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**PROJECT NAME** : PREFEASIBILITY STUDY INTO MEASURES TO IMPROVE  
THE MANAGEMENT OF THE LOWER ORANGE RIVER  
AND TO PROVIDE FOR FUTURE DEVELOPMENTS  
ALONG THE BORDER BETWEEN NAMIBIA AND  
SOUTH AFRICA

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Submitted on behalf of the Project Team by Lower Orange River Consultants:

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#### **PERMANENT WATER COMMISSION**

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## LIST OF REPORTS

TITLE	REPORT NUMBER		
	DWAF RSA	DWA Namibia	LORC (NS)
<b>Main Report</b>	<b>PB D000/00/4703</b>	<b>400/8/1/P-13</b>	<b>3749/97331</b>
Legal, Institutional, Water Sharing, Cost Sharing, Management and Dam Operation	PB D000/00/4603	400/8/1/P-10	3692/97331
Specialist Report on the Environmental Flow Requirements - Riverine	PB D000/00/4503	400/8/1/P-07	3519/97331
Specialist Report on the Determination of the Preliminary Ecological Reserve on a Rapid Level for Orange River Estuary	PB D000/00/4503	400/8/1/P-08	3663/97331
Water Requirements	PB D000/00/4202	400/8/1/P-02	3486/97331
Hydrology, Water Quality and Systems Analysis (Volume A)	PB D000/00/4303	400/8/1/P04	3736/97331
Hydrology, Water Quality and Systems Analysis (Volume B)	PB D000/00/4303	400/8/1/P-03	3485/97331
Water Conservation and Demand Management	PB D000/00/4903	400/8/1/P-12	3487/97331
Dam Development Options and Economic Analysis – Volume 1	PB D000/00/4403	400/8/1/P-05	3484/97331
Dam Development Options and Economic Analysis – Volume 2 (Appendices)	PB D000/00/4403	400/8/1/P-05	3484/97331
Environmental Assessment of the Proposed Dam Sites on the Orange River	PB D000/00/4503	400/8/1/P-06	3873/97331
Vioolsdrift/Noordoewer Joint Irrigation Scheme: Assessment of Viability	PB D000/00/4803	400/8/1/P-11	3525/97331
Public Consultation	PB D000/00/4503	400/8/1/P-09	3869/97331
Inception Report	PB D000/00/4102	400/8/1/P-01	3365/97331

