dam make it very difficult to release the required flow with accuracy. As a result of the problems mentioned above, it is clear that some operational requirement should be allowed for. Operational requirements are currently estimated to be in the order of a 180 million m^3/a, which is significantly less than the initial 356 million m^3/a estimated in 1999.

***Environmental flows** in a river are the flow required to maintain the ecosystem in a negotiated ecological condition. This condition is normally a compromise between social, economic and ecological values of water for various uses. Environmental requirements are dependent on the natural flow generated in the upstream catchments and therefore differ from month to month and for each year. The environmental flows to be released from the LHWP main structures are the product of negotiations between the Lesotho Highlands Development Authority (LHDA), the governments of Lesotho, South Africa, Namibia, the World Bank and various other interested and affected parties. These agreed on environmental flows depends on the generated natural streamflow from the upstream catchment and vary between 19% and 40% of the mean annual runoff at the specific site and were already included in the current models and used in analyses for quite some time.*

The Vaal River is one of the largest tributaries of the Orange River. The environmental water requirements (EWRs) released from the Vaal to finally enter the Orage River just downstream of Douglas will thus impact on the available flow in the Orange River and need to be taken into account. The most recent environmental water requirements (EWRs) available for the Integrated Vaal River System (IVRS) were determined in the study "Classification of Significant Water Resources in the Upper, Middle and Lower Vaal Water Management Areas". The purpose of the study was to determine the Reserve that needs to be implemented in the IVRS. These results are available and will be used in the Orange Reconciliation Study. Conclusions from the Classification Study stated that the EWR structures that need to be included in future are EWR 8 and EWR IFR1. At EWR 8 in the Wilge River the releases from Sterkfontein Dam should try to mimic a seasonal release pattern, but at the same time limit the reduction in the firm supply from Vaal Dam. Changes in EWR 8 will however have very small impacts if any on the Orange system. The inclusion of EWR IFR 1 at Douglas at the downstream end of the Vaal River, results in a significant reduction in the yield available from the Vaal. It will therefore not be easy to implement this in practise. The Douglas EWR will also have a direct impact on the Orange and will therefore be the most important EWR to take into account in the scenarios to be analysed for the purpose of the Orange Recon Study.

*Updated environmental requirements were determined for the Orange River as part of the ORASECOM study "**Support to Phase II ORASECOM basin wide integrated water resources management plan" dated November 2010. These environmental flow requirements EFRs were assessed at an Intermediate Level at selected key areas of the Orange River basin.***

***Further environmental flow work is currently being done under the ORASECOM study "UNDP-GEF Orange-Senqu Strategic Action Programme: Research Project on Environmental Flow Requirements of the Fish River and the Orange-Senqu River Mouth*". *The focus of this study is on the Orange River Mouth requirement and the Fish River in Namibia as well as the Orange River downstream of the confluence of the Fish with the Orange River. The work on this ORASECOM study is completed and the reports are currently in process. A summary of the results from the ORASECOM GEF study can therefore not yet be included in this report, but will be added as soon as the relevant reports are available.*

Several transfer systems *are located in the study area. These transfers include:*

- *The Lesotho Highlands Transfer Scheme, transferring water from Katse Dam in Lesotho to the Vaal System in the RSA. The transfer volume has been phased in over a number of years and has already reached its maximum agreed transfer volume of 780 million m^3/a. With Phase 2 (Polihali Dam) in place the maximum transfer volume will be increased by an additional 460 million m^3/a. Phase 2 is expected to start delivering water to the RSA by 2022.*

- *The Caledon/Modder transfer system is used to support the water supply to Bloemfontein, Mangaung, Botshabelo, Thaba N'chu and several small towns located in the Modder/Riet River catchment. The total volume transferred depends on the combination of the water requirements and the water levels the dams within the Modder Riet River basin. The maximum volume that can currently be transferred is 88 million m^3/a (2.79 m^3/s).*

- *The Orange/Fish tunnel transfer to the Eastern Cape from Gariep Dam. Water is distributed through a combination of canals, tunnels, balancing dams and natural river courses to irrigators and small towns to eventually reach the Port Elizabeth (Nelson Mandela Bay Metro) abstraction point near the downstream end of the Sundays River. For the year 2012 the transfer volume was determined as 620 million m^3/a, of which 577.6 million m^3/a was used for irrigation and 42.4 million m^3/a for urban/industrial purposes.*

- *The Orange/Riet Transfer scheme abstracts water from Vanderkloof Dam, to be transferred to the Riet River catchment. The water is primarily used for irrigation but is also used to supply the urban requirements of Koffiefontein, Richie and Jacobsdal. The total volume transferred is in the order of 260 million m^3/a, and depends on the scheduled irrigation area and urban demands. From time to time an additional 5 million m^3/a is released through the canal, to improve the water quality situation in the Lower Riet. It is expected that the irrigation in this area will significantly increase over time due to the development of resource poor farmers with allocations from Vanderkloof Dam. This will be dealt with in the Irrigation Report prepared as part of this study.*

- *The Orange-Vaal transfer scheme is mainly used for irrigation purposes but also to supply the town of Douglas with water as well as to improve the quality of the water in the Douglas weir. The volume transferred depends on the water available in the Vaal River and the water level in the Douglas Weir. The volume transferred can therefore vary considerably* *from year to year, but is in the order of 120 million m^3/a, to a maximum of 142 million m^3/a.*

Most of these transfers are already captured by the demands given in this report except for the Lesotho Highlands Transfer Scheme. The irrigation demand component of the transfer to the Eastern Cape will however be addressed in the Irrigation report prepared as part of this study. The largest of these large transfers is the transfer from the Lesotho Highlands to the Vaal River system, in support of Vaal Dam and is followed by the Eastern Cape transfer system as the second largest.

***Possible new future users** to be considered in the planning process of the Orange River System include:*

- *The Karoo hydraulic fracturing project. Initial estimates of water use are 0.24 million m^3/a in 2014 and 2015 increasing to 4 million m^3/a by 2022 during the production phase, if the project is allowed to go ahead.*
- *Solar Power. Eskom is planning a Solar Park at Olyvenhoutsdrift, 15 km west of Upington in the Northern Cape and Solafrica is proposing the construction of a 75 MW CSP Plant on the Farm Bokpoort situated in the !Kheis Local Municipality. The expected water requirements for these two plants are in the order of 1.7 million m^3/a and 0.85 million m^3/a respectively but with the Eskom plant increasing over time to almost 10 million m^3/a by 2030. Several licences were issued for smaller solar power plants along the Lower Orange requiring approximately 0.11 million m^3/a water supply from the Orange River.*
- *Square Kilometre Array Radio Telescope (SKA) Development. From now until 2016 South Africa will be constructing 64 Meerkat dishes in the Karoo. The construction of another 190 SKA Phase 1 dishes is then expected to start. Phase 2 of the SKA project is planned to start in 2019 and to be completed by 2024. The SKA development will be constructed in the Northern Cape Province, about 80 km from the town of Carnarvon. Licences for groundwater were already obtained for the Meerkat project and includes a total of 118 802 m^3/a (0.119 million m^3/a). No information is yet available on the phase 1 and 2 water requirements of the SKA project only for the Meerkat component of the project.*
- *Possible future hydropower generation at Augrabies. Three Companies RVM 1 Hydro Electric Power (Pty) Ltd, RVM 2 Hydro Electric Power (Pty) Ltd & RVM 3 Hydro Electric Power (Pty) Ltd are investigating the possible construction of one 10 Megawatt (MW) and one 9.9MW hydropower station on the Orange River, on the farm Riemvasmaak1, north of the Augrabies Falls. These will however be non-consumptive use.*

Conclusions and Recommendations

The total urban industrial demand within the study area that is supplied from surface water resources is in the order of 230 million m^3/a at 2012 development level and is expected to increase *to almost 450 million m^3/a by 2040. Although this is a significant volume, it most probably only represents in the order of 5% of the total water use from the study area.*

The high water demand scenario as obtained from the All Town Study was in general used for all the urban/industrial demand projections applicable to the RSA part of the study area. This projection is probably a slight overestimation of the future demand. A new adjusted high demand is currently being developed for the "Continuation and Maintenance of Reconciliation Strategies for All Towns in the Central Region" study. This is however not yet available. It is recommended that this adjusted high demand projection be considered for use in the second phase of the Orange Reconciliation Study.

The water requirements for Namibia are currently updated to a more detailed level as part of an ORASECOM project. This data is not yet available and it is recommended to use this updated information for the final strategy to be developed for the Orange Reconciliation Strategy study.

Development of Reconciliation Strategies for for Large Bulk Water Supply Systems: Orange River

Current and Future Urban/Industrial Water Requirements

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Development of a Reconciliation Strategies for Large Bulk Water Supply Systems: Orange River

Current and Future Urban/Industrial Water Requirements

1 INTRODUCTION

1.1 BACKGROUND

The Department of Water Affairs (DWA) has identified the need for detailed water resource management strategies as part of their Internal Strategic Perspective (ISP) planning initiative, which recommended studies to identify and formulate intervention measures that will ensure enough water can be made available to supply the water requirements for the next three to four decades.

The DWA Directorate: National Water Resource Planning (NWRP) therefore commenced the strategy development process in 2004 by initially focusing on the water resources supporting the large metropolitan clusters, followed by the systems supplying the smaller urban areas to systematically cover all the municipalities in the country.

As part of this process the need for the Reconciliation Strategy Study for the Large Bulk Water Supply Systems in the Orange River was also defined. Given the location of the Orange River System and its interdependencies with other WMAs as well as other countries (see study area description in **Section 1.3**), various water resource planning and management initiatives compiled during the past few years as well as those currently in progress will form an integral part of the strategy development process.

Major water resource infrastructure in the study area are the Gariep and Vanderkloof dams with associated conveyance conduits supporting large irrigation farming in the provinces of the Free State, Northern Cape and the Eastern Cape - through the Orange-Fish Tunnel. This system is currently almost in balance.

The Caledon-Modder System supplies water to the Mangaung-Bloemfontein urban cluster (largest urban centre in the study area). The 2 200 km long Orange-Senqu River is the lifeline for various industries, mines, towns and communities located along the way until the river discharges into the Atlantic Ocean in the far west at Alexander Bay.

Since 1994, a significant driver of change in the water balance of the Orange River System was brought about by the storing of water in Katse Dam as the first component of the multi-phase Lesotho Highlands Water Project (LHWP). Currently Phase 1 of the LHWP (consisting of Katse, and Mohale dams, Matsoku Weir and associated conveyance tunnels) transfers 780 million cubic metres per annum via the Liebenbergsvlei River into the Vaal Dam to augment the continuously growing water needs of the Gauteng Province. Phase 2 of the LWHP comprising of Polihali Dam and connecting tunnel to Katse Dam is already in its planning stages and is expected to be in place by 2022. Flows that are currently still entering into Gariep and Vanderkloof dams will then be captured by Polohali Dam, thus reducing the inflow to Gariep and Vanderkloof dams. This will result in a reduction in yield of the Orange River Project (Gariep and Vanderkloof dams) to such an extent that shortages will be experienced in the ORP system. Some sort of yield replacement is then required in the Orange River to correct the yield versus demand imbalance in the ORP system.

The above description illustrates the complex assortment of interdependent water resources and water uses which spans across various international and institutional boundaries that will be considered in the development of the Orange River Reconciliation Strategy.

1.2 MAIN OBJECTIVES OF THE STUDY

The objective of the study is to develop a reconciliation strategy for the bulk water resources of the Orange River System, to ensure that sufficient water can be made available to supply the current and future water needs of all the users up to the year 2040. This Strategy must be flexible to accommodate future changes in the actual water requirements and transfers, with the result that the Strategy will evolve over time as part of an on-going planning process.

Appropriate integration with other planning and management processes, as well as cooperation among stakeholders, will be key success factors in formulating coherent recommendations and action plans.

The outcomes of the Strategy will be specific interventions with particular actions needed to balance the water needs with the availability through the implementation of regulations, demand management measures, as well as infrastructure development options.

1.3 STUDY AREA

As depicted in **Figure A-1** of **Appendix A** (Map of study area), the study will focus on the water resources of the Upper and Lower Orange River Water Management Areas (WMAs), while also considering all the tributary rivers and transfers affecting the water balance of the system. This core area forms part of the Orange-Senqu River Basin, which straddles four International Basin States with the Senqu River originating in the highlands of Lesotho, Botswana in the north eastern part of the Basin, the Fish River in Namibia and the largest area situated in South Africa.

The focus area of the study comprises only the South African portion of the Orange River Basin, excluding the Vaal River Catchment. The Vaal River is an important tributary of the Orange River, but since the Vaal River Reconciliation Strategy has already been developed, the Vaal River

Catchment will not form part of the study area. However, strategies developed for the Vaal River System that will have an impact on the Orange River, will be taken into account as well as the impacts of flows from the Vaal into the Orange for selected Integrated Vaal system scenarios.

The Orange River is an international resource, shared by four countries i.e. Lesotho, South Africa, Botswana and Namibia. Any developments, strategies or decisions taken by any one of the countries that will impact on the water availability or quality in South Africa must be taken into account and will form part of this study. The opposite is also applicable. If this strategy plans anything in South Africa that will impact on any of the other countries, this impact must be considered as part of this study in terms of South Africa's international obligations.

The Orange River, the largest river in South Africa, has its origin in the high lying areas of Lesotho. The river drains a total catchment area of about 1 million km^2, runs generally in a westerly direction and finally discharges into the Atlantic Ocean at Alexander Bay.

The Caledon River, forming the north-western boundary of Lesotho with the Republic of South Africa (RSA), is the first major tributary of the Orange River. The Caledon and the Orange (called the Senqu River in Lesotho) rivers have their confluence in the upper reaches of the Gariep Dam.

Other major tributaries into the Orange River are:

- The Kraai River draining from the North Eastern Cape.
- The Vaal River joining the Orange River at Douglas.
- The Ongers and Sak Rivers draining from the northern parts of the Karoo.
- The Molopo and Nossob Rivers in Namibia, Botswana and the Northern Cape Province have not contributed to the Orange River in recorded history as the stream bed is impeded by sand dunes.
- The Fish River draining the southern part of Namibia.

A separate study was also done for the Greater Bloemfontein Area i.e. Water Reconciliation Strategy Study for Large Bulk Water Supply Systems: Greater Bloemfontein Area with it's follow up continuation study currently in process. The recommendations of this strategy and its continuation study will also be taken into account in this study.

Although the Senqu River Catchment in Lesotho does not form part of the focus study area, the development in this catchment impacts directly on the water availability in the study area.

The South African portion of the Orange River Basin is currently divided in two Water Management Areas, i.e. the Upper and Lower Orange WMAs. The Upper WMA stretches from the headwaters of the Caledon River and Lesotho boundary down to the confluence of the Vaal River and the Lower Orange WMA from this point to the sea. (See **Figure A-1 in Appendix A**). It should be noted that the DWA recently proposed that the two WMAs are managed as a unit.

1.4 PURPOSE OF THE REPORT

The purpose of this report is to document and describe the current urban/industrial and mining demands as well as the projected future demands. A comprehensive record of historical water usage and return flows will be determined and documented in the report. The methodology followed to develop different growth demand scenarios will be explained and results included in this report.

The water demand information will take cognisance of the supply from groundwater since some of the areas are supplied from groundwater and opportunities to further develop and utilise groundwater exist in the study area. Details on groundwater resources and related supply and demands will however be documented in a separate report (DWA, 2014).

Although not the main focus of this report, information on water requirements for a few other components or sectors will also be included in this report such as river and operational requirements and main system transfers. A section will be included in the report providing a summary on the current and possible future environmental requirements as obtained from the current Environmental Flows project by ORASECOM UNDP-GEF. Reference will also be included on the current hydro-power generation requirements. Irrigation requirements will be addressed in a separate report.

1.5 REPORT LAYOUT

Chapter two of the report focus on the methodology used to determine the urban industrial and mining requirements. The urban/industrial requirements are discussed in **Sections 3** to **5** for the RSA, Lesotho and Namibia respectively. On a similar basis the mining demands are covered in **Sections 6** and **7** for the RSA and Namibia respectively. In **Section 8** the return flows from the urban/industrial sector are covered. Possible new water users for the future are addressed in **Section 9**. The riverine and operational requirements represents quite a large portion of the total demand imposed on the system and is covered in **Section 10**. The major transfer systems and related transfer volumes are described in **Section 11** and the environmental requirements summarised in **Section 12**. Although the volumes used for existing hydro-power generation is a non-consumptive requirement, it is briefly described in **Section 13**.

2 METHODOLOGY

Domestic water requirements are largely driven by the population and socio-economic circumstances. All data sources and information from past studies were reviewed. The Development of Reconciliation Strategies for All Towns in the Central Region (DWA, 2011) was used as the main resource for urban water requirements and projections in the Orange River Basin and compared to the latest data releases. Selected All Town strategies within the Northern and Southern regions were also used. Discussions were held with relevant district and local municipalities when required.

The All Towns Study developed three scenarios for water requirement projections according to each of the town's population projections. The three scenarios are described as follows:

- Scenario I: Constant level of service (LOS) throughout the projection period
- Scenario II: LOS assumed to be at a minimum of RDP level by 2015, with a 5% growth in Residential (Low Income) by 2015 and a further 15% growth in Residential (Low Income) by 2030 (total growth in Residential (Low Income) of 20%)
- Scenario III: LOS assumed to be at a minimum of Residential (Low Income) by 2015, with a 5% growth in Residential (Medium Income) by 2015 and a further 15% growth in Residential (Medium Income) by 2030 (total growth in Residential (Medium Income) of 20%)

Where the All Towns Study water requirement projections were applied in this study, the high projection (Scenario III) was used.

The base information for the current and future mining water requirements were sourced from the Lower Orange Management Study **(DWAF, 2004)**. Aspart of the current study discussions were also held with mining managers and water user associations where possible. The Lower Orange Management Study collected information on water requirements for urban and mining consumers through questionnaires and directly from bulk suppliers of water, both in South Africa and Namibia. The information was processed and validated by comparison with information in previous reports.

For the most part, water requirement projections obtained from past studies extended up to the year 2025 or 2030. In those cases the growth rate for the last five years of the projection were applied to extrapolate the projections to the year 2040.

3 URBAN AND INDUSTRIAL RSA

RSA study area includes the sub-systems of the Caledon, Upper Orange, Lower Vaal, Riet/Modder, and Lower Orange Main stem. The water requirements provided in the All Towns Study (**DWA, 2011**) was used for most towns, however a description of updated or alternative data that was used for individual towns is provided below.

An updated 2011 demand for Prieska was obtained from the Water Demand Management Strategy and Business Plan for Siyathemba Local Municipality **(DWA, 2012)**. The same growth rate used in the All Towns Study projection was applied to the updated demand.

For the demand centres that are partly supplied from Kalkfontein Dam (Koffiefontein, Jacobsdal, Jagersfontein, Fauresmith, and De Beers mines) updated demands for 2012 was obtained from the Kalkfontein Scheme Report **(DWA, 2013)** which is part of the study called "Establishment of Drought Operating Rules for Stand Alone Dams and Schemes typical of Rural/Small Municipal Water Supply Schemes (Central Region)". Most of these towns also receive water from groundwater and from the the Orange/Riet canal. For the projections, the same growth rate used in the All Towns Study was applied to the updated demands.

Updated water requirement projections for Ficksburg, Clocolan and Marquard were obtained from the Ficksburg, Clocolan, Marquard Water Supply System Analysis Report **(DWA, 2013).**

In the Upper Orange Catchment, the water requirement projections for the Gariep Fish Breeding Station, Aventura, and Orania were sourced from the Orange River System 2012/2013 System Analysis (DWA, 2012).

Water requirement projections for Bloemfontein, Thaba N'chu and Botshabelo, as well as the smaller towns of Wepener, Dewetsdorp, Reddersburg, Edenburg, and Excelsior were obtained from the Reconciliation Strategy Report for the Large Bulk Water Supply Systems of the Greater Bloemfontein Area (DWA, 2012). A number of different growth scenarios were performed in the Greater Bloemfontein Reconciliation Study. The high growth (3% per annum) with the most probable water conservation and water demand management scenario was used for the purposes of this assessment.

The Lower Orange Management Study (DWAF, 2004) was used as a basis for the water requirement projections for Boegoeberg small users and the Karos-Geelkoppan Scheme

The historic and current urban/industrial RSA water requirements are provided in **Table 3-1**, and the future water requirements are shown in **Table 3-2**.

Table 3-1 Urban and Industrial RSA Historic and Current Water requirements (million m^3/a)

SUB-SYSTEM	DESCRIPTION	2009	2010	2011	2012
Caledon	Ladybrand, Ficksburg, Clocolan	5.993	6.446	6.741	7.035
	Van Stadensrus	0.063	0.066	0.068	0.071
	Rouxville	0.475	0.499	0.522	0.544
	Smithfield	0.397	0.414	0.435	0.455
	Tweespruit	0.611	0.616	0.626	0.637
	Thaba Patchoa & Hobhouse	0.213	0.224	0.233	0.242
	Fouriesburg & Clarens	1.309	1.390	1.466	1.542
Sub-Total Caledon		**9.061**	**9.655**	**10.091**	**10.527**
Upper Orange	Sterkspruit	3.845	4.380	4.733	5.087
	Zastron & Lady Grey	1.541	1.581	1.638	1.694
	Aliwal North	1.578	1.667	1.753	1.838
	Molteno	0.406	0.409	0.414	0.418
	Burgersdorp	0.639	0.663	0.685	0.707
	Dordrecht	0.228	0.235	0.267	0.299
	Jamestown	0.117	0.121	0.126	0.131
	Rhodes & Barkley East	0.456	0.477	0.492	0.508
	Eastern Cape Urban (1)	35.365	38.719	42.114	42.381

SUB-SYSTEM	DESCRIPTION	2009	2010	2011	2012
	Urban between Gariep and Vanderkloof [(2)]	5.045	5.134	5.247	5.359
	Hopetown, Vanderkloof & Petrusville	1.867	1.936	2.008	2.081
Sub-Total Upper Orange		**51.087**	**55.321**	**59.475**	**60.503**
Lower Vaal	Douglas	1.826	1.919	2.020	2.120
Sub-Total Lower Vaal		**1.826**	**1.919**	**2.020**	**2.120**
Riet/Modder	Botshabelo Abstractions	9.209	7.873	10.060	9.625
	Manguang LM Demand supplied from Rustfontein	30.132	27.713	22.720	31.493
	Thaba N'Chu Demand	4.637	6.041	6.298	4.846
	Bloemfontein from Welbedacht, Rustfontein, Knellpoort and Mockes	35.833	37.102	37.914	37.453
	Small users abstracting along Welbedacht pipeline [(3)]	3.294	3.113	2.524	3.443
	Kalkfontein Urban	3.176	3.121	3.067	3.012
	Krugersdrift Urban	0.532	0.554	0.576	0.599
	Richie, Luckhoff, and Oppermans	1.808	1.923	2.041	2.158
Sub-Total Riet/Modder		**88.619**	**87.440**	**85.198**	**92.629**
Lower Orange Main Stem	Prieska Urban Demand	1.567	1.592	1.624	1.657
	Boegoeberg Small users	0.600	0.600	0.600	0.600
	Karos Geelkoppan	0.040	0.040	0.040	0.040
	Upington and Others Urban [(4)]	14.413	14.933	15.450	15.966
	Kakamas Urban Demand	2.111	2.188	2.258	2.327
	Pelladrift Water Board [(5)]	3.906	3.922	3.937	3.951
	Namakwa Water Board [(6)]	10.294	10.294	10.294	10.294
Sub-Total Lower Orange Main Stem		**31.015**	**31.653**	**32.286**	**32.919**
Total Urban/Industrial RSA		**119.634**	**119.093**	**117.484**	**125.548**

Notes: [(1)] - Includes Cradock, Grahamstown, Enon, Addo, Kirkwood, Goodhouse, Somerset East, Bedfort and part of the Nelson Mandela Bay Metro demand.

[(2)] - Includes Gariep fish breeding station, Aventura, Venterstad, Norvalspont, Colesberg, Gariep, Trompsburg, Springfontein, Bethuli and Phillipolis.

[(3)] – Includes Excelsior, Wepener, Dewetsdorp, Reddersburg and Edenburg.

[(4)] – Includes Upington, Grobleshoop and solar enegergy water requirements

[(5)] – Includes Pella, Onseepkans, Pofadder, Aggeneys and Black Mountain Mine.

[(6)] – Includes Concordia, Sprinbok Cluster and De Beers Mine, Kleinsee and Steinkopf.

Table 3-2 Urban and Industrial RSA Estimated Future Water Requirements (million m^3/a)

SUB-SYSTEM	DESCRIPTION	2012	2015	2020	2025	2030	2035	2040
Caledon	Ladybrand, Ficksburg & Clocolan	7.035	7.919	9.063	10.210	11.367	12.523	13.679
	Van Stadensrus	0.071	0.079	0.085	0.092	0.099	0.106	0.113
	Rouxville	0.544	0.611	0.667	0.721	0.777	0.834	0.890
	Smithfield	0.455	0.516	0.557	0.600	0.645	0.690	0.735
	Tweespruit	0.637	0.670	0.678	0.685	0.691	0.697	0.703
	Thaba Patchoa & Hobhouse	0.242	0.270	0.291	0.313	0.336	0.359	0.382
	Fouriesburg & Clarens	1.542	1.770	1.915	2.060	2.207	2.354	2.501
Sub-Total Caledon		**10.527**	**11.834**	**13.256**	**14.681**	**16.122**	**17.563**	**19.004**
Upper Orange	Sterkspruit	5.087	6.147	6.305	6.449	6.762	7.075	7.388
	Zastron & Lady Grey	1.694	1.864	1.867	1.869	1.879	1.890	1.900
	Aliwal North	1.838	2.095	2.219	2.332	2.504	2.677	2.850
	Molteno	0.418	0.433	0.456	0.478	0.500	0.512	0.524
	Burgersdorp	0.707	0.773	0.827	0.875	0.945	1.015	1.085
	Dordrecht	0.299	0.394	0.553	0.597	0.641	0.691	0.741
	Jamestown	0.131	0.145	0.162	0.178	0.204	0.229	0.255
	Rhodes & Barkley East	0.508	0.554	0.571	0.586	0.615	0.645	0.675
	Eastern Cape Urban (1)	42.381	70.985	72.073	73.300	74.527	75.727	76.927
	Urban between Gariep and Vanderkloof (2)	5.359	5.696	5.997	6.297	6.611	6.925	7.239
	Hopetown, Vanderkloof & Petrusville	2.081	2.298	2.496	2.698	2.903	3.108	3.313
Sub-Total Upper Orange		**60.503**	**91.384**	**93.526**	**95.657**	**98.091**	**100.494**	**102.897**
Lower Vaal	Douglas	2.120	2.422	2.729	3.004	3.258	3.512	3.766
Sub-Total Lower Vaal		**2.120**	**2.422**	**2.729**	**3.004**	**3.258**	**3.512**	**3.766**
Riet/ Modder	Botshabelo Abstractions	9.625	9.827	11.505	13.535	15.889	18.617	21.461
	Manguang LM Demand supplied from Rustfontein	31.493	32.156	37.644	44.287	51.989	60.917	70.223
	Thaba N'Chu Demand	4.846	4.948	5.793	6.815	8.000	9.374	10.806
	Bloemfontein	37.453	38.240	44.767	52.668	61.826	72.444	83.511
	Small users abstracting along Welbedacht pipeline(3)	3.443	3.515	4.115	4.841	5.683	6.659	7.677
	Kalkfontein Urban	3.012	3.315	3.819	4.324	4.828	5.333	5.837
	Krugersdrift Urban	0.599	0.666	0.757	0.820	0.882	0.943	1.004

SUB-SYSTEM	DESCRIPTION	2012	2015	2020	2025	2030	2035	2040
	Richie, Luckhoff, and Oppermans	2.158	2.511	2.706	2.898	3.094	3.289	3.484
Sub-Total		**92.629**	**95.178**	**111.107**	**130.189**	**152.190**	**177.575**	**204.002**
Lower Orange Main Stem	Prieska Urban Demand	1.657	1.753	1.875	2.002	2.131	2.260	2.389
	Boegoeberg Small users	0.600	0.600	0.600	0.600	0.600	0.600	0.600
	Karos Geelkoppan	0.040	0.040	0.040	0.040	0.040	0.040	0.040
	Upington and Others Urban[(4)]	15.966	17.517	18.687	19.890	21.217	22.363	23.600
	Kakamas Urban Demand	2.327	2.536	2.758	2.974	3.199	3.424	3.649
	Pelladrift Water Board[(5)]	2.035	2.078	2.118	2.163	2.209	2.255	2.302
	Namakwa Water Board[(6)]	10.294	10.294	10.294	10.294	10.294	10.294	10.294
Sub-Total		**32.919**	**34.819**	**36.372**	**37.963**	**39.600**	**41.237**	**42.873**
Total Urban/Industrial RSA		**198.698**	**235.637**	**256.990**	**281.494**	**309.262**	**340.381**	**372.543**

Notes: [(1)] - Includes Cradock, Grahamstown, Enon, Addo, Kirkwood, Goodhouse, Somerset East, Bedfort and part of the Nelson Mandela Bay Metro demand.

[(2)] - Includes Gariep fish breeding station, Aventura, Venterstad, Norvalspont, Colesberg, Gariep, Trompsburg, Springfontein, Bethuli and Phillipolis.

[(3)] – Includes Excelsior, Wepener, Dewetsdorp, Reddersburg and Edenburg.

[(4)] – Includes Upington, Grobleshoop and solar enegergy water requirements

[(5)] – Includes Pella, Onseepkans, Pofadder, Aggeneys and Black Mountain Mine.

[(6)] – Includes Concordia, Sprinbok Cluster and De Beers Mine, Kleinsee and Steinkopf.

4 URBAN AND INDUSTRIAL LESOTHO

The current and future water requirements for the demand centres in Lesotho were obtained from The Lesotho Water Sector Improvement Project Second Phase. During that project actual demands were received for the 2009 and 2010 years from the Water and Sewerage Company (WASCO). Demand projections were based on the growth used in the Orange River Integrated Water Resources Management Plan, Summary of Water Requirements from the Orange River Report (ORASECOM, 2007). For the demand centres that will be supplied from Metolong Dam (Teyateyaneng, Maseru, Roma, Mazenod and Morija) the demand projections were based on the growth used in the Metolong Dam Feasibility Study (CEC, 2003). The rural Lesotho demands were derived based on the rural demographic information per district and assuming a unit consumption of 50 litres/capita/day. Based on the information presented in the “National and Sub-National Population Projections” document produced by the Bureau of Statistics (Lesotho), it can be seen that the population growth in the rural areas is more or less constant or slightly negative. In order to be conservative a growth of 3% was however included in the projections as it was assumed that water demands in the rural sector will still grow, mainly as result of improved service levels.

The current urban and industrial Lesotho water requirements are provided in **Table 4-1**, and the future water requirements are shown in **Table 4-2**.

Table 4-1 Urban and Industrial Lesotho Historic and Current Water requirements (million m^3/a)

SUB-SYSTEM	DESCRIPTION	2009	2010	2011	2012
Senqu/Makaleng	Mokhotlong	0.203	0.195	0.201	0.207
	Thaba-Tseka	0.110	0.146	0.151	0.156
	Qachas Nek	0.046	0.073	0.080	0.087
	Quithing	0.134	0.110	0.111	0.113
	Mohales Hoek	0.274	0.271	0.299	0.328
	Total Senqu/Makaleng Rural Demand	0.127	0.131	0.135	0.139
Sub-Total Senqu/Makaleng		**0.895**	**0.926**	**0.977**	**1.029**
Caledon	Morija	0.038	0.037	0.057	0.077
	Mazenod (Metolong)	0.000	0.000	0.000	0.000
	Roma (Metolong)	0.000	0.000	0.000	0.000
	Tateyaneng (Metolong)	0.000	0.000	0.000	0.000
	Maseru (Metalong)	0.000	0.000	0.000	0.000
	Butha-Buthe	0.183	0.185	0.198	0.211
	Leribe (Hlotse)	0.452	0.389	0.400	0.412
	Mapotsoe	0.574	0.333	0.345	0.356
	Peka	0.071	0.066	0.068	0.070
	Mapoteng	0.164	0.125	0.129	0.132
	Teyateyaneng	0.374	0.328	0.428	0.528
	Maseru	12.770	12.352	13.308	14.264
	Roma	0.197	0.161	0.208	0.255
	Mazenod	0.540	0.589	0.645	0.700
	Mafeteng	0.545	0.558	0.565	0.572
	Morija (Metolong)	0.000	0.000	0.000	0.000
	Total Caledon Rural Demand	0.178	0.183	0.189	0.194
Sub-Total Caledon		**16.086**	**15.306**	**16.539**	**17.773**
Total Urban/Industrial Lesotho		**16.980**	**16.233**	**17.515**	**18.802**

Table 4-2 Urban and Industrial Lesotho Estimated Future Water Requirements (million m^3/a)

SUB-SYSTEM	DESCRIPTION	2012	2015	2020	2025	2030	2035	2040
Senqu/Makaleng	Mokhotlong	0.207	0.225	0.261	0.301	0.348	0.402	0.457
	Thaba-Tseka	0.156	0.171	0.199	0.232	0.270	0.314	0.358
	Qachas Nek	0.087	0.110	0.153	0.203	0.261	0.327	0.394
	Quithing	0.113	0.117	0.125	0.133	0.141	0.150	0.159
	Mohales Hoek	0.328	0.429	0.650	0.959	1.392	2.000	2.608
	Total Senqu/Makaleng Rural Demand	0.139	0.152	0.176	0.205	0.237	0.275	0.313
Sub-Total Senqu/Makaleng		**1.029**	**1.205**	**1.564**	**2.033**	**2.650**	**3.469**	**4.288**
Caledon	Morija	0.077	0.097	0.097	0.097	0.097	0.097	0.097
	Mazenod (Metolong)	0.000	0.111	0.390	0.495	0.600	0.706	0.811
	Roma (Metolong)	0.000	0.094	0.331	0.390	0.449	0.509	0.568
	Tateyaneng (Metolong)	0.000	0.201	0.702	0.827	0.951	1.076	1.200
	Maseru (Metalong)	0.000	1.912	6.693	13.280	19.867	26.454	33.041
	Butha-Buthe	0.211	0.254	0.337	0.436	0.554	0.696	0.838
	Leribe (Hlotse)	0.412	0.447	0.512	0.586	0.670	0.766	0.861
	Mapotsoe	0.356	0.393	0.461	0.538	0.626	0.725	0.824
	Peka	0.070	0.076	0.088	0.102	0.118	0.136	0.155
	Mapoteng	0.132	0.144	0.167	0.193	0.223	0.258	0.293
	Teyateyaneng	0.528	0.629	0.629	0.629	0.629	0.629	0.629
	Maseru	14.264	15.220	15.220	15.220	15.220	15.220	15.220
	Roma	0.255	0.302	0.302	0.302	0.302	0.302	0.302
	Mazenod	0.700	0.756	0.756	0.756	0.756	0.756	0.756
	Mafeteng	0.572	0.593	0.631	0.671	0.713	0.757	0.801
	Morija (Metolong)	0.000	0.040	0.140	0.174	0.208	0.242	0.276
	Total Caledon Rural Demand	0.194	0.212	0.246	0.285	0.331	0.383	0.436
Sub-Total Caledon		**17.773**	**21.484**	**27.702**	**34.981**	**42.315**	**49.711**	**57.108**
Total Urban/Industrial Lesotho		**18.802**	**22.688**	**29.266**	**37.014**	**44.965**	**53.180**	**61.396**

5 URBAN AND INDUSTRIAL NAMIBIA

The current and future demand projections for Hardap and Naute urban requirements were based on the information from the Orange River Integrated Water Resources Management Plan, Summary of Water Requirements from the Orange River Report (ORASECOM, 2007).