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## EXECUTIVE SUMMARY

### BACKGROUND

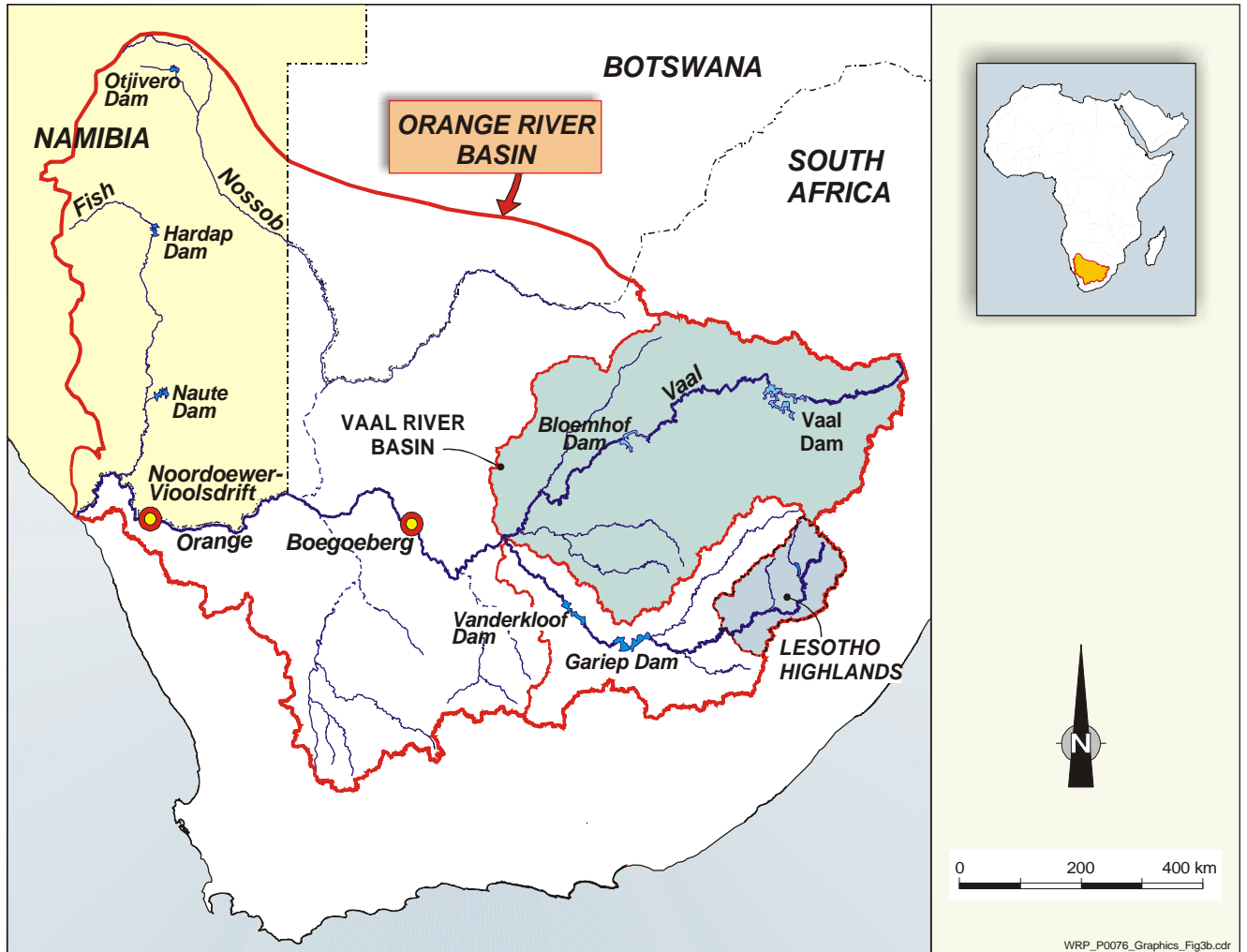
*The Orange River, with a catchment area of approximately 1 million km<sup>2</sup>, originates in the highlands of Lesotho and flows west for approximately 2 200 km to the Atlantic Ocean. The last 600 km of the Orange River forms the border between South Africa and Namibia, and any measure to improve the management of the water resources available in the Lower Orange River, will benefit both countries. This Joint Study, under the control of the Permanent Water Commission between Namibia and South Africa, investigated and made recommendations on the more efficient management and use of water resources in the Lower Orange River.*

*The overall study objective was stated as “Investigate and report on the availability of water and options for improved management through the efficiency of water use and supply management measures to promote the strategic objectives of the countries involved”. The countries’ Strategic Objectives for the joint management of the Lower Orange River were agreed by the countries to be:*

- Regional Economic Development;*
- Poverty Alleviation;*
- Job Creation;*
- Food Security;*
- Protection of the Environment;*
- Ensuring Water Supply to Downstream Users; and*
- Water Resources Management aligned with National Policies, Objectives and Strategies for Water Resources.*

*The water resources and use in the whole Orange River Basin, as shown on Figure 1, were assessed. The river reach west of the 20° longitude, where the river forms the border between Namibia and South Africa, was subject to the most detailed study. The Vaal River System was not studied in any detail since the results of recent studies by South Africa were suitable for use in this study.*

*It has been estimated that the natural runoff of the Orange River Basin is in the order of 11 300 Million m<sup>3</sup>/a. Much of the runoff originating from the Orange River downstream of the Orange/Vaal confluence is highly erratic and cannot be relied upon to support the downstream water requirements unless regulation is provided. The portion of runoff originating from the Fish River in Namibia can support some of the downstream demands, particularly the environmental demands at the river mouth.*



**Figure 1: Orange River Basin**

*The Basin of the Lower Orange River largely corresponds with that of the Northern Cape Province in South Africa and the South, Central and Eastern regions in Namibia. The largest primary contributions to the economy are made by mining and irrigated agriculture. Mining activities are centred around Alexander Bay and Oranjemund, while extensive irrigation occurs at locations along the Orange River, as shown in **Figure 2**. Demographic projections show a steady decline in the population in the region over the next 25 years. Economic activity is likely to remain dependant on mining and irrigation for the foreseeable future, with modest contributions from eco-tourism.*