The Lower Orange Management Study (DWAF, 2004) was used as a basis for the water requirement projections in the Lower Orange catchment. These include the urban towns of Aussenkehr, Noordoewer, Rosh Pinah, Skorpion, and Oranjemund.

The current urban industrial Namibia water requirements areas provided in **Table 5-1**, and the future water requirements are shown in **Table 5-2**.

Table 5-1 Urban and Industrial Namibia Current Water Allocations and Abstractions (million m^3/a)

SUB-SYSTEM	DESCRIPTION	2009	2010	2011	2012
Lower Orange Main Stem	Aussenkehr Noordoewer	0.224	0.237	0.261	0.286
	Urban Rosh Pinah, Skorpion, Oranjemund	8.378	8.416	8.449	8.482
Sub-Total Lower Orange Main Stem		**8.602**	**8.653**	**8.711**	**8.768**
Fish	Hardap	0.953	0.953	0.953	0.953
	Naute	1.948	1.948	1.948	1.948
Sub-Total Fish		**2.902**	**2.902**	**2.902**	**2.902**
Total Urban/Industrial Namibia		**11.503**	**11.555**	**11.612**	**11.670**

Table 5-2 Urban and Industrial Namibia Estimated Future Water Requirements (million m^3/a)

SUB-SYSTEM	DESCRIPTION	2012	2015	2020	2025	2030	2035	2040
Lower Orange Main Stem	Aussenkehr Noordoewer	0.286	0.359	0.577	0.645	0.713	0.781	0.849
	Urban Rosh Pinah, Skorpion, Oranjemund	8.482	8.581	8.802	8.829	8.857	8.884	8.911
Sub-Total		**8.768**	**8.940**	**9.378**	**9.474**	**9.569**	**9.665**	**9.760**
Fish	Hardap	0.953	0.953	0.953	0.953	0.953	0.953	0.953
	Naute	1.948	1.948	1.948	1.948	1.948	1.948	1.948
Sub-Total		**2.902**	**2.902**	**2.902**	**2.902**	**2.902**	**2.902**	**2.902**
Total Urban/Industrial Namibia		**11.670**	**11.842**	**12.280**	**12.375**	**12.471**	**12.566**	**12.662**

6 MINING RSA

Black Mountain Mine currently requires 1.880 million m^3/a for operations and 0.036 million m^3/a for irrigation of the golf course. Pella Water Board have allocated 4 million m^3/a to Black Mountain mine. This will increase significantly when the Gamsberg project is online by 2014 resulting in the requirements increasing by an additional 12 million m^3/a. The additional 12 million m^3/a needs to be supplied through the current Pella Water Board system.

Information for the Kalkfontein mines was obtained from the Kalkfontein Scheme Report (DWA, 2013), while the Lower Orange Management Study (DWAF, 2004) was used as the source for Alexander Bay, Transhex and Small Mines.

The current mining RSA water requirements are provided in **Table 6-1**, and the future water requirements are shown in **Table 6-2**.

Table 6-1 Mining RSA Current Water Allocations and Abstractions (million m^3/a)

SUB-SYSTEM	DESCRIPTION	2009	2010	2011	2012
Riet/Modder	Kalkfontein Mines	1.500	1.500	1.500	1.500
Sub-Total Riet/Modder		**1.500**	**1.500**	**1.500**	**1.500**
Lower Orange Main Stem	Black Mountain Mine	1.916	1.916	1.916	1.916
	Alexander Bay Transhex Small Mines	4.902	4.935	4.991	5.047
Sub-Total Lower Orange Main Stem		**6.818**	**6.852**	**6.908**	**6.963**
Total Mines RSA		**8.318**	**8.352**	**8.408**	**8.463**

Table 6-2 Mining RSA Estimated Future Water Requirements (million m^3/a)

SUB-SYSTEM	DESCRIPTION	2012	2015	2020	2025	2030	2035	2040
Riet/ Modder	Kalkfontein Mines	1.500	1.690	2.005	2.321	2.637	2.953	3.269
Sub-Total		**1.500**	**1.690**	**2.005**	**2.321**	**2.637**	**2.953**	**3.269**
Lower Orange Main Stem	Black Mountain Mine	1.916	13.916	13.916	13.916	13.916	13.916	13.916
	Alexander Bay Transhex Small Mines	5.047	5.214	2.869	3.026	3.184	3.342	3.500
Sub-Total		**6.963**	**19.131**	**16.786**	**16.943**	**17.100**	**17.258**	**17.416**
Total Mines		**8.463**	**20.820**	**18.791**	**19.264**	**19.738**	**20.211**	**20.685**

7 MINING NAMIBIA

The Lower Orange Management Study (DWAF, 2004) was used as a basis for the Namibia mines situated along the Lower Orange Main Stem. The current Namibia mining water requirements are provided in **Table 7-1**, and the future water requirements are shown in **Table 7-2**.

Table 7-1 Mining Namibia Current Water Allocations and Abstractions (million m^3/a)

SUB-SYSTEM	DESCRIPTION	2009	2010	2011	2012
Lower Orange Main Stem	Haib Mine	0.000	0.000	0.000	0.000
	Mines Rosh Pinah, Auchas, Skorpion	7.528	7.573	7.607	7.642
Sub-Total Lower Orange Main Stem		**7.528**	**7.573**	**7.607**	**7.642**
Total Mines RSA		**7.528**	**7.573**	**7.607**	**7.642**

Table 7-2 Mining Namibia Estimated Future Water Requirements (million m^3/a)

SUB-SYSTEM	DESCRIPTION	2012	2015	2020	2025	2030	2035	2040
Lower Orange Main Stem	Haib Mine	0.000	3.000	3.000	3.000	3.000	3.000	3.000
	Mines Rosh Pinah, Auchas, Skorpion	7.642	7.745	7.973	8.224	8.474	8.725	8.975
Sub-Total Lower Orange Main Stem		**7.642**	**10.745**	**10.973**	**11.224**	**11.474**	**11.725**	**11.975**
Total Mines Namibia		**7.642**	**10.745**	**10.973**	**11.224**	**11.474**	**11.725**	**11.975**

8 RETURN FLOWS

The return flows from the Urban/Industrial and mining sector is relatively small in the Orange River Basin. Some of the water supply systems such as Pelladrift and Namakwa schemes supply water to towns located far from the Orange River and return flows will not reach the river. Most of the smaller towns, direct their return flows to evaporation ponds or pan areas, preventing these flows to return to the main river. The mines re-circulate their water to a large extent and their waste water is generally evaporated through evaporation ponds (ORASECOM, 2007). **Table 8-1** presents return flow estimations derived from the All Towns Study (DWA, 2011).

Table 8-1: Return Flow Estimations

SUB-SYSTEM	DESCRIPTION	2012 Gross Demand (million m^3/a)	2012 Return Flows (million m^3/a)	Percentage Return Flow (%)
Caledon	Maseru	14.264	1.820	12.8
	Ficksburg	2.932	1.466	50.0
	Ladybrand	2.688	0.533	19.8
Upper Orange	Lady Grey	0.281	0.141	50.0
	Aliwal North	1.838	0.919	50.0
	Burgersdorp	0.707	0.353	50.0
	Barkley East	0.417	0.208	50.0
Riet/Modder	Bloemfontein	68.946	35.321	51.2
	Botshabelo	9.625	4.139	43.0
	Thaba N'Chu	4.846	2.423	50.0
Lower Orange Main Stem	Upington	14.644	5.222	35.7

9 POSSIBLE NEW WATER USERS

9.1 HYDRAULIC FRACTURING

The Karoo hydraulic fracturing project is currently in the process of a three year exploration phase during which an estimated 6 to 24 vertical wells will undergo hydraulic fracturing. The formations under consideration as possible sources of shale gas in the Karoo are the Whitehill, Prince Albert and Collingham Formations. It is expected that hydraulic fracturing of 15 horizontal wells will take place in the 2 year verification period, and 8 to 16 horizontal wells in the 2 year pilot study. The pilot study may be extended by a further two years depending on the success of the study. Should hydraulic fracturing be implemented, then, during the production phase, a total of 6 000 gas wells would be required to mine 0.5 TCF (Trillion Cubic Feet) per year for 30 years. The hydraulic fracturing of a horizontal well typically requires 20 000 m^3. The water required for the hydraulic fracturing process could be sourced from ground water, sea water, surface water, water imported by truck or recycled grey water. At this stage suitable water supply options have not yet been identified for hydraulic fracturing in the Karoo. Based on the information given above, a low confidence water requirement estimate was determined for the hydraulic fracturing in the Karoo which is provided in **Table 9-1**.

Table 9-1: Hydraulic Fracturing Water Requirements (million m^3/a)

DESCRIPTION	2013	2014	2015	2016	2017	2018	2021	2022	2040
Hydraulic fracturing in Karoo	0.00	0.24	0.24	0.15	0.15	0.16	0.16	4.00	4.00

9.2 SOLAR POWER

In an effort to utilise renewable energy resources to meet the growing demand in electricity the South African Government is planning to establish a Solar Park at Olyvenhoutsdrift, 15 km west of Upington in the Northern Cape. The Solar park will use the sun's energy to eventually generate 5 000 megawatt (MW) of electricity. The Upington area has been identified as one of the highest solar radiation locations in the world, providing the best opportunities for using the sun to generate electricity. Eskom is kicking off the development with the construction of a 150 megawatt (MW) Concentrating Solar Power (CSP) plant at Solar Park. Solar Water Consumption estimates based on IRP 2010 Moderate – Policy Adjusted Energy Forecast were provided by Eskom. **Table 9-2** shows estimates for dry and wet cooling as well as Photovoltaic (PV) water requirements.

Table 9-2: Solar Water Consumption based on IRP 2010 Moderate – Policy Adjusted Energy Forecast

Solar Water Consumption	2013	2014	2015	2020	2025	2030
Water (dry cooling) (million m^3/a)	0.000	0.119	0.238	0.836	1.417	1.431
Water (wet cooling) (million m^3/a)	0.000	0.756	1.513	5.310	9.002	9.093
TWh	1	1	2	6	11	16
CSP dry (million m^3/a)	0.00	0.12	0.24	0.84	1.42	1.43
PV (million m^3/a)	0.01	0.01	0.01	0.04	0.07	0.12

Table 9-3: Licence applications - Solar Water Consumption

Solar Water Consumption	Licenced volume (m^3/a)
Aurora Power Solutions (Pty) Ltd: Konkoonsies Solar	13 000
Aurora Power Solutions (Pty) Ltd: Aries Solar	13 000
National Research Foundation SKA SA: Meerkat Losberg 73	#
NRF SKA MeerKat	#
Solafrica	875 000
Eskom Distribution Divison	1 430 000*
KaXu CSP South Africa (Pty) Ltd	11 200
Khi CSP South Africa(Pty) Ltd	21 700
Solar Capital	27 800
Solar Capital De Aar 3	21 700
Solar Reserve South Africa	#
Renewable Energy Investments SA (Pty) Ltd	#

Notes: # - No data on volumes available at the time

*- This volume can increase to 9 093 000 when wet cooling is used (volume not yet final)

Several licences were already issued for solar power generation purposes as summarised in **Table 9-3.**

Solafrica is proposing the construction of a 75 MW CSP Plant on the Farm Bokpoort situated in the !Kheis Local Municipality of the Northern Cape Province just north west of Groblershoop. The farm covers a total area of 6 700 hectares and borders the Orange River to the south-west. It is expected to extract a volume of 2 336.0 m³ per day (0.85 million m^3/a) from the Orange River for the project.

9.3 SQUARE KILOMETRE ARRAY RADIO TELESCOPE (SKA) DEVELOPMENT

From now until 2016 South Africa will be constructing 64 Meerkat dishes in the Karoo. The construction of another 190 SKA Phase 1 dishes is expected to start more or less by the completion of the Meerkat dishes. The SKA development will be constructed in the Northern Cape Province, about 80 km from the town of Carnarvon. Phase 2 of the SKA project is planned to start in 2019 and to be completed by 2024. The consultants (SEF) appointed to conduct the necessary environmental authorisation for the Meerkat project stated that water licences for groundwater were already obtained for a total of 118 802 m^3/a (0.119 million m^3/a). No information is yet available on the phase 1 and 2 water requirements of the SKA project.

9.4 POSSIBLE FUTURE HYDRO POWER

The following three Companies RVM 1 Hydro Electric Power (Pty) Ltd, RVM 2 Hydro Electric Power (Pty) Ltd & RVM 3 Hydro Electric Power (Pty) Ltd are investigating the possible construction of one 10 Megawatt (MW) and one 9.9MW hydropower station on the Orange River, on the farm Riemvasmaak1, north of the Augrabies Falls, approximately 40 km North West of Kakamas in the Northern Cape Province of South Africa. The proposed hydropower stations would be adjacent to each other.

The project would entail the construction of a weir to facilitate the abstraction of water, a concrete canal, pipelines or culverts and steel penstocks to transfer the water from the weir to the power station sites, and two outlet works to release the abstracted water back into the riverine environment, downstream of the weir. A power line would also be required to evacuate the power from the proposed hydropower stations to a nearby substation. The proposed projects would entail the abstraction of water at a combined maximum rate of some 35 m^3/s. This will however be a non consumptive use.

10 RIVERINE AND OPERATIONAL REQUIREMENTS

10.1 GENERAL

Riverine and operational requirements from the lower Orange River System represent important "demands" that must be taken into account. The main losses modelled in the analysis are normal transmission or conveyance losses, river requirements or losses from the Orange River and operating requirements/losses. Details of the river requirements and operating requirements/losses are given in the following sections.

10.2 RIVERINE REQUIREMENTS

The riverine requirements are a natural phenomenon to both regulated and unregulated rivers. In the case of unregulated rivers the actual volume of these requirements is seldom quantified, as it is included in the hydrology process used to determine the natural runoff. In the event of the Orange River where water is released from Vanderkloof Dam and conveyed by means of the river to users as far as 1 380 km downstream from the point of release, it is of utmost importance to obtain a good estimation of the actual volume of the riverine requirements, as it has to be included as part of the total releases required from Vanderkloof Dam. Only approximately 6% (4% from the Namibia Fish River and 2% Orange River) of the total natural flow generated in the Orange River catchment (Vaal River included) is generated downstream of the Orange/Vaal confluence. The runoff generated in the Lower Orange (downstream of Vaal confluence) therefore contributes an almost negligible amount to the downstream demands in the Lower Orange River. As result of the long conveyance distance and extreme dry and hot conditions, large riverine requirements or losses are bound to occur. These riverine requirements are mainly due to evaporation from the river surface area, but also include seepage losses and evapo-transpiration from the riparian vegetation.

During periods of high flows the accuracy of the riverine requirements is not that critical, as there is sufficient water available under these conditions to satisfy the water requirements of the users along the Orange River, as well as to cover the riverine requirements. During low flow conditions when the river flow is mainly regulated by releases from Vanderkloof Dam, the accurate estimation of the riverine requirements becomes increasingly critical. Underestimating the riverine requirements will result in shortages in supply along the Orange River, which depending on the time of occurrence can have a significant effect on the irrigated crop yield. Overestimating the riverine requirements will result in a total loss of the excess releases, as there is no significant storage available downstream of Vanderkloof Dam, to capture these releases.

The best and most reliable estimation of the Orange Riverine requirements currently available is the results from Phase II of the Orange River Losses Study as published in the WRC Report No 638/1/99, dated December 1998 (WRC, 1988). Results from this report clearly showed that the average annual flow rate in the Orange River has a noticeable effect on the riverine requirements. Estimations of the annual riverine requirements are given for three typical average annual river flows, 50 m^3/s, 120 m^3/s and 400 m^3/s. The riverine requirements associated with the average river flows are 575 million m^3/a, 706 million m^3/a and 989 million m^3/a respectively. It is therefore proposed that the most recent updated water demands to be released from Vanderkloof Dam should be used to determine the initial estimate of the Orange Riverine requirements for use in the Orange Reconciliation Study (ORECONS). The most recent estimate of the releases required from Vanderkloof Dam can be obtained from the draft report "Orange River System 2012/2013 System Analysis" dated October 2012 (DWA, 2012b). These analyses are carried out on an annual basis to determine the surplus available in the Orange River System, which can be used for hydropower generation over and above the normal releases from Vanderkloof used to supply the downstream requirements. The results from this report showed that the required annual release from Vanderkloof Dam for the 20012/20013 planning year is 66.8 m³/s (2107 million m³/a). Based on the riverine requirements versus annual river flow as published in the WRC Report, the representative riverine requirements for an average annual river flow of 66.8 m³/s, is 615 million m³/a. The proposed riverine requirements based on the 66.8 m³/s average annual river flow is summarised for each river reach in **Table 10-1**.

The monthly distribution of the river requirements is given in **Table 10-2**. The distribution takes into account both the variation in evaporation as well as the variation in the river flow over the year.For the purpose of the riverine requirement study, the Orange River was split into seven river reaches as shown in **Figure 10-1**.

Table 10-1: Riverine Requirements proposed to be used as the initial estimation for the ORECONS analysis

Reach	From	To	Gross Evap (mm/a)	Rainfall (mm/a)	River losses (million m³/a)		
					At 50 m³/s river flow	Proposed at 66.8 m³/s river flow	At 400m³/s river flow
1	Vanderkloof	Marksdrift	2 665	301	52.4	56.0	83.1
2a	Marksdrift	Prieska	2 761	257	73.1	78.1	107.4
2b	Prieska	Boegoeberg	2 795	216	45.2	48.3	65.9
3a	Boegoeberg	Gifkloof	2 865	178	79.3	84.8	120.8
3b	Gifkloof	Neusberg	2 885	146	43.1	46.1	79.5
4	Neusberg	20° E	2 920	109	34.7	37.1	54.9
5a	20° E	Pella	2 938	75	60.8	65.0	111.6
5b	Pella	Vioolsdrift	2 921	42	73.8	78.9	143.1
6	Vioolsdrift	Fish	2 942	31	50.7	54.2	100.0
7a	Fish	BrandKaros	2 925	29	38.1	40.7	73.9
7b	BrandKaros	Mouth	2 765	39	24.1	25.8	48.9
Total	**Vanderkloof**	**Mouth**	**2 849**	**145**	**575.2**	**615.0**	**989.0**

Figure 10-1: River reaches used in the calculation of the Riverine Requirements along the Lower Orange

Table 10-2: Monthly distribution of the proposed riverine requirements (million m^3/month)

Reach	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1	7.83	5.86	4.69	3.18	2.41	1.73	2.00	2.95	4.44	5.86	7.22	7.85	56.0
2a	10.92	8.17	6.54	4.44	3.36	2.41	2.78	4.12	6.19	8.17	10.08	10.95	78.1
2b	6.75	5.05	4.05	2.75	2.08	1.49	1.72	2.55	3.83	5.05	6.23	6.77	48.3
3a	11.84	8.86	7.10	4.82	3.65	2.62	3.02	4.47	6.72	8.86	10.93	11.88	84.8
3b	6.44	4.82	3.86	2.62	1.98	1.42	1.64	2.43	3.65	4.82	5.94	6.46	46.1
4	5.18	3.88	3.11	2.11	1.60	1.15	1.32	1.96	2.94	3.88	4.78	5.20	37.1
5a	9.08	6.80	5.44	3.70	2.80	2.01	2.32	3.43	5.15	6.80	8.38	9.11	65.0
5b	11.02	8.25	6.61	4.49	3.39	2.44	2.81	4.16	6.25	8.25	10.17	11.06	78.9
6	7.57	5.67	4.54	3.08	2.33	1.67	1.93	2.86	4.29	5.67	6.99	7.60	54.2
7a	5.69	4.26	3.41	2.32	1.75	1.26	1.45	2.15	3.23	4.26	5.25	5.71	40.7
7b	3.60	2.69	2.16	1.46	1.11	0.80	0.92	1.36	2.04	2.69	3.32	3.61	25.8
Total	**85.92**	**64.30**	**51.49**	**34.97**	**26.46**	**19.00**	**21.91**	**32.43**	**48.73**	**64.30**	**79.29**	**86.20**	**615.0**

10.3 OPERATING REQUIREMENTS

Gariep and Vanderkloof dams are used to support the demands along the lower Orange River from Vanderkloof Dam to the Orange River mouth. These demand centres are located along a river length of approximately 1 380 km, which, together with riverine requirements, unpredictable heat waves that results in increased demands over the short-term, unlawful abstractions as well as inflows from the Vaal and Fish rivers, contribute to the complexity of operating the system and determining how much water to release from Vanderkloof Dam. A further complication concerns releases from Vanderkloof Dam to generate hydropower, which are sometimes in excess of the downstream demands. The large controlling structures (sluice gates, hydro-power turbines etc.), at Vanderkloof Dam make it very difficult to release the required flow with accuracy.

As a result of the problems mentioned above, it is clear that some operational requirement should be allowed for. In view of the fact that in the past there has been excess water in the Orange River system, the whole question of such operational requirements has been of little importance. Had excess water not been released from Vanderkloof Dam through the turbines, it would eventually have spilled or evaporated. It was therefore of greater benefit to the country to use such water for power generation. The whole situation has however changed, and it has become necessary to release only as much as is needed to supply the various downstream users (including the needs of the environment and the riverine requirements).

The historic operating requirements were for the first time quantified as part of the ORRS (DWAF, 1999). The operational requirement of 280 million m^3/a as determined from the ORRS was the best estimate that could be made at the time with the available data.

On request of the DWA regional office, the operational requirements were increased in May 1999 by 76 million m^3/a, to 356 million m^3/a. This adjustment was based on their practical experience in the day-to-day operation of the system.

In the year 2000 an additional task were carried out for DWA over and above the normal annual hydropower operating analysis. The use of the annual operating analyses since May 1997 resulted in tighter control measures for river releases and increased the availability as well as improved the reliability of data regarding the water requirements and surplus releases. One of the purposes of the additional task was to update the operational requirement based on observed releases from Vanderkloof Dam and the observed flow as gauged at various points along the Orange River downstream of Vanderkloof Dam. During the execution of this task, it was discovered that part of the previously increased operational requirements were as a result of the fact that 38.6 million m^3 of the Middle Orange GWS annual irrigation requirement was never included in the ORRS data sets. The operational requirements were therefore reduced by the 38.6 million m^3/a to 317,7 million m^3/a and the irrigation requirement subsequently increased.

The updated irrigation demand as received from the DWA Regional offices for the 2002 annual hydropower operating analysis, increased by another almost 70 million m^3/a in comparison with that used for the 2001 analysis. The main reason for this was the updated data that became available from the registration process. It is therefore possible that the operational requirements can be reduced again by a similar volume depending on when the additional irrigation developments have taken place.

From discussions with DWA (RSA) at the time, it seemed that most of the increase in the irrigation due to the registration process was as result of allocated permits that were previously not included in the list of scheduled areas. For the purpose of the annual operating analysis at the time it was assumed that 50 million m^3/a of the 70 million m^3/a "increase" was previously catered for as part of the operational requirements. It was therefore suggested that the operational requirements be reduced by 50 million m^3/a, to 270 million m^3/a.

Some years later, the irrigation demand was again found to be 139 million m^3/a higher than those provided by DWA in the previous years as input to the annual operating analysis. This was mainly as result of existing irrigation areas not previously captured in the data base. After discussions with DWA regional offices in this regard, it was decided to reduce the operational requirements by a further 90 million m^3/a, to 180 million m^3/a.

The 180 million m^3/a operating requirement is currently still being used in the annual operating analysis and it is therefore suggested to use this requirement also for the purpose of the Orange Reconciliation study.

11 MAJOR TRANSFERS FROM THE ORANGE SENQU RIVER

11.1 GENERAL

The transfers described in this section refer to the large transfer systems taking water out of the Orange Senqu River. Transfers from the Vaal River are however excluded. Transfers taking water out of the Orange Senqu to supply relatively small towns that is located outside the basin will be included in the demands as described in **Sections 3** to **7**.

The largest of these large transfers is the transfer from the Lesotho Highlands to the Vaal River system, in support of Vaal Dam. This is followed by the Eastern Cape transfer system, taking water from Gariep Dam and supplying water through the Orange/Fish tunnel to the Fish and Sundays rivers. This transfer is mainly in support of irrigation, but also for urban/industrial requirements of which Port Elizabeth (Algoa Water Supply Area) is the largest and most downstream of the urban/industrial demand centres.

11.2 LESOTHO HIGHLANDS WATER PROJECT

The Lesotho Highlands Transfer Scheme started to operate in 1998, and comprises of Katse and Mohale dams, the Matsoku Diversion Weir and a series of tunnels and a hydro-power station. Water is gravitated from Katse Dam through the tunnels to Liebenbergsvlei River from where it flows into the Wilge River then into the Vaal River and finally into Vaal Dam.

The transfer volume has been phased in over a number of years and has already reached its maximum agreed transfer volume of 780 million m^3/a. This volume is according to the agreement between the RSA and Lesotho and is transferred to the RSA on a continuous basis, independent of the water situation in Vaal or the water levels in the Vaal River System.

Phase 2 of the LHWP has already been announced. This phase comprises of the Polihali Dam and connecting tunnel to Katse Dam. With Phase 2 in place the maximum transfer volume will be increased by an additional 460 million m^3/a. The operating rule to be used in conjunction with the additional transfer volume still needs to be agreed on between Lesotho and the RSA. Phase 2 is expected to start delivering water to the RSA by 2022.

11.3 CALEDON MODDER TRANSFER

The Caledon Modder transfer system is used to support the water supply to Bloemfontein, Mangaung, Botshabelo, Thaba N'chu and several small towns located in the Modder Riet River catchment. Water resources in the Modder Riet River catchment is insufficient to supply in the water requirements of these demand centres and water therefore need to be transferred from the neighbouring Caledon River catchment, having a much higher available annual runoff.

Water is transferred by pipeline from Welbedacht Dam in the Caledon River to Bloemfontein and several of the smaller towns. Welbedacht Dam has almost fully silted up over the years and Knellpoort Dam an off channel dam was built to avoid the silting up of a second dam. Water is being pumped from the Tienfontein pump station located along the Caledon River to Knellpoort. The Caledon-Modder transfer scheme was then extended by adding the so called Novo Transfer scheme, comprising of the Novo pump station, pumping water from Knellpoort Dam over the water shed to Rustfontein Dam located in the upper Modder River.

The total volume transferred depends on the combination of the water requirements and the water levels in the dams within the Modder Riet River basin. These dams are Rustfontein, Mockes and Groothoek dams. The transfer volume is further limited to the maximum transfer capacity of 47 million m^3/a (1.49 m^3/s) from Welbedacht and 52.7 million m^3/a (1.67 m^3/s) via the Novo transfer system. Latest indications are that the Novo transfer capacity has reduced to approximately 1.3 m^3/s (41 million m^3/a). The maximum volume that can currently be transferred is therefore 88 million m^3/a (2.79 m^3/s).

The current planning is to increase the Novo transfer capacity to 2.4 m^3/s by end of 2013.

11.4 EASTERN CAPE TRANSFER

Water is transferred from Gariep Dam via the Orange/Fish tunnel to the Fish and Sundays rivers in the Eastern Cape. Water is distributed through a combination of canals, tunnels, balancing dams and natural river courses to irrigators and small towns to eventually reach the Port Elizabeth (Nelson Mandela Bay Metro) abstraction point near the downstream end of the Sundays River.

The target transfer volume through the Orange/Fish tunnel is based on the total scheduled irrigated area in the Eastern Cape times the quota allocated to the different irrigation areas listed under the scheme, plus the urban industrial requirements applicable to the specific year under consideration. For the year 2012 this volume was determined as 620 million m^3/a, of which 577.6 million m^3/a was for irrigation and 42.4 million m^3/a for urban/industrial purposes.

The total requirement imposed on Gariep Dam to be supplied via the Orange Fish tunnel will however vary around this target volume, depending on the rainfall as well as the water quality conditions in the Eastern Cape sub-system. Indications are that this can be as much as 25% higher than the target volume. Whether this additional volume will or need to be supplied from Gariep Dam, has not yet been solved. Discussions in this regard are still taking place between the irrigators and the DWA.

The urban/industrial centres supplied with water from this scheme are shown in **Table 11-1**. The current demand of 42.4 million m^3/a, is expected to grow to 76.9 million m^3/a by 2040.

Table 11-1: Eastern Cape urban/industrial demand centres (million m^3/a)

Urban demand centre	2012	2015	2020	2025	2030	2035	2040
Cradock	1.86	1.98	2.20	2.39	2.59	2.63	2.67
Grahamstown	3.77	3.96	4.27	4.64	5.01	5.42	5.83
Enon	0.20	0.21	0.23	0.24	0.26	0.29	0.31
Addo	1.33	1.40	1.51	1.64	1.77	1.92	2.07
Kirkwood	2.20	2.31	2.49	2.70	2.92	3.16	3.40
Cookhouse	1.35	1.42	1.53	1.66	1.79	1.94	2.09
Somerset East	0.44	0.49	0.57	0.66	0.76	0.86	0.97
Bedford	0.19	0.22	0.28	0.36	0.43	0.52	0.61
NMBM (Port Elizabeth)	31.05	59.00	59.00	59.00	59.00	59.00	59.0
Subtotal	**42.38**	**70.98**	**72.07**	**73.30**	**74.53**	**75.73**	**76.93**

A total of 4000ha of irrigation area in the Eastern Cape is allocated for the development of resource poor farmers. None of these developments have yet taken place. The development of these areas will in future result in an increase in the total irrigation demands by approximately 44 million m^3/a. There is currently no certainty on when these developments will start taking place or be fully developed. Detail on the irrigation developments will be given in a separate report on the irrigation requirements.

11.5 ORANGE RIET TRANSFER

The Orange/Riet Transfer scheme abstracts water from Vanderkloof Dam, to be transferred to the Riet River catchment. The water is primarily used for irrigation but is also used to supply the urban requirements of Koffiefontein, Richie and Jacobsdal.

The Orange/Riet canal has a total length of 112.6 km with a capacity of 15.6 m^3/s. The canal supplies water to irrigation in the order of 3 800ha along the canal, to Riet River Settlement (7 800ha) near Jacobsdal, the Scholtsburg Irrigation Board (740ha), Richie Irrigation Board (97ha) and the Lower Riet Irrigation Board of 3 940ha.

The total volume transferred is in the order of 260 million m^3/a, and depends on the scheduled irrigation area and urban demands. From time to time an additional 5 million m^3/a is released through the canal, to improve the water quality situation in the Lower Riet. It is expected that the irrigation in this area will significantly increase over time due to the development of resource poor farmers with allocations from Vanderkloof Dam. Canal improvements and increase in capacity will however be required before this can take place.

The urban/industrial centres supplied with water from this transfer scheme are summarised in **Table 7.2**. The current demand of 4.9 million m^3/a, is expected to grow to 7.2 million m^3/a by 2040. This demand comprises of a very small percentage of the total transferred volume.

Table 7.2: Urban/industrial demand centres supplied from the Orange Riet transfer scheme

Urban demand centres	2012	2015	2020	2025	2030	2035	2040
Ritchie	1.541	1.824	1.958	2.096	2.238	2.381	2.523
Luckhoff Urban	0.344	0.393	0.428	0.458	0.489	0.519	0.549
Oppermans Urban	0.274	0.294	0.321	0.344	0.367	0.389	0.412
Koffiefontein municipality	1.200	1.309	1.491	1.673	1.855	2.036	2.218
De Beers (Koffiefontein)	1.500	1.500	1.500	1.500	1.500	1.500	1.500
Subtotal	**4.858**	**5.320**	**5.697**	**6.071**	**6.448**	**6.825**	**7.203**

11.6 ORANGE VAAL TRANSFER

This scheme was constructed in 1984 as an emergency scheme to overcome shortages and salinity problems in Douglas. This scheme is also known as the Orange-Douglas Government Water Scheme consisting of a pumping station at Marksdrift in the Orange River, a rising main and a 22 km, 6 m^3/s canal, terminating at the Douglas Weir on the Vaal River.

The transferred water is mainly used for irrigation purposes but also to supply the town of Douglas with water. The volume transferred depends on the water available in the Vaal River and the water level in the Douglas Weir. The volume transferred can therefore vary considerably from year to year, but is in the order of 120 million m^3/a, to a maximum of 142 million m^3/a.

The current demand for Douglas Town is 2.120 million m^3/a and it is expected to increase to 3.766 million m^3/a by 2040.