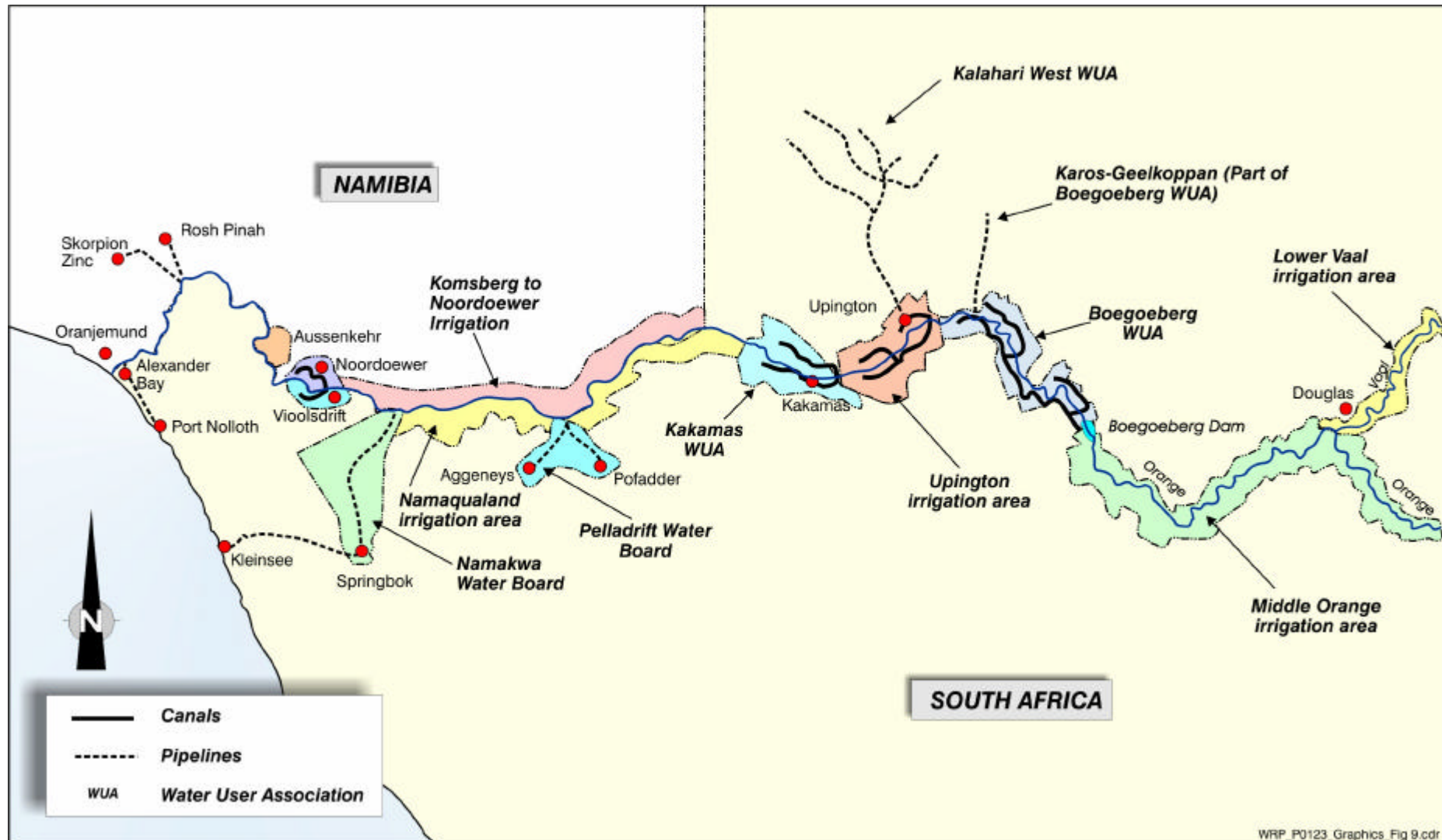


Figure 2: Major Water Demand Areas along the Lower Orange River

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## **ENVIRONMENTAL WATER REQUIREMENTS**