12 ENVIRONMENTAL REQUIREMENTS

12.1 GENERAL

Environmental flows in a river are the flow required to maintain the ecosystem in a negotiated ecological condition. This condition is normally a compromise between social, economic and ecological values of water for various uses.

12.2 LESOTHO HIGHLANDS WATER PROJECT

The environmental flows to be released from the LHWP main structures are the product of negotiations between the Lesotho Highlands Development Authority (LHDA), the governments of Lesotho, South Africa, Namibia, the World Bank and various other interested and affected parties. The agreed on environmental flows vary between 19% and 40% of the mean annual runoff at the specific site. These environmental requirements are described in a document referred to as “Draft Procedures for the Implementation of the LHWP Phase 1 Instream Flow Requirement Policy” dated February 2003 (LHDA, 2003).

The approach followed to determine the required environmental flows used statistical methods to divide the hydrological record at the Instream Flow Requirement (IFR) site into five hydrological classes, based on the percentile flow intervals. (See **Table 12-1**)

Table 12-1: Hydrological classes used in LHDA approach to determine IFRs

Percentile	Class	Class Description
0 – 20	1	Plus 2 – Extremely wet years
20 – 40	2	Plus 1 – wetter than normal years
40 – 60	3	Average – years with near-normal rainfall and runoff
60 – 80	4	Minus 1 – drier than normal years
80 - 100	5	Minus 2 – extremely dry years

Based on these hydrological classes a representative MAR was determined as well as the required monthly releases related to the particular class and MAR. The required IFR flows at IFR site 2 just downstream of Katse Dam is summarised in **Table 12-2** and for IFR site 7 just downstream of Mohale Dam in **Table 12-3**.

Table 12-2: IFR release schedule for IFR site 2 downstream of Katse Dam

Class	MAR (million m^3/a)	Monthly IFR (million m^3/a)											
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	756.6	3.21	22.74	12.21	11.48	12.14	11.48	7.74	4.71	7.35	4.45	7.18	4.09
2	563.8	2.95	13.61	3.21	11.48	12.14	6.98	7.74	3.21	2.85	2.41	6.91	3.83
3	501.7	2.95	12.11	3.21	7.98	12.14	3.48	7.74	3.21	2.85	2.41	6.67	2.15
4	348.4	2.68	2.85	3.08	7.71	12.14	2.95	4.09	2.41	1.45	1.61	6.64	2.33
5	0.0	2.28	2.33	2.68	2.68	2.30	2.41	6.70	2.14	1.81	1.61	5.97	2.07

Table 12-3: IFR release schedule for IFR site 7 downstream of Mohale Dam

Class	MAR (million m^3/a)	Monthly IFR (million m^3/a)											
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	413.8	2.08	10.54	2.02	4.48	14.38	3.50	3.12	3.58	2.53	1.99	2.70	2.28
2	321.6	2.41	2.07	2.68	2.52	10.44	2.79	2.05	1.61	1.43	1.34	5.37	1.94
3	278.9	2.00	3.28	1.44	2.38	10.66	2.02	2.40	1.59	0.72	0.39	4.56	0.49
4	192.0	0.99	1.37	1.87	1.77	6.59	2.18	1.70	0.83	0.52	0.54	4.60	0.41
5	0.0	0.94	1.30	1.53	1.12	5.35	1.55	0.62	0.91	0.78	0.54	0.54	0.65

12.3 INTEGRATED VAAL RIVER SYSTEM (IVRS)

The most recent environmental requirements available for the Integrated Vaal River System (IVRS) was determined in the study “Classification of Significant Water Resources in the Upper, Middle and Lower Vaal Water Management Areas” (DWA, 2012). The purpose of the study was to determine the Reserve that needs to be implemented in the IVRS.

Results from the study indicated that the Environmental Water Requirement (EWR) sites with a High Environmental Importance were all located in the Upper Vaal WMA with almost none in the Middle and Lower Vaal WMAs except for the Douglas EWR in the Lower Vaal. All these sites in the Middle and Lower Vaal WMAs are in a reasonable to good PES (Present Ecological State) with the majority in a B/C environmental class and require non-flow related interventions to achieve the required improvements. For the Middle and Lower Vaal EWR sites, it was therefore concluded that the present flow regime and operation of the system should be signed off as the Reserve.

The implementation of the Douglas EWR will however affect the available yield in the Vaal River System. Results from the Classification study indicated a decrease of approximately 70 million m^3/a for development conditions in the Vaal between 2011 and 2020. For the 2020 development level with Polihali Dam in place the reduction in the Vaal system yield is expected to increase to 99 million m^3/a, when the Douglas EWR is implemented.

It therefore seems that the proposed EWRs in the Vaal System will in general have almost no affect on the flows from the Vaal into the Orange, except for the Douglas EWR. A summary of the EWRs for the Vaal is given in **Table 12-4**.

Table 12-4: Summarised information on EWR sites in the Upper, Middle and Lower Vaal WMA

No	EWR Site Reference	Recommended ERC	Natural MAR (NMAR) 1920-1994 (million m³/a)	EWR Demand (Incl High Flows)		EWR Demand (Low Flows only)	
				(million m³/a)	(% NMAR)	(million m³/a)	(% NMAR)
1	RE-EWR1	C (LF)	26.02	6.31	24.3	2.53	9.7
2	EWR1	B/C (LF)	288.73	117.02	40.5	88.97	30.8
3	EWR2	C (HF)	457.68	58.24	12.7	27.16	5.9
4	EWR3	C (LF)	852.13	126.03	14.8	93.15	10.9
5	WA1	D (LF)	76.71	11.33	14.8	2.71	3.5
6	WA2	D (LF)	147.43	19.92	13.5	9.42	6.4
7	EWR4	B/C (LF)	1977.26		0.0	410.53	20.8
8	EWR5	C (LF)	2288.02		0.0	712.67	31.1
9	EWR6	B/C (LF)	95.35	22.33	23.4	14.79	15.5
10	EWR7	A/B	23.16		0.0		
11	EWR8	C (LF)	474.26	54.49	11.5	23.42	4.9
12	EWR9	B/C (HF)	31.31	10.21	32.6	7.79	24.9
13	EWR10	C/D (LF)	86.97	60.80	69.9	55.19	63.5
14	EWR11	D (LF)	29.14	25.65	88.0	19.18	65.8
15	RE-EWR2	D (HF)	37.69	8.30	22.0	5.79	15.4
16	R1	C	59.14	7.97	13.5	7.97	13.5
17	R2	C	111.08	15.33	13.8	15.33	13.8
18	EWR12	D (LF)	2546.42	508.44	20.0	332.14	13.0
19	S1	D	59.38	21.26	35.8	21.26	35.8
20	S3	D	89.96	27.80	30.9	27.80	30.9
21	S4	D	102.09	31.81	31.2	31.81	31.2
22	EWR13	C (LF)	2654.29	619.95	23.4	460.04	17.3
23	EWR14	C/D (LF)	147.61	23.47	15.9	7.63	5.2
24	EWR15	D (LF)	413.55	56.54	13.7	32.65	7.9
25	EWR16	D (HF)	3242.50	635.80	19.6	541.93	16.7
26	H1		58.96	7.77	13.2	7.77	13.2
27	EWR17	D (HF)	147.85	36.32	24.6	29.76	20.1
28	EWR18	C/D (LF)	3347.19	199.31	6.0	82.16	2.5
29	EWR IFR1	C/D (HF&LF)	3759.35	208.43	5.5	208.43	5.5

Conclusions from the Classification Study stated that the EWR structures that need to be included in future are EWR 8 and EWR IFR1. At EWR 8 in the Wilge River the releases from Sterkfontein Dam should try to mimic a seasonal release pattern, but at the same time limit the reduction in the firm supply from Vaal Dam. Changes in EWR 8 will however have very small impacts if any on the Orange system. The inclusion of EWR IFR 1 at Douglas at the downstream end of the Vaal River, results in a significant reduction in the yield available from the Vaal. It will therefore not be easy to implement this in practise. Any opportunity that can be utilised to improve the flows at the EWR IFR site 1 downstream of Douglas Weir, without reducing the Vaal System yield needs to be utilised when available. The Douglas EWR will have a direct impact on the Orange and will therefore be the most important EWR to take into account in the scenarios to be analysed for the purpose of the Orange Recon Study (See **Appendix B).**

12.4 CURRENT ORANGE SYSTEM ENVIRONMENTAL REQUIREMENT RELEASES

Releases are currently made from Vanderkloof Dam to supply the environmental requirement at the Orange River mouth. These environmental requirements were determined as part of the ORRS (Orange River Replanning Study) (DWAF, 1999), but are based on totally outdated methods. For the purpose of the Orange Reconciliation Study, these outdated environmental requirements will still be used for at least the base or current day scenario, as it represents the current EWR releases. These releases are summarised in **Table 12-5**.

Table 12-5: Current releases to supply the Orange River mouth EWR

Description	Environmental flow requirements (million m^3/a)											
Months	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
Normal	32.14	31.10	32.14	32.14	29.29	32.14	31.10	24.11	15.55	9.37	9.37	10.37	288.85
Drought	32.10	31.10	13.40	13.40	12.20	32.10	31.10	10.70	5.20	2.70	2.70	9.10	195.80

In the current WRPM setup, the drought EWR is supplied at a high assurance of 99.5% (1:200 year) and the normal EWR at a 95% (1:20 year) assurance.

12.5 RECENT ORANGE RIVER ENVIRONMENTAL REQUIREMENTS

Updated environmental requirements were determined for the Orange River as part of the ORASECOM study “Support to Phase II ORASECOM basin wide integrated water resources management plan” dated November 2010. These environmental flow requirements EFRs were assessed at an Intermediate Level at selected key areas of the Orange River basin.

It was stated in the relevant ORASECOM report that the information gathered during the EWR study is suitable for the baseline, and it was strongly recommended that an Ecological Water Resources Monitoring (EWRM) programme be initiated as soon as possible.

The locations of the selected EWR sites are shown on **Figure 12-1**. Summarised details of the EWRs determined are shown in **Table 12-6**. The EWR data sets required as input to the Water Resources Yield Model (WRYM) and Water Resourcesing Model (WRPM) for the different EWR sites are given in **Appendix B.** A summary of the EWR results is given in **Table 12-7.** (Please note that Environmental Water Requirement (EWR) and Environmental Flow Requirement (EFR) is two different names for the same thing)

Table 12-6: Locality and characteristics of Environmental Flow Requirement (EFR) sites

EFR site number	EFR site name	River	Decimal degrees S	Decimal degrees E	EcoRegion (Level II)	Geozone	Altitude (m)	MRU	Quat	Gauge
EFR O1	Hopetown	Orange	-29.516	24.00927	26.01	Lowland	1060	MRU Orange B	D33G	
EFR O2	Boegoeberg	Orange	-29.0055	22.16225	26.05	Lowland	871	MRU Orange D, RAU D.1	D73C	D7H008
EFR O3	Augrabies	Orange	-28.4287	19.9983	28.01	Lowland	434	MRU Orange E	D81B	D7H014
EFR O4	Vioolsdrif	Orange	-28.7553	17.71696	28.01	Lowland	167	MRU Orange F	D82F	D8H003 D8H013
EFR C5	Upper Caledon	Caledon	-28.6508	28.3875	15.03	Lower Foothills	1640	MRU Caledon A/B	D21A	
EFR C6	Lower Caledon	Caledon	-30.4523	26.27088	26.03	Lowland	1270	MRU Caledon D	D24J	
EFR K7	Lower Kraai	Kraai	-30.8306	26.92056	26.03	Lowland	1327	MRU Kraai C	D31M	D1H011
EFR M8	Molopo Wetland	Molopo	-25.8812	26.01592	11.01	Lower Foothills	1459	MRU UM C	D41A	D4H030 D4H014

Further environmental flow work is currently being done under the ORASECOM study “UNDP-GEF Orange-Senqu Strategic Action Programme: Research Project on Environmental Flow Requirements of the Fish River and the Orange-Senqu River Mouth”. The focus of this study is on the Orange River Mouth requirement and the Fish River in Namibia as well as the Orange River downstream of the confluence of the Fish with the Orange River. The work on this ORASECOM study is completed and the reports are currently in process. A summary of the results from the ORASECOM GEF study can therefore not yet be included in this report, but will be added as soon as the relevant reports are available.

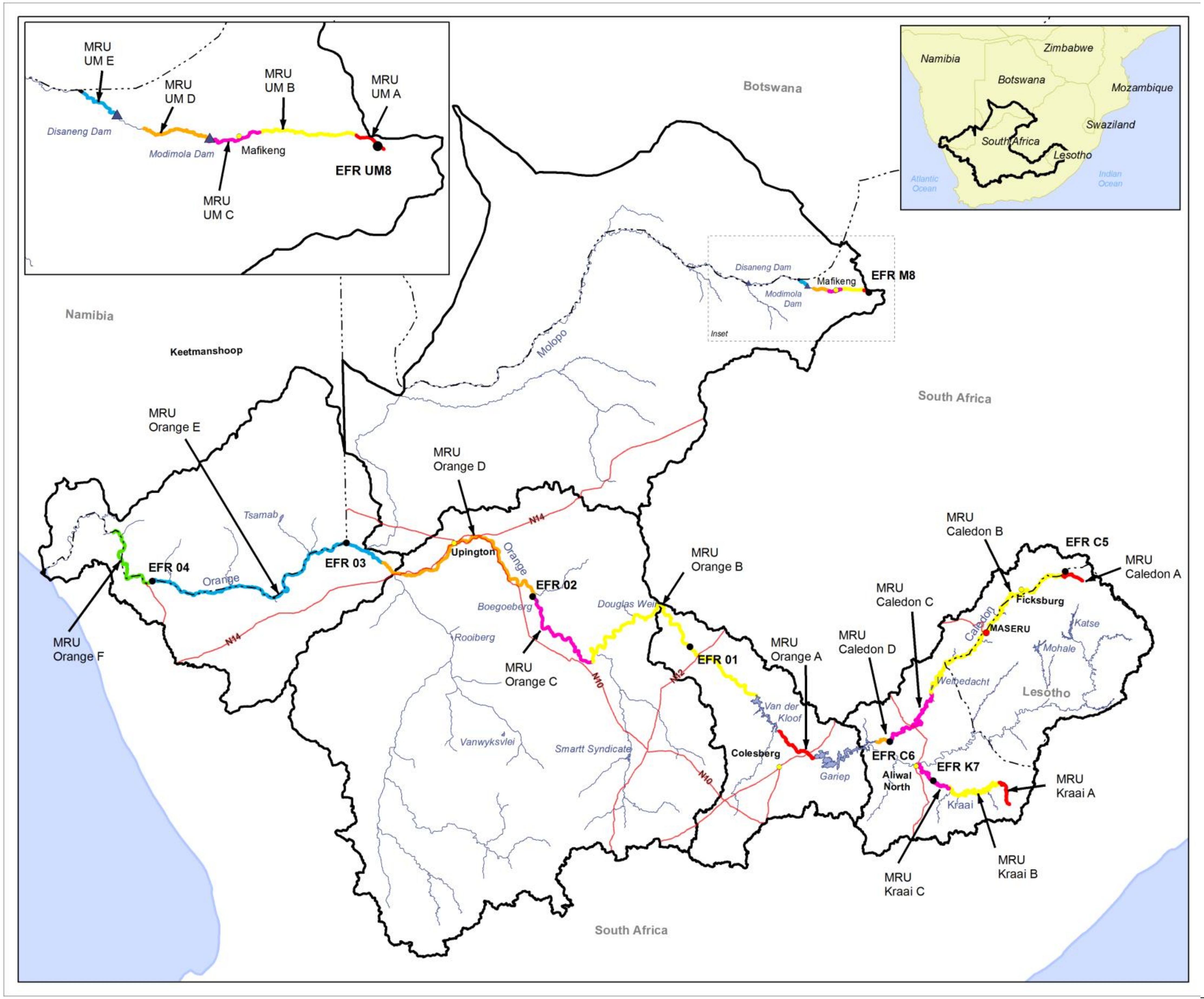

Figure 12-1: Location of EFR sites in the Orange River

Table 12-7: Summary of ORASECOM EFR results as a percentage of the natural MAR

EFR site	EC	Maintenance low flows		Drought low flows		High flows		Long term mean	
		(%nMAR)	Flow	(%nMAR)	Flow	(%nMAR)	Flow	(%nMAR)	Flow
Virgin MARs (million m³/a))									
EFR O2	PES/REC	11.6	1226.55	4.4	465.24	5.4	570.98	15.2	1607.20
	AEC↓: D	5.8	613.27	3.1	327.78	5	528.69	11.3	1194.83
EFR O3	PES: C	8.4	883.10	2.6	273.34	4.7	494.12	11.9	1251.06
	REC: B	17.6	1850.31	3.4	157.37	4.7	494.12	19.2	2018.52
	AEC↓: D	4.1	431.04	2.2	231.29	4.4	462.58	9	946.18
EFR O4	PES: C	6.3	651.11	0.9	35.16	4.2	434.07	8.9	919.82
	REC: B/C	10.1	1043.85	1.3	134.36	4.2	434.07	12.2	1260.88
	AEC↓: D	3.1	320.39	0.8	31.25	3.8	392.73	6.9	713.12
EFR C5	PES/REC: C/D	13.8	7.85	5.8	3.30	11.4	6.49	26	14.80
EFR C6	PES/REC: D	8.8	118.62	0.3	3.40	10.5	141.54	20.1	270.94
	AEC↑: C	15.5	208.93	2.2	29.66	13.1	176.58	26.1	351.82
EFR K7	PES/REC: C	11.4	77.81	0	0.00	8.4	57.33	18.1	123.53
	AEC↑: B	16.5	112.61	1.2	7.70	8.4	57.33	21.8	148.79
	AEC↓: D	5.1	34.81	0	0.00	7.1	48.46	12.9	88.04

13 EXISTING HYDRO-POWER GENERATION REQUIREMENTS

Hydro-power is generated at both Gariep and Vanderkloof dams. Four 90MW generating sets were installed at Gariep dam and two 120 MW sets at Vanderkloof Dam. These stations are mainly used for the generation of peaking power with a load factor of approximately 10%. This means that the hydro-power plants will be operated at the equivalent of the full potential for 10% of their time.

The agreement between Eskom and DWA establishes the principle of priority of water use for irrigation, urban/industrial, mining and environmental purposes with the allowance to generate hydro-power with the water released for such purposes. Hydro-power generated with these releases is therefore limited by the flow volumes and monthly distribution pattern required by the downstream users. This means that most of the energy will be generated in the summer months when the downstream demands are high and low in the winter months when the water demand is low. The power demand is however following an almost inverse pattern, where power demand is higher in winter time and lower in the summer months. To be able to improve the monthly hydro-power generation distribution pattern, the releases from Gariep Dam are based on the inverse monthly distribution pattern from Vanderkloof Dam. This is not a problem for users between Gariep and Vanderkloof dams, as their demand is very small. Vanderkloof Dam is then used to correct the distribution pattern for the downstream users.

When the dams are relatively full and there is a short-term surplus available in the system, Eskom is allowed to generated additional hydro-power at a time that suits them best. This hydro-power then generated is over and above that generated by means of the normal releases for downstream users.

Under spill conditions water flowing over the spillway crest of these dams, will be lost for power generation purposes. To be able to utilise as much as possible of these spills for hydro-power generation purposes, an additional operating rule was added. This rule allows Eskom to run the hydro-power turbines at maximum capacity as soon as the water level in the dam reaches or exceeds a predetermined level in the dam. This level varies from month to month and is dependent on the typical monthly inflow pattern to the particular dam. By implementing this, Eskom can in advance release water at maximum capacity through the turbines to reduce the risk of spilling and rather use the water to generate power. These predetermined levels in the two dams are referred to as the storage control curves.

Analyses are carried out in May and November each year to determine the short-term surplus available in the ORP system that can be used by Eskom to generate additional hydro-power at the time when it's required.

14 CONCLUSIONS AND RECOMMENDATIONS

The total urban industrial demand within the study area that is supplied from surface water resources is in the order of 230 million m^3/a at 2012 development level and is expected to increase to almost 450 million m^3/a by 2040. Although this is a significant volume, it most probably only represents in the order of 5% of the total water use from the study area.

The high water demand scenario as obtained from the All Town Study (DWA, 2011) was in general used for all the urban/industrial demand projections applicable to the RSA part of the study area. This projection is probably a slight overestimation of the future demand. With the urban/industrial requirement comprising a relative small portion of the total demand, it should not be a problem. A new adjusted high demand is currently being developed for the "Continuation and Maintenance of Reconciliation Strategies for All Towns in the Central Region" study. This is however not yet available. It is recommended that this adjusted high demand projection be considered for use in the second phase of the Orange Reconciliation Study.

The water requirements for Namibia are currently updated to a more detailed level as part of an ORASECOM project. This data is not yet available and it is recommended to use this updated information in phase 2 of the Orange Reconciliation study.

First order indication of the water requirements for possible future users such as hydraulic fracturing, solar power generation, the SKA project and hydro-power generation was included in this report. These estimates need to be updated in future when more detailed and final information become available.

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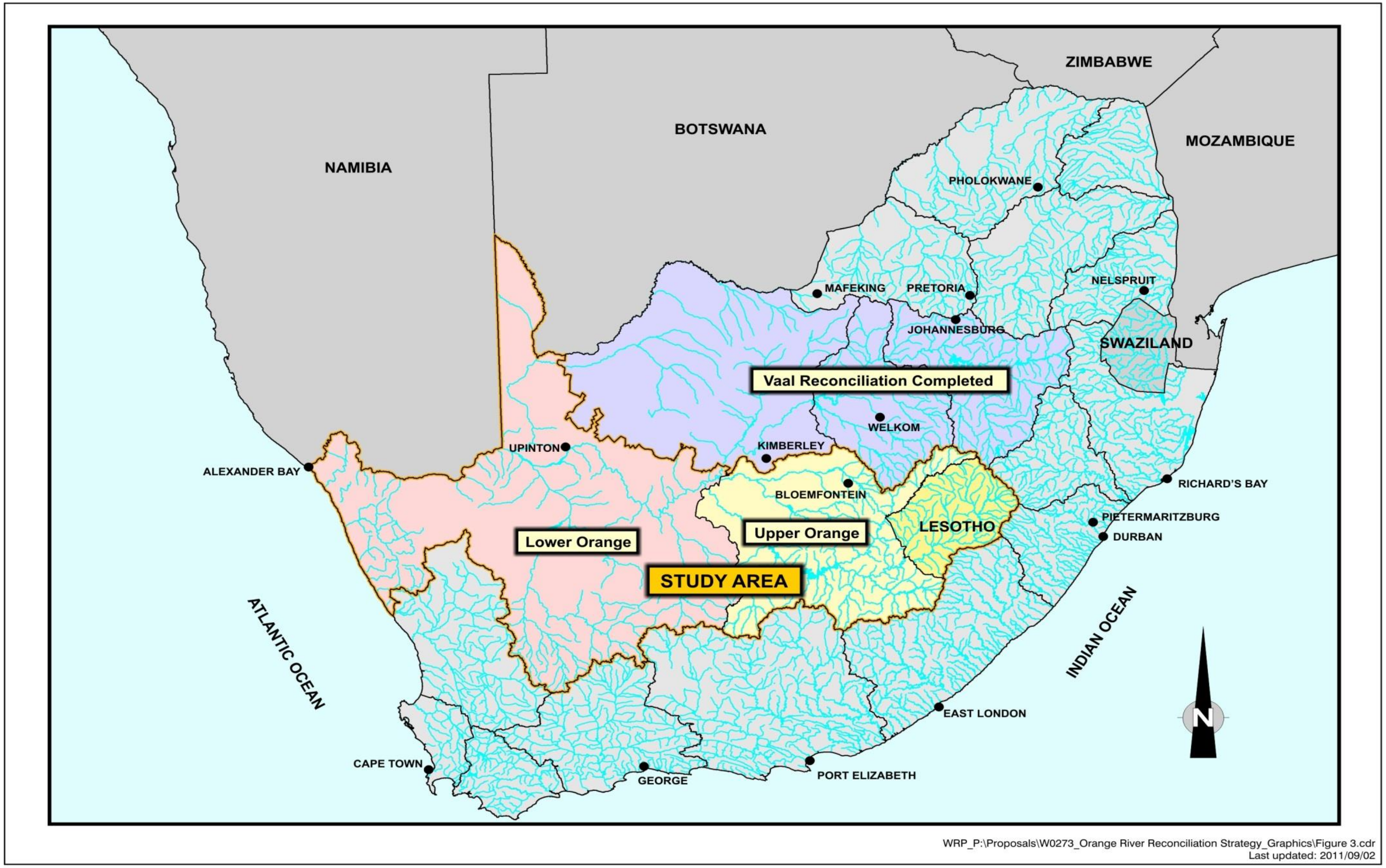
Appendix A

MAPS



DEVELOPMENT OF RECONCILIATION STRATEGIES FOR
LARGE BULK WATER SUPPLY SYSTEMS: ORANGE RIVER: PROPOSAL

Study area locality map

Urban Demand Centres
Orange River Basin
Water Management Area Boundaries
International Boundaries
Main Study Area
Existing Dams
Urban Demand Centres
Transfer Schemes
Pipelines
Namibia
Botswana
Lower Vaal WMA
Middle Vaal WMA
Upper Vaal WMA
Lower Orange WMA
Upper Orange WMA
Olifants
Komati
Usutu
Thukela
Senqu
Mzimvubu
Fish
Sundays
Main Study Area
WINDHOEK
GABARONE
PRETORIA
JOHANNESBURG
VEREENIGING
KIMBERLEY
BLOEMFONTEIN
MASERU
WELKOM
Upington
Springbok
Port Nolloth
Alexander Bay
Oranjemund
Mariental
Keetmanshoop
Kuruman
De Aar
Carnarvon
Williston
Victoria West
Middelburg
Cradock
Harrismith
Standerton
100
0
100
200
300
400
500 km

Appendix B

Environmental Requirement Structures as used in the WRYM & WRPMs

ORANGE RIVER EFR

1 EFR 01 - HOPETOWN

The REC is to maintain the PES in a C category. Due to the unlikely situation that the present operation of the dam will change and the strategic use (Eskom) that results in this operation, the setting of flow requirements were not undertaken.

2 EFR 02 - BOEGOEBERG

EFR O2: Assurance rules for PES and REC: C

Desktop Version 2, Printed on 2010/11/03
Summary of IFR rule curves for: EFRO2 Natural Flows
Determination based on defined BBM Table with site specific assurance rules.
Regional Type: Vaal PES and REC = C

Data are given in m^3/s mean monthly flow

% Points

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	41.794	41.290	40.355	38.693	35.879	31.408	24.876	16.404	7.318	0.886
Nov	78.886	73.772	68.755	63.201	53.796	46.506	37.174	27.231	19.120	15.301
Dec	81.831	76.003	70.433	64.246	54.201	46.139	36.811	28.390	22.927	21.077
Jan	86.915	81.014	75.267	68.727	58.092	49.246	39.134	30.201	24.623	22.993
Feb	167.673	147.682	130.734	114.213	88.708	72.594	55.999	43.593	37.338	35.992
Mar	212.180	209.565	202.463	186.957	160.086	123.942	87.367	60.804	48.008	41.514
Apr	61.872	61.103	59.035	54.536	46.721	36.114	25.189	17.023	12.905	12.019
May	48.843	48.166	46.652	43.699	38.752	31.794	23.840	16.814	12.427	11.144
Jun	40.975	40.456	39.304	37.064	33.308	27.997	21.852	16.304	12.705	11.486
Jul	34.839	34.425	33.615	32.153	29.748	26.210	21.682	16.858	12.923	11.070
Aug	35.162	34.856	34.289	33.280	31.571	28.857	24.892	19.749	14.233	10.328
Sep	37.215	36.958	36.513	35.750	34.456	32.304	28.403	21.748	13.353	7.494

Reserve flows without High Flows

Oct	41.794	41.290	40.355	38.693	35.879	31.408	24.876	16.404	7.318	0.886
Nov	51.211	50.561	49.289	46.994	43.219	37.667	30.560	22.988	16.810	13.902
Dec	53.136	52.548	51.243	48.705	44.449	38.431	31.468	25.182	21.104	19.723
Jan	58.221	57.564	56.095	53.229	48.428	41.677	33.959	27.141	22.883	21.639
Feb	71.576	70.962	69.309	65.713	59.466	50.988	42.256	35.728	32.437	31.729
Mar	67.585	67.014	65.465	62.082	56.221	48.336	40.357	34.563	31.771	31.280
Apr	61.872	61.103	59.035	54.536	46.721	36.114	25.189	17.023	12.905	12.019
May	48.843	48.166	46.652	43.699	38.752	31.794	23.840	16.814	12.427	11.144
Jun	40.975	40.456	39.304	37.064	33.308	27.997	21.852	16.304	12.705	11.486
Jul	34.839	34.425	33.615	32.153	29.748	26.210	21.682	16.858	12.923	11.070
Aug	35.162	34.856	34.289	33.280	31.571	28.857	24.892	19.749	14.233	10.328
Sep	37.215	36.958	36.513	35.750	34.456	32.304	28.403	21.748	13.353	7.494

Natural Duration curves

Oct	631.571	345.904	243.160	171.151	109.282	82.788	63.762	40.931	25.336	5.780
Nov	918.985	673.117	500.725	372.319	254.479	224.730	170.517	136.802	59.047	17.191
Dec	1020.120	723.973	540.834	415.502	339.382	299.522	213.527	114.475	82.269	33.774
Jan	1270.557	903.875	638.303	521.184	395.508	298.484	227.173	172.547	96.210	43.003
Feb	2052.472	1278.741	891.353	538.802	436.872	319.498	273.276	229.588	135.235	45.705
Mar	1562.280	1034.289	698.014	607.411	468.765	335.738	252.647	200.396	126.176	41.514
Apr	899.541	636.867	406.590	319.606	288.630	238.515	170.093	119.487	75.598	29.344
May	353.271	265.091	197.431	133.277	106.732	82.154	72.353	47.551	34.606	11.470
Jun	192.647	140.895	91.454	71.937	60.683	56.296	43.534	33.029	22.477	11.617
Jul	149.578	100.896	84.569	67.040	47.525	39.221	32.818	26.329	19.108	15.084
Aug	152.337	106.582	83.796	60.140	50.881	34.069	27.770	23.466	18.246	14.445
Sep	229.946	126.123	86.844	65.251	48.935	39.734	28.403	21.748	13.353	8.333

3 EFR 03 - AUGRABIES

EFR O3: Assurance rules for PES: C

Desktop Version 2, Printed on 2010/11/04

Summary of IFR rule curves for: EFR O3 Natural Flows

Determination based on defined BBM Table with site specific assurance rules.

Regional Type: Vaal PES = C

Data are given in m^3/s mean monthly flow

% Points

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	31.557	31.178	30.480	29.242	27.155	23.841	18.990	12.651	5.723	0.000
Nov	65.933	60.925	56.132	50.999	42.292	36.002	27.841	18.899	11.195	6.982
Dec	68.900	62.971	57.368	51.403	42.074	35.325	27.632	20.516	15.497	13.222
Jan	76.372	69.112	62.097	54.413	43.272	34.906	26.535	19.904	15.927	14.331
Feb	159.208	134.641	113.429	93.237	66.395	51.557	38.472	29.439	24.667	22.895
Mar	184.526	177.511	162.886	139.020	108.533	78.046	54.180	39.555	32.540	30.055
Apr	51.049	49.491	46.254	40.754	33.170	24.759	17.341	12.220	9.515	8.510
May	39.997	39.086	37.217	33.943	29.104	23.159	17.211	12.499	9.673	8.539
Jun	33.355	32.813	31.727	29.787	26.745	22.627	17.932	13.590	10.527	9.138
Jul	28.504	28.148	27.459	26.223	24.194	21.196	17.307	13.045	9.374	7.366
Aug	28.089	27.831	27.356	26.514	25.094	22.840	19.539	15.227	10.513	7.115
Sep	23.717	23.529	23.203	22.645	21.700	20.127	17.579	13.631	7.996	1.988

Reserve flows without High Flows

Oct	31.557	31.178	30.480	29.242	27.155	23.841	18.990	12.651	5.723	0.000
Nov	38.256	37.703	36.635	34.718	31.573	26.926	20.896	14.289	8.597	5.484
Dec	40.268	39.631	38.355	36.076	32.502	27.663	22.148	17.046	13.447	11.816
Jan	45.989	45.032	43.069	39.630	34.547	28.303	22.056	17.107	14.138	12.948
Feb	58.295	56.840	53.818	48.682	41.601	33.747	26.821	22.040	19.514	18.576
Mar	56.174	54.453	50.864	45.008	37.528	30.047	24.192	20.603	18.882	18.272
Apr	51.049	49.491	46.254	40.754	33.170	24.759	17.341	12.220	9.515	8.510
May	39.997	39.086	37.217	33.943	29.104	23.159	17.211	12.499	9.673	8.539
Jun	33.355	32.813	31.727	29.787	26.745	22.627	17.932	13.590	10.527	9.138
Jul	28.504	28.148	27.459	26.223	24.194	21.196	17.307	13.045	9.374	7.366
Aug	28.089	27.831	27.356	26.514	25.094	22.840	19.539	15.227	10.513	7.115
Sep	23.717	23.529	23.203	22.645	21.700	20.127	17.579	13.631	7.996	1.988

Natural Duration curves

Oct	625.022	339.729	238.616	164.643	103.756	76.240	57.239	34.909	18.821	0.000
Nov	914.267	664.780	492.404	364.016	246.127	219.066	162.211	129.147	50.710	8.954
Dec	1012.929	715.192	532.706	406.933	331.291	290.737	204.794	105.802	74.175	24.985
Jan	1262.321	923.439	638.792	513.740	386.914	298.574	219.079	163.956	87.623	34.476
Feb	2068.130	1297.202	903.282	548.251	432.614	313.600	268.556	222.359	128.001	38.447
Mar	1579.234	1029.312	705.279	602.210	475.821	337.481	248.693	196.181	122.525	38.041
Apr	909.772	633.503	413.584	324.093	285.313	244.904	175.428	122.145	72.234	25.667
May	355.152	262.418	195.744	130.589	107.056	81.851	69.739	45.669	32.053	8.793
Jun	190.698	138.897	89.664	74.742	60.035	54.333	41.539	33.013	20.652	11.323
Jul	147.345	99.836	89.595	65.315	45.613	36.989	31.127	24.709	17.085	12.851
Aug	149.029	112.541	83.065	62.724	48.092	34.629	25.291	20.535	14.938	11.137
Sep	224.877	120.988	81.709	60.116	44.159	34.688	26.505	16.725	8.252	3.221

EFR O3: Assurance rules for REC: B

Desktop Version 2, Printed on 2010/11/04

Summary of IFR rule curves for: EFRO3 Natural Flows

Determination based on defined BBM Table with site specific assurance rules.