*Updated preliminary assessments were made of the ecological water requirements for the Orange River, downstream of Augrabies, and the River Estuary, as the releases currently being made from Vanderkloof Dam for ecological water requirements, were determined before current methodologies were available.*

*The Present Ecological Status of various river reaches was assessed for a suite of ecological disciplines and generally assessed (using the RSA methodology) to be a 'D' (largely modified) for each of the disciplines. The ecological condition of the river is deemed to be on a negative trajectory.*

*The recommended category for the river from a comprehensive study of Ecological Water Requirements would most likely be a C-Category. Controlling the present mechanical manipulation of the river bed, banks and floodplain is extremely important as these factors are major contributors towards the decline in the condition of the riverine ecosystem, which together with the current manipulation of the flow regime, will eventually lead to its complete collapse.*

*The Orange River Estuary is considered to be an estuary of 'high importance'. The Orange River Mouth Wetland is a RAMSAR site and is on the Montreaux Record. The study concluded that the Present Ecological Status of the Estuary is a D+ largely modified and that it is not possible to reverse the flow modifications and anthropogenic development to the extent that would improve the Ecological Category to the desired Category of A or B. The Best Attainable State for the Estuary is considered to be a Category C and that the first step would be to achieve and maintain a Category D estuarine state. If the estimated volumes of water are released to maintain the estuary, either category D or C, the necessary variability in flow should be re-introduced to stop the negative trajectory of the river and the non-flow related issues must be addressed.*

*In terms of water resource planning and yield analysis, it is the estuarine flow requirements which control the allocatable yield.*

## CONSUMPTIVE WATER REQUIREMENTS

*The current and estimated future water requirements of the whole Orange River Basin up to 2025 and a proposed curtailment model for implementation during times of drought, assigning different assurances of supply to different sections, were developed. In South Africa, a slow growth in demand from the urban and industrial sectors was predicted. In Namibia, the majority of the present and future demands are for irrigation, with some increase in demands by mining. The Namibian water requirements, to be met from the Orange River, are all along the common border area.*

*The potential future agricultural water demand along the cross border area, in both Namibia and South Africa, was assessed on the basis of potentially irrigable land, a percentage that might reasonably be developed and an annual application of water. The detailed analysis included visits to site. However, South African Government Policy only allocates water from the Orange River to resource poor farmers for the following areas of irrigation:*

- *4 000 ha in Lower Orange at 15 000 m<sup>3</sup>/ha;*
- *4 000 ha in Eastern Cape at 11 000 m<sup>3</sup>/ha; and*
- *4 000 ha in Upper and Middle Orange at 11 000 m<sup>3</sup>/ha.*

*However, there are more “resource poor” farmers and developable agricultural land in the Orange River Basin to whom water would be allocated if it is available. A total irrigation development for Namibia of 15115 ha, is projected for 2025.*

*The combined “most probable” projections of growth in water demand for the Orange River Basin are given in **Table 1**.*

## WATER RESOURCES

*While the main focus was on the Middle and Lower Orange, downstream of Gariep Dam and excluding the Vaal System, developments in the Vaal System and upstream of Gariep Dam, such as the Lesotho Highlands Water Project and various other dams and users, affect the yield available from Gariep and Vanderkloof Dams and were considered in the yield analysis of the Gariep and Vanderkloof Dams.*

*Water released at Vanderkloof Dam, travels 1 400 km to the most downstream users. Operational losses, estimated to be 270 Million m<sup>3</sup>/annum, and “transmission losses” (evaporation losses and water used by the riparian zone), must be released in addition to the user requirements. Local inflows from the catchment downstream of the Orange/Vaal confluence are sporadic and contribute less than 7% of the total runoff under natural conditions.*