Regional Type: Vaal   REC = B

Data are given in m^3/s mean monthly flow

% Points

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	45.572	45.145	44.182	42.204	38.529	32.471	23.869	13.822	4.967	0.000
Nov	98.751	93.748	88.716	82.693	71.750	61.056	45.959	28.578	13.718	6.808
Dec	112.793	106.347	99.404	90.547	76.024	61.632	44.979	29.944	20.193	16.890
Jan	131.804	124.946	117.059	106.342	88.710	70.025	48.667	29.796	18.015	14.571
Feb	239.908	216.227	192.258	164.745	125.280	94.919	66.705	46.745	36.637	34.307
Mar	269.643	262.286	246.887	219.882	180.747	134.750	92.006	61.765	46.452	38.041
Apr	121.675	118.015	110.355	96.921	77.453	54.571	33.308	18.264	10.647	8.890
May	79.624	78.350	75.503	69.947	60.639	47.550	32.588	19.369	11.116	8.703
Jun	52.356	51.609	49.950	46.724	41.316	33.667	24.818	16.828	11.646	9.891
Jul	33.211	32.985	32.471	31.410	29.431	26.171	21.571	16.274	11.745	9.639
Aug	30.269	30.071	29.624	28.707	27.003	24.195	20.207	15.549	11.443	9.272
Sep	30.834	30.741	30.397	29.686	28.290	25.729	21.438	15.107	7.476	1.735

Reserve flows without High Flows

Oct	45.572	45.145	44.182	42.204	38.529	32.471	23.869	13.822	4.967	0.000
Nov	70.979	70.350	68.922	65.968	60.464	51.397	38.599	23.865	11.267	5.409
Dec	84.098	82.892	80.214	75.005	66.273	53.924	39.637	26.736	18.370	15.536
Jan	103.110	101.496	97.887	90.845	79.047	62.456	43.491	26.736	16.275	13.217
Feb	144.274	140.567	132.809	119.202	99.485	76.310	54.774	39.537	31.822	30.044
Mar	146.201	142.472	134.667	120.979	101.143	77.829	56.164	40.836	33.074	31.285
Apr	121.675	118.015	110.355	96.921	77.453	54.571	33.308	18.264	10.647	8.890
May	79.624	78.350	75.503	69.947	60.639	47.550	32.588	19.369	11.116	8.703
Jun	52.356	51.609	49.950	46.724	41.316	33.667	24.818	16.828	11.646	9.891
Jul	33.211	32.985	32.471	31.410	29.431	26.171	21.571	16.274	11.745	9.639
Aug	30.269	30.071	29.624	28.707	27.003	24.195	20.207	15.549	11.443	9.272
Sep	30.834	30.741	30.397	29.686	28.290	25.729	21.438	15.107	7.476	1.735

Natural Duration curves

Oct	625.022	339.729	238.616	164.643	103.756	76.240	57.239	34.909	18.821	0.000
Nov	914.267	664.780	492.404	364.016	246.127	219.066	162.211	129.147	50.710	8.954
Dec	1012.929	715.192	532.706	406.933	331.291	290.737	204.794	105.802	74.175	24.985
Jan	1262.321	923.439	638.792	513.740	386.914	298.574	219.079	163.956	87.623	34.476
Feb	2068.130	1297.202	903.282	548.251	432.614	313.600	268.556	222.359	128.001	38.447
Mar	1579.234	1029.312	705.279	602.210	475.821	337.481	248.693	196.181	122.525	38.041
Apr	909.772	633.503	413.584	324.093	285.313	244.904	175.428	122.145	72.234	25.667
May	355.152	262.418	195.744	130.589	107.056	81.851	69.739	45.669	32.053	8.793
Jun	190.698	138.897	89.664	74.742	60.035	54.333	41.539	33.013	20.652	11.323
Jul	147.345	99.836	89.595	65.315	45.613	36.989	31.127	24.709	17.085	12.851
Aug	149.029	112.541	83.065	62.724	48.092	34.629	25.291	20.535	14.938	11.137
Sep	224.877	120.988	81.709	60.116	44.159	34.688	26.505	16.725	8.252	3.221

4 EFR 04 - VIOOLSDRIFT

EFR O4: Assurance rules for PES: C

Desktop Version 2, Printed on 2010/11/05

Summary of IFR rule curves for: EFRO4 Natural Flows

Determination based on defined BBM Table with site specific assurance rules.

Regional Type: Vaal PES = C

Data are given in m^3/s mean monthly flow

% Points

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	18.927	18.675	18.198	17.333	15.852	13.492	10.084	5.827	1.688	0.000
Nov	57.741	52.179	46.926	41.387	31.962	25.570	17.583	9.487	3.514	0.000
Dec	72.078	63.462	55.516	47.320	34.552	26.293	17.409	9.971	5.545	4.425
Jan	70.583	62.303	54.184	45.173	32.261	22.852	14.108	7.922	4.790	4.068
Feb	146.798	122.512	100.934	79.747	51.969	36.569	24.104	16.465	13.024	12.277
Mar	143.662	138.431	127.394	108.778	83.896	57.826	36.723	23.790	17.966	16.700
Apr	42.016	40.453	37.157	31.597	24.165	16.379	10.077	6.214	4.475	4.096
May	29.914	29.105	27.412	24.443	20.141	15.084	10.384	7.060	5.376	4.988
Jun	21.732	21.280	20.353	18.682	16.081	12.663	8.987	5.908	4.077	3.613
Jul	16.449	16.194	15.686	14.760	13.236	11.012	8.233	5.417	3.339	2.726
Aug	15.297	15.125	14.799	14.207	13.195	11.581	9.251	6.340	3.510	2.438
Sep	12.402	12.289	12.088	11.734	11.119	10.076	8.364	5.720	2.113	0.000

Reserve flows without High Flows

Oct	18.927	18.675	18.198	17.333	15.852	13.492	10.084	5.827	1.688	0.000
Nov	26.382	25.894	24.924	23.156	20.243	15.995	10.687	5.307	1.337	0.000
Dec	29.357	28.684	27.304	24.819	20.951	15.867	10.397	5.819	3.094	2.405
Jan	36.161	35.070	32.786	28.781	22.976	16.154	9.814	5.328	3.057	2.533
Feb	48.810	47.134	43.598	37.634	29.663	21.311	14.550	10.406	8.541	8.135
Mar	48.782	47.107	43.571	37.609	29.639	21.289	14.529	10.387	8.521	8.116
Apr	42.016	40.453	37.157	31.597	24.165	16.379	10.077	6.214	4.475	4.096
May	29.914	29.105	27.412	24.443	20.141	15.084	10.384	7.060	5.376	4.988
Jun	21.732	21.280	20.353	18.682	16.081	12.663	8.987	5.908	4.077	3.613
Jul	16.449	16.194	15.686	14.760	13.236	11.012	8.233	5.417	3.339	2.726
Aug	15.297	15.125	14.799	14.207	13.195	11.581	9.251	6.340	3.510	2.438
Sep	12.402	12.289	12.088	11.734	11.119	10.076	8.364	5.720	2.113	0.000

Natural Duration curves

Oct	617.290	332.064	230.880	156.915	96.778	68.504	49.507	27.274	11.092	0.000
Nov	905.096	654.931	482.554	354.171	236.273	209.336	152.365	119.425	40.860	0.000
Dec	1002.860	704.824	522.461	396.565	321.263	280.369	194.437	95.456	63.937	4.734
Jan	1252.087	913.206	628.491	503.655	376.613	288.986	208.748	153.655	77.326	24.190
Feb	2063.864	1293.461	898.313	539.790	424.611	305.035	260.007	213.802	119.444	29.882
Mar	1577.203	1023.167	701.430	596.027	472.200	331.343	242.742	190.181	116.629	31.851
Apr	906.879	629.217	411.092	322.631	281.034	241.238	171.188	117.909	67.948	21.323
May	352.830	259.244	192.753	127.412	104.600	78.995	66.577	42.641	28.902	5.619
Jun	188.345	136.535	87.346	72.380	58.627	51.979	39.182	30.687	18.326	9.340
Jul	144.710	97.420	86.962	63.045	43.037	34.353	28.491	22.073	14.490	10.215
Aug	145.128	108.639	79.648	58.830	44.194	30.727	21.408	16.637	11.036	5.238
Sep	218.835	114.934	75.656	54.063	38.171	28.546	20.455	10.683	2.218	0.000

EFR O4: Assurance rules for REC: B/C

Desktop Version 2, Printed on 2010/11/05

Summary of IFR rule curves for: EFRO4 Natural Flows

Determination based on defined BBM Table with site specific assurance rules.

Regional Type: Vaal   REC = B/C

Data are given in m^3/s mean monthly flow

% Points

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	31.766	31.447	30.704	29.141	26.200	21.373	14.701	7.399	1.800	0.000
Nov	74.473	69.078	63.966	58.310	48.043	39.468	27.617	14.645	4.699	0.000
Dec	86.512	77.922	69.818	60.962	46.615	35.624	23.222	12.514	6.096	4.514
Jan	85.724	78.848	71.898	63.615	50.112	38.119	24.586	12.902	5.899	4.173
Feb	163.354	142.077	122.406	102.019	72.867	54.170	36.795	24.502	18.278	16.843
Mar	161.737	157.177	147.634	130.898	106.645	78.140	51.650	32.909	23.419	21.231
Apr	61.069	59.224	55.363	48.591	38.778	27.243	16.525	8.942	5.102	4.217
May	44.994	44.266	42.629	39.424	34.059	26.559	18.097	10.790	6.411	5.332
Jun	34.071	33.550	32.377	30.081	26.237	20.865	14.802	9.568	6.431	5.658
Jul	29.066	28.816	28.233	27.005	24.697	20.908	15.672	9.940	5.546	4.289
Aug	26.878	26.632	26.059	24.852	22.582	18.855	13.705	8.068	3.746	2.509
Sep	26.715	26.506	26.061	25.162	23.454	20.449	15.694	9.267	2.218	0.000

Reserve flows without High Flows

Oct	31.766	31.447	30.704	29.141	26.200	21.373	14.701	7.399	1.800	0.000
Nov	42.999	42.567	41.562	39.445	35.465	28.930	19.900	10.015	2.437	0.000
Dec	43.684	42.929	41.228	37.900	32.328	24.540	15.750	8.162	3.614	2.493
Jan	53.204	52.277	50.189	46.103	39.263	29.702	18.913	9.597	4.015	2.639
Feb	70.452	68.578	64.656	57.777	47.808	36.092	25.204	17.501	13.601	12.701
Mar	69.789	67.935	64.055	57.251	47.392	35.803	25.034	17.415	13.557	12.667
Apr	61.069	59.224	55.363	48.591	38.778	27.243	16.525	8.942	5.102	4.217
May	44.994	44.266	42.629	39.424	34.059	26.559	18.097	10.790	6.411	5.332
Jun	34.071	33.550	32.377	30.081	26.237	20.865	14.802	9.568	6.431	5.658
Jul	29.066	28.816	28.233	27.005	24.697	20.908	15.672	9.940	5.546	4.289
Aug	26.878	26.632	26.059	24.852	22.582	18.855	13.705	8.068	3.746	2.509
Sep	26.715	26.506	26.061	25.162	23.454	20.449	15.694	9.267	2.218	0.000

Natural Duration curves

Oct	617.290	332.064	230.880	156.915	96.778	68.504	49.507	27.274	11.092	0.000
Nov	905.096	654.931	482.554	354.171	236.273	209.336	152.365	119.425	40.860	0.000
Dec	1002.860	704.824	522.461	396.565	321.263	280.369	194.437	95.456	63.937	4.734
Jan	1252.087	913.206	628.491	503.655	376.613	288.986	208.748	153.655	77.326	24.190
Feb	2063.864	1293.461	898.313	539.790	424.611	305.035	260.007	213.802	119.444	29.882
Mar	1577.203	1023.167	701.430	596.027	472.200	331.343	242.742	190.181	116.629	31.851
Apr	906.879	629.217	411.092	322.631	281.034	241.238	171.188	117.909	67.948	21.323
May	352.830	259.244	192.753	127.412	104.600	78.995	66.577	42.641	28.902	5.619
Jun	188.345	136.535	87.346	72.380	58.627	51.979	39.182	30.687	18.326	9.340
Jul	144.710	97.420	86.962	63.045	43.037	34.353	28.491	22.073	14.490	10.215
Aug	145.128	108.639	79.648	58.830	44.194	30.727	21.408	16.637	11.036	5.238
Sep	218.835	114.934	75.656	54.063	38.171	28.546	20.455	10.683	2.218	0.000

5 EFR 05 – UPPER CALEDON

EFR C5: Assurance rules for PES and REC: C/D

Desktop Version 2, Printed on 2010/11/02

Summary of IFR rule curves for: EFRC5 Natural Monthly Flows

Determination based on defined BBM Table with site specific assurance rules.

Regional Type: Vaal   PES and REC = D

Data are given in m^3/s mean monthly flow

% Points

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.280	0.273	0.259	0.234	0.198	0.154	0.111	0.078	0.060	0.053
Nov	1.576	1.319	1.099	0.894	0.601	0.452	0.307	0.197	0.135	0.113
Dec	1.186	1.010	0.859	0.714	0.507	0.394	0.285	0.202	0.155	0.101
Jan	1.252	1.075	0.921	0.773	0.561	0.442	0.327	0.239	0.190	0.153
Feb	1.408	1.243	1.096	0.952	0.727	0.594	0.442	0.302	0.203	0.158
Mar	1.610	1.587	1.543	1.463	1.332	1.139	0.888	0.613	0.376	0.217
Apr	0.754	0.741	0.715	0.668	0.595	0.495	0.382	0.278	0.204	0.170
May	0.429	0.420	0.402	0.369	0.322	0.264	0.209	0.166	0.142	0.134
Jun	0.343	0.337	0.323	0.299	0.264	0.222	0.181	0.149	0.132	0.125
Jul	0.266	0.261	0.250	0.232	0.206	0.174	0.143	0.120	0.107	0.102
Aug	0.237	0.233	0.223	0.207	0.183	0.153	0.125	0.103	0.091	0.087
Sep	0.234	0.229	0.218	0.200	0.173	0.141	0.109	0.085	0.072	0.067

Reserve flows without High Flows

Oct	0.280	0.273	0.259	0.234	0.198	0.154	0.111	0.078	0.060	0.053
Nov	0.386	0.376	0.355	0.320	0.267	0.204	0.143	0.096	0.069	0.060
Dec	0.383	0.375	0.357	0.327	0.281	0.227	0.174	0.133	0.111	0.101
Jan	0.449	0.440	0.420	0.386	0.336	0.275	0.216	0.171	0.146	0.137
Feb	0.571	0.561	0.540	0.504	0.447	0.370	0.282	0.200	0.143	0.117
Mar	0.603	0.596	0.581	0.555	0.512	0.449	0.367	0.277	0.199	0.157
Apr	0.560	0.551	0.533	0.500	0.449	0.380	0.301	0.228	0.177	0.153
May	0.429	0.420	0.402	0.369	0.322	0.264	0.209	0.166	0.142	0.134
Jun	0.343	0.337	0.323	0.299	0.264	0.222	0.181	0.149	0.132	0.125
Jul	0.266	0.261	0.250	0.232	0.206	0.174	0.143	0.120	0.107	0.102
Aug	0.237	0.233	0.223	0.207	0.183	0.153	0.125	0.103	0.091	0.087
Sep	0.234	0.229	0.218	0.200	0.173	0.141	0.109	0.085	0.072	0.067

Natural Duration curves

Oct	4.051	1.919	1.004	0.541	0.418	0.299	0.235	0.179	0.131	0.078
Nov	6.617	5.015	3.156	1.971	1.335	0.544	0.417	0.336	0.201	0.120
Dec	5.585	3.890	2.606	1.837	1.098	0.612	0.411	0.343	0.202	0.101
Jan	6.459	5.615	3.360	2.083	1.471	0.806	0.474	0.358	0.243	0.153
Feb	8.428	5.907	3.848	3.084	2.488	1.550	0.653	0.587	0.372	0.215
Mar	6.705	5.578	4.432	3.502	2.535	1.680	1.113	0.624	0.441	0.217
Apr	5.359	4.059	3.225	2.211	1.551	1.262	0.833	0.691	0.455	0.359
May	2.662	1.744	1.441	0.956	0.683	0.575	0.474	0.414	0.291	0.228
Jun	1.937	0.938	0.710	0.563	0.440	0.394	0.347	0.313	0.201	0.150
Jul	0.803	0.538	0.467	0.414	0.340	0.280	0.250	0.213	0.157	0.105
Aug	0.803	0.538	0.414	0.302	0.254	0.220	0.187	0.168	0.119	0.093
Sep	1.184	0.490	0.363	0.289	0.224	0.201	0.170	0.139	0.116	0.081