**Table 1: Summary of the Probable Water Demands on the Orange River System**

Category	Expected water demand (Mm <sup>3</sup> /a)					
	RSA					
	2002	2005	2010	2015	2020	2025
<b>Irrigation</b>						
Vaal <sup>1</sup>	796	796	796	796	796	796
Upper & Middle Orange <sup>2</sup>	1 371	1 381.2	1 398.1	1 415	1 415	1 415
Eastern Cape <sup>3</sup>	607	617.5	634.4	651	651	651
Diffuse Irrigation <sup>4</sup>	397	397	397	397	397	397
Lower Orange <sup>5</sup>	62	82	102	122	122	122
<b>Subtotal Irrigation</b>	<b>3 233</b>	<b>3 273</b>	<b>3 328</b>	<b>3 381</b>	<b>3 381</b>	<b>3 381</b>
<b>Urban, Industrial &amp; Mining</b>						
Vaal <sup>6</sup>	1 840	1 968	2 039	2 088	2 163	2 270
Upper & Middle Orange	101	110	122	134	143	153
Eastern Cape	19	20	20	20	20	41
Lower Orange	15	17	23	24	22	23
<b>Subtotal Urban, Industrial, Mining</b>	<b>1 975</b>	<b>2 115</b>	<b>2 204</b>	<b>2 266</b>	<b>2 348</b>	<b>2 487</b>
<b>TOTAL - South Africa</b>	<b>5 208</b>	<b>5 389</b>	<b>5 531</b>	<b>5 647</b>	<b>5 729</b>	<b>5 868</b>
		<b>NAMIBIA</b>				
Irrigation - Lower Orange <sup>7</sup>	41	60	103	150	197	227
Urban	9	16	31	47	47	48
<b>Total - Namibia</b>	<b>50</b>	<b>76</b>	<b>134</b>	<b>197</b>	<b>244</b>	<b>274</b>
		<b>Lesotho</b>				
Irrigation		9	9	9	9	9
Urban		11	12	14	15	17
<b>Total - Lesotho</b>		<b>20</b>	<b>21</b>	<b>23</b>	<b>24</b>	<b>26</b>
<b>TOTAL (RSA, Namibia &amp; Lesotho)</b>		<b>5 485</b>	<b>5 687</b>	<b>5 867</b>	<b>5 997</b>	<b>6 168</b>

## Notes:

1. The irrigation figures used for the Vaal are those used in the yield modelling and estimated by Loxton Venn.
2. Upper Orange Irrigation allows for 4000 ha development from present to 2010 @ 11 000 m<sup>3</sup>/ha/a.
3. Eastern Cape irrigation allows for 4000 ha development from present to 2010 @ 11 000 m<sup>3</sup>/ha/a.
4. The Diffuse Irrigation refers to irrigation from farm dams and from tributaries of the Orange. There are no irrigation allocations for these irrigators. The hectares under irrigation vary annually and are not known. Only the irrigation consumption has been estimated.
5. Lower Orange refers to the Common Border Area and RSA Irrigation allows for 4000 ha development @ 15 000 m<sup>3</sup>/ha/a by 2015.
6. 2025 Urban, industrial, mining demand of Vaal is an extrapolated figure.
7. Lower Orange refers to Common Border Area, Namibia Irrigation allows for 15115 ha irrigation by 2025.



A current scenario was defined and analysed, using historic flow records, to determine the benefit in terms of incremental yield of possible developments and the impacts on the system of supplying the projected water demands up to 2025. The current scenario comprises the system with 2005-development level urban, industrial and mining demands and with the current (2002) irrigation demands imposed on the system. It was assumed that:

- The full Phase 1 of the Lesotho Highlands Water Project is in place with the recently updated environmental requirements from the Lesotho Highlands Water Project and the resulting reduced transfer to the Vaal of 780 million m<sup>3</sup>/a.
- The environmental water requirements, recommended by this study, to maintain the estuary in Category D are provided.
- The minimum operating levels in Gariiep and Vanderkloof Dams are the levels of the Orange/Fish tunnel and canal outlets, respectively.
- Hydropower is only generated at Gariiep and Vanderkloof Dams with the water released into the river for downstream users below both dams.
- Spills from the Vaal, as well as any inflows from Lower Orange catchments, are not utilised by users along the Orange River.

Analyses were also carried out with the most probable irrigation demands in 2005, 2015 and 2025, and the results are shown in **Table 2**.

**Table 2: Results of Historic Yield Analysis for Different Development Scenarios**

Description	Units	Surplus/deficit Yield
2005-development level: - 2002 irrigation - 2005 irrigation	million m <sup>3</sup> /a	14 -47
2015-development level: - 2002 irrigation - 2015 irrigation	million m <sup>3</sup> /a	-42 -308
2025-development level: - 2002 irrigation - 2025 irrigation	million m <sup>3</sup> /a	-75 -418

Note: Growth in urban/mining water use is included

It can be seen that with the 2002 irrigation water requirements, there is an estimated surplus of only 14 Million m<sup>3</sup>/a at 2005-development level with increasing deficits in subsequent years.

Three Management Strategies were identified to meet the future water resource objectives. For each strategy, a number of management and development options were identified. The benefits of each of the management and development options, in terms of incremental yield and their ability to meet future demands were determined, using the historic firm yield analysis.

The historic firm yield of the system, which is available for consumptive use, is dependent on the agreed ecological category for the estuary. At 2005-development levels and 2002 irrigation water use, it has been calculated that:

- To maintain the Estuary at a Category D: Surplus yield = 14 Million m<sup>3</sup>/a.
- To improve the Estuary to a Category C: Deficit of 500 Million m<sup>3</sup>/a will be experienced.

## **STRATEGY FOR IMPROVED USE OF EXISTING INFRASTRUCTURE**

### **Utilise Vaal River Surplus**

As a result of the Lesotho Highlands Water Project and other transfers to augment the Vaal System, there is a temporary, conditional, surplus in the Vaal System, which can be utilised in several areas, including support to the Orange River System. The possible increases in system yield if all the surplus from the Vaal were supplied to the Orange, after allowing for some losses, would be 94 Million m<sup>3</sup>/annum, reducing to 10 Million m<sup>3</sup>/annum in 2015. The direct costs of 20c/m<sup>3</sup> of this option arise from the cost of pumping from the Thukela System and some increase in operating costs. However, new users on the Vaal System are required to pay the full Vaal water tariff, which is currently R1,46/m<sup>3</sup>. There are no social impacts specifically associated with using the surplus Vaal water in the Orange River System. The potential environmental impacts would be related to the ecological flow regime and how the system would be operated.

### **Hydraulic River Modelling and Improved System Operation**

Results from the Water Resources Yield Model showed that at 2005-development level, on average, 1 680 Million m<sup>3</sup>/a enters the Orange River from the Vaal. The monthly flows vary from almost zero to extremely high flows during periods of high runoff when the major dams are spilling. Currently, these flows are not taken into account when releases are made from Vanderkloof Dam to supply downstream requirements. Real time modelling will enable the operator at Vanderkloof Dam to reduce releases from Vanderkloof Dam at the required time to utilise the inflows from the Vaal for users in the Lower Orange.

Results from a combination of hydraulic river modelling and the Water Resources Yield Model system modelling indicated that the surplus yield in the system can be increased by 80 Million m<sup>3</sup>/a when real time modelling is used to utilise inflows from the Vaal more effectively. However, the benefit of the 80 Million m<sup>3</sup>/a is already included in the current scenario to support the Ecological Water Requirements. The estimated capital cost, primarily related to additional flow measuring stations, was estimated at R 35 Million. The operating costs were estimated to be R100 000/annum. There will be no social impacts. Implementation of this option will improve the operation of the river system and this can have benefits for the ecology through helping to meet the Ecological Water Requirements.

### **Utilisation of Vanderkloof Low Level Storage**

There is a significant volume of storage in Vanderkloof Dam below the level of the outlets to the irrigation systems. This storage can be accessed by installing a pumping system to lift the water into the irrigation canals. However, this will impact on the energy that can be generated by the hydropower plant at the dam. The increase in yield of 143 Million m<sup>3</sup>/a can be achieved by the utilisation of the lower level storage in Vanderkloof Dam below the minimum operating level defined by the outlets to the irrigation canals. The capital costs were estimated at R85,4 million. The operating costs were estimated at R2,8 Million/annum. The economic impact of reduced hydropower generation is the subject of a separate study. There will be very limited social and ecological impacts during construction and limited social benefits through temporary job creation during construction.