6 EFR 06 – LOWER CALEDON

EFR C6: Assurance rules for PES and REC: D

Desktop Version 2, Printed on 2010/11/02
Summary of IFR rule curves for: EFRC6 Natural Monthly Flows
Determination based on defined BBM Table with site specific assurance rules.
Regional Type : Vaal PES and REC = D
Data are given in m^3/s mean monthly flow

	% Points									
Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	2.583	2.544	2.437	2.193	1.751	1.140	0.533	0.152	0.066	0.066
Nov	14.507	12.789	11.240	9.654	7.097	5.393	3.471	1.812	0.817	0.572
Dec	15.390	13.664	12.077	10.447	7.898	6.201	4.266	2.477	1.214	0.642
Jan	40.662	34.956	30.007	25.341	18.048	14.250	9.920	5.915	3.090	1.810
Feb	47.119	40.757	35.185	29.855	21.525	16.972	11.782	6.982	3.595	2.060
Mar	43.120	42.214	40.398	37.156	32.072	25.190	17.345	10.088	4.969	2.649
Apr	13.789	13.490	12.891	11.823	10.147	7.878	5.292	2.899	1.212	0.447
May	7.164	7.009	6.697	6.142	5.270	4.090	2.746	1.502	0.624	0.226
Jun	3.138	3.070	2.933	2.688	2.304	1.785	1.193	0.645	0.259	0.084
Jul	0.981	0.963	0.923	0.845	0.715	0.532	0.327	0.149	0.042	0.016
Aug	0.498	0.490	0.469	0.421	0.334	0.214	0.095	0.020	0.003	0.003
Sep	0.682	0.677	0.648	0.565	0.400	0.187	0.036	0.004	0.004	0.004

Reserve flows without High Flows

Oct	2.583	2.544	2.437	2.193	1.751	1.140	0.533	0.152	0.066	0.066
Nov	5.668	5.567	5.340	4.894	4.148	3.106	1.929	0.914	0.305	0.155
Dec	6.855	6.706	6.409	5.878	5.045	3.917	2.631	1.442	0.603	0.223
Jan	11.094	10.854	10.372	9.512	8.163	6.338	4.257	2.331	0.974	0.358
Feb	14.383	14.071	13.446	12.331	10.581	8.212	5.511	3.014	1.252	0.453
Mar	16.489	16.131	15.413	14.132	12.123	9.403	6.303	3.436	1.413	0.496
Apr	13.789	13.490	12.891	11.823	10.147	7.878	5.292	2.899	1.212	0.447
May	7.164	7.009	6.697	6.142	5.270	4.090	2.746	1.502	0.624	0.226
Jun	3.138	3.070	2.933	2.688	2.304	1.785	1.193	0.645	0.259	0.084
Jul	0.981	0.963	0.923	0.845	0.715	0.532	0.327	0.149	0.042	0.016
Aug	0.498	0.490	0.469	0.421	0.334	0.214	0.095	0.020	0.003	0.003
Sep	0.682	0.677	0.648	0.565	0.400	0.187	0.036	0.004	0.004	0.004

Natural Duration curves

Oct	84.237	37.784	21.479	16.334	9.860	6.291	4.794	3.670	2.905	1.505
Nov	133.665	74.533	53.472	41.258	33.117	23.252	15.089	9.333	4.417	2.361
Dec	107.475	82.658	58.513	44.889	32.680	25.907	22.510	13.852	10.081	2.042
Jan	176.467	115.875	92.757	68.694	49.500	32.967	25.930	16.424	8.639	3.308
Feb	211.004	158.172	95.176	74.024	46.970	36.822	26.852	21.028	12.140	4.824
Mar	195.971	149.705	95.523	77.457	51.979	46.532	32.994	21.558	12.377	4.940
Apr	171.840	89.853	57.450	47.948	29.865	21.493	17.701	12.137	7.299	4.367
May	62.231	36.249	15.879	12.922	9.704	8.038	6.433	5.234	4.667	2.595
Jun	27.037	14.387	9.961	7.296	6.647	5.849	4.753	3.974	3.465	2.284
Jul	10.107	7.960	6.653	5.735	5.066	4.760	3.737	3.218	2.718	1.770
Aug	13.015	8.109	5.996	5.167	4.443	3.778	3.394	2.793	2.404	1.729
Sep	13.534	10.177	6.416	5.147	4.062	3.387	3.048	2.593	2.215	1.304

7 EFR 07 – LOWER KRAAI

EFR K7: Assurance rules for PES and REC: C

Desktop Version 2, Printed on 2010/11/02

Summary of IFR rule curves for: EFR K7 Natural Monthly Flows

Determination based on defined BBM Table with site specific assurance rules.

Regional Type: E.Cape PES and REC: = C

Data are given in m^3/s mean monthly flow % Points

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	2.411	2.363	2.267	2.089	1.796	1.373	0.861	0.373	0.056	0.015
Nov	10.355	9.125	8.017	6.924	5.056	4.029	2.759	1.496	0.599	0.370
Dec	10.307	9.116	8.046	6.995	5.198	4.215	2.976	1.697	0.719	0.265
Jan	6.694	6.583	6.365	5.972	5.326	4.376	3.159	1.863	0.806	0.308
Feb	8.110	7.980	7.729	7.279	6.540	5.448	4.032	2.480	1.142	0.411
Mar	25.399	22.142	19.314	16.699	12.208	10.238	7.681	4.880	2.467	0.638
Apr	5.111	5.026	4.862	4.567	4.084	3.370	2.443	1.428	0.553	0.075
May	3.779	3.713	3.585	3.354	2.975	2.416	1.700	0.938	0.317	0.024
Jun	3.035	2.980	2.872	2.674	2.350	1.875	1.276	0.658	0.186	0.019
Jul	2.311	2.267	2.180	2.020	1.757	1.374	0.900	0.429	0.094	0.015
Aug	2.076	2.035	1.952	1.799	1.546	1.182	0.741	0.321	0.048	0.013
Sep	2.142	2.098	2.007	1.838	1.560	1.163	0.693	0.267	0.014	0.014

Reserve flows without High Flows

Oct	2.411	2.363	2.267	2.089	1.796	1.373	0.861	0.373	0.056	0.015
Nov	3.127	3.068	2.949	2.733	2.377	1.859	1.218	0.580	0.128	0.020
Dec	3.311	3.251	3.133	2.918	2.563	2.045	1.392	0.718	0.202	0.021
Jan	3.499	3.438	3.320	3.106	2.754	2.237	1.574	0.869	0.293	0.022
Feb	4.543	4.467	4.321	4.060	3.630	2.995	2.172	1.269	0.492	0.067
Mar	5.757	5.662	5.477	5.145	4.601	3.796	2.752	1.609	0.623	0.084
Apr	5.111	5.026	4.862	4.567	4.084	3.370	2.443	1.428	0.553	0.075
May	3.779	3.713	3.585	3.354	2.975	2.416	1.700	0.938	0.317	0.024
Jun	3.035	2.980	2.872	2.674	2.350	1.875	1.276	0.658	0.186	0.019
Jul	2.311	2.267	2.180	2.020	1.757	1.374	0.900	0.429	0.094	0.015
Aug	2.076	2.035	1.952	1.799	1.546	1.182	0.741	0.321	0.048	0.013
Sep	2.142	2.098	2.007	1.838	1.560	1.163	0.693	0.267	0.014	0.014

Natural Duration curves

Oct	26.908	18.832	10.805	9.304	6.422	5.089	3.286	2.009	1.154	0.803
Nov	85.316	35.652	26.790	14.676	10.606	8.349	5.721	3.437	1.393	0.370
Dec	68.444	46.345	30.559	19.486	11.985	9.834	6.089	3.584	1.411	0.265
Jan	56.459	40.267	27.908	21.405	14.897	8.326	5.063	3.648	1.822	0.523
Feb	90.943	56.316	37.785	26.360	17.415	14.178	7.660	5.820	2.505	0.934
Mar	126.426	66.991	42.380	33.946	24.462	15.057	11.574	8.247	5.238	0.638
Apr	83.144	57.323	41.289	22.600	14.877	10.440	7.971	5.802	2.890	0.945
May	39.139	21.942	13.482	10.055	7.396	6.216	5.048	3.073	2.061	0.784
Jun	24.745	11.547	7.276	6.069	5.162	4.653	3.248	2.650	1.535	0.579
Jul	14.139	9.009	5.518	4.716	3.913	3.271	2.852	2.535	1.751	0.455
Aug	11.466	8.352	5.485	4.596	3.454	2.767	2.449	1.979	1.759	0.329
Sep	25.864	12.824	7.589	5.170	3.731	3.048	2.481	1.867	1.377	0.579

VAAL RIVER EFR

8 EWR 08 WILGE RIVER AT BAVARIA

Wilge River at Bavaria: EWR8

Excedance	Oct		Nov		Dec		Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep	
Probability	Ref Flow	EWR	Ref Flow	EWR	Ref Flow	EWR	Ref Flow	EWR	Ref Flow	EWR	Ref Flow	EWR	Ref Flow	EWR	Ref Flow	EWR	Ref Flow	EWR	Ref Flow	EWR	Ref Flow	EWR	Ref Flow	EWR
Max	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
99	0.452	0.019	0.737	0.246	0.952	0.286	1.647	0.330	3.548	0.439	1.900	0.370	0.621	0.283	0.299	0.069	0.197	0.038	0.019	0.017	0.022	0.020	0.521	0.123
90	0.862	0.061	1.439	0.300	2.080	0.349	5.164	0.400	6.408	0.528	3.707	0.451	1.968	0.348	0.814	0.118	0.559	0.072	0.545	0.049	0.448	0.046	0.760	0.148
80	1.512	0.154	4.201	0.418	4.540	0.487	9.577	0.556	10.808	0.724	6.119	0.629	2.955	0.492	1.228	0.226	0.887	0.148	0.874	0.118	0.945	0.102	0.938	0.205
70	1.747	0.285	5.810	0.585	8.094	0.683	10.924	0.778	14.557	1.002	9.013	0.881	4.360	0.696	1.568	0.379	1.096	0.256	0.963	0.217	1.049	0.183	1.038	0.285
60	2.755	0.427	7.589	0.766	11.354	0.895	15.636	1.017	17.396	1.303	11.540	1.154	5.502	0.917	2.169	0.544	1.358	0.372	1.277	0.323	1.273	0.269	1.350	0.371
50	3.689	0.551	9.973	0.925	16.502	1.081	18.836	1.227	22.132	1.567	13.803	1.393	6.362	1.110	2.744	0.689	1.890	0.474	1.576	0.417	1.385	0.346	1.647	0.447
40	5.903	0.643	15.926	1.042	22.166	1.218	25.299	1.382	24.885	1.762	18.963	1.570	9.483	1.253	3.368	0.796	2.373	0.550	1.826	0.486	1.807	0.402	2.238	0.503
30	10.286	0.702	22.635	1.117	28.103	1.305	31.761	1.481	31.064	1.886	24.197	1.682	11.532	1.345	4.757	0.865	2.716	0.598	2.221	0.530	2.177	0.438	3.044	0.539
20	14.064	0.735	35.972	1.159	35.510	1.354	42.813	1.536	49.025	1.956	29.570	1.745	13.870	1.396	6.153	0.903	3.584	0.625	3.237	0.555	3.047	0.458	4.375	0.559
10	29.977	0.751	60.980	1.180	58.330	1.379	63.064	1.564	81.186	1.990	35.880	1.777	18.233	1.421	9.453	0.922	6.134	0.638	5.626	0.567	5.208	0.468	9.194	0.569
Min	9999.9	0.751	9999.9	1.180	9999.9	1.379	9999.9	1.564	9999.9	1.990	9999.9	1.777	9999.9	1.421	9999.9	0.922	9999.9	0.638	9999.9	0.567	9999.9	0.468	9999.9	0.569

9 EWR (IFR1) VAAL RIVER DOWNSTREAM OF DOUGLAS WEIR

Vaal River downstream of Douglas Weir : Douglas EWR (IFR1)

Excedance	Oct		Nov		Dec		Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep	
Probability	Ref Flow	EWR	Ref Flow	EWR	Ref Flow	EWR	Ref Flow	EWR	Ref Flow	EWR	Ref Flow	EWR	Ref Flow	EWR	Ref Flow	EWR	Ref Flow	EWR	Ref Flow	EWR	Ref Flow	EWR	Ref Flow	EWR
Max	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
99	6.847	0.551	11.559	3.539	14.714	3.838	23.772	4.241	20.805	5.150	17.772	4.644	9.217	2.951	7.157	1.847	7.122	1.046	6.959	0.045	8.371	0.049	8.063	0.549
90	9.972	0.675	17.215	3.599	28.831	3.896	52.580	4.305	47.206	5.227	35.073	4.713	20.664	3.075	10.932	2.066	10.502	1.451	10.279	0.963	9.950	0.473	10.050	0.777
80	16.047	1.214	41.015	3.875	47.133	4.166	76.098	4.598	74.586	5.583	51.609	5.030	32.797	3.612	15.300	2.977	12.029	2.883	11.555	3.342	11.514	1.977	10.652	1.728
70	19.960	2.279	53.704	4.490	73.525	4.766	88.609	5.250	104.585	6.375	72.499	5.733	43.129	4.673	17.634	4.482	13.140	4.704	13.008	5.264	13.232	3.888	12.523	3.298
60	26.191	3.784	79.005	5.492	113.030	5.745	134.158	6.313	123.312	7.666	87.112	6.882	51.049	6.172	20.262	6.161	14.803	6.287	14.942	6.371	15.065	5.550	13.634	5.049
50	31.814	5.404	94.302	6.730	137.653	6.954	158.692	7.627	131.367	9.261	106.579	8.300	59.336	7.786	23.219	7.566	16.667	7.363	16.413	6.899	17.036	6.680	16.339	6.515
40	47.159	6.782	140.502	7.912	172.428	8.108	211.735	8.881	161.205	10.784	137.444	9.653	93.769	9.159	29.260	8.502	19.649	7.972	18.638	7.120	18.365	7.319	18.445	7.491
30	57.613	7.733	194.803	8.796	219.489	8.971	242.029	9.819	298.611	11.923	243.687	10.666	125.370	10.106	41.704	9.016	22.234	8.270	21.251	7.205	21.076	7.632	24.448	8.027
20	131.705	8.275	242.122	9.320	262.575	9.483	365.274	10.375	457.194	12.598	353.259	11.267	157.886	10.647	66.211	9.254	34.884	8.400	26.553	7.205	26.747	7.768	31.412	8.276
10	253.483	8.534	429.171	9.569	445.542	9.726	502.643	10.639	952.327	12.918	460.286	11.551	281.671	10.905	86.499	9.348	49.070	8.431	39.247	7.205	38.960	7.801	49.055	8.374
Min	9999.9	8.534	9999.9	9.569	9999.9	9.726	9999.9	10.639	9999.9	12.918	9999.9	11.551	9999.9	10.905	9999.9	9.348	9999.9	8.431	9999.9	7.205	9999.9	7.801	9999.9	8.374

LESOTHO HIGHLANDS WATER PROJECT EFR

10 IFR RELEASE SCHEDULE FOR IFR SITE 2 DOWNSTREAM OF KATSE DAM

Class	MAR (million m^3/a)	Monthly IFR (million m^3/a)											
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	756.6	3.21	22.74	12.21	11.48	12.14	11.48	7.74	4.71	7.35	4.45	7.18	4.09
2	563.8	2.95	13.61	3.21	11.48	12.14	6.98	7.74	3.21	2.85	2.41	6.91	3.83
3	501.7	2.95	12.11	3.21	7.98	12.14	3.48	7.74	3.21	2.85	2.41	6.67	2.15
4	348.4	2.68	2.85	3.08	7.71	12.14	2.95	4.09	2.41	1.45	1.61	6.64	2.33
5	0.0	2.28	2.33	2.68	2.68	2.30	2.41	6.70	2.14	1.81	1.61	5.97	2.07

11 IFR RELEASE SCHEDULE FOR IFR SITE 7 DOWNSTREAM OF MOHALE DAM

Class	MAR (million m^3/a)	Monthly IFR (million m^3/a)											
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	413.8	2.08	10.54	2.02	4.48	14.38	3.50	3.12	3.58	2.53	1.99	2.70	2.28
2	321.6	2.41	2.07	2.68	2.52	10.44	2.79	2.05	1.61	1.43	1.34	5.37	1.94
3	278.9	2.00	3.28	1.44	2.38	10.66	2.02	2.40	1.59	0.72	0.39	4.56	0.49
4	192.0	0.99	1.37	1.87	1.77	6.59	2.18	1.70	0.83	0.52	0.54	4.60	0.41
5	0.0	0.94	1.30	1.53	1.12	5.35	1.55	0.62	0.91	0.78	0.54	0.54	0.65