## **STRATEGY FOR WATER CONSERVATION AND DEMAND MANAGEMENT**

Opportunities were identified for more efficient water use in all sectors and these included improved management control.

The irrigation sector is the highest consumer of water in the Lower Orange River Management Study area and it also has the biggest potential for savings. **Table 3** summarise the potential benefits of Water Demand Management initiatives. The success of the measures will depend on:

- the creation of clear policy guidelines pertaining to tariff policies/rebates;
- advice on scheduling and training of farmers.

**Table 3: Summary of Expected Savings through Water Demand Management Initiatives**

Activity and Location	Volume Million m <sup>3</sup> /a	Costs/ m <sup>3</sup> saved (cent)	Remarks
<b>Water Efficiency Unit</b> (Upington)	Unknown	Unknown	Improves water productivity.
<b>Scheduling</b>			Improves water productivity.
Upstream Vanderkloof	7.2	6.95	10.0% saving less 30% return flow
Downstream Vanderkloof	63.9	3.20	7.2% savings less 30% return flow
Common Border	3.6	10.24	5.0% savings less 30% return flow
<b>Metering &amp; Pricing</b>			Improves water productivity.
Upstream Vanderkloof	6.7	5.13	7.0 % savings on the reduced
Downstream Vanderkloof	84.3	3.12	consumption after the implementation of
Common Border	6.9	2.88	scheduling.
<b>Irrigation Systems</b>			Improves water productivity by 24.1%.
Gifkloof/Neusberg	53.4	89.7	
<b>Conveyance losses</b>			
Orange Riet Canal	Unknown	Unknown	Requires a detail investigation.

Given the potential benefits shown in **Table 3**, at a capital investment cost of R 240.9 Million, the costs and benefits of water conservation and demand management measures in the area between Gifkloof and the Namibian border, were assessed in detail. The conclusions are given below.

- The benefits of scheduling and metering-pricing could reach their full potential at the beginning of 2012 with a nett benefit of 55 Million m<sup>3</sup>/a. A further nett benefit of 63 Million m<sup>3</sup>/a from improved irrigation systems would be achieved in 2015.
- The estimated costs for the establishment of a Water Efficiency Unit from Upington downstream are estimated to be a capital investment of R 1.0 Million and annual costs of R 1.5 Million.
- No environmental impacts are anticipated. Social impacts of water conservation and demand management could be significant if the reduction in water use result in reductions of irrigated areas or crop yields. However, if the anticipated reductions in water use as a result of more efficient use of the water occur, then no reductions in areas under irrigation or crop yields are anticipated. While there will be social issues to be managed, there should not be any negative impacts.

The funding of the R 240,9 Million capital investment is problematic. The capital will be required for improved irrigation systems that are mostly privately-owned.

## STRATEGY FOR INFRASTRUCTURE DEVELOPMENT

### Identification of Dam Sites

The potential dam sites identified in the Orange River Re-planning Study were reviewed and a Desk Study undertaken to identify any new options. Each potential dam site was evaluated against the specified pre-screening criteria to identify the most favourable sites for further assessment. It was concluded that upstream of the common border, the only favourable site is the New Boegoeberg site, approximately 1 km downstream of the existing small dam. The site is suitable for either a smaller re-regulating dam or for a large dam to improve the system yield.

Along the common border area, the Vioolsdrif site is suitable, either for a smaller re-regulating dam, or for large dam to improve the yield of the system, while the Komsberg site could be suitable for a re-regulating dam only.

### Assessment of Re-regulating Dams

The benefits of a re-regulating dam at Vioolsdrif, Komsberg or a new dam at Boegoeberg, to reduce operating losses and therefore increase the allocatable yield of the system, were analysed using the hydraulic river modelling and yield analysis models. The costs of each were determined and the unit reference values calculated. The results are given in **Table 4** and indicate that the Vioolsdrif option provides a significantly higher yield and lower unit reference value than a re-regulating dam at either the New Boegoeberg or the Komsberg sites.

**Table 4: Yield Results for Re-regulating Dams**

Description	Total Storage (Million m <sup>3</sup> /a)	Live Storage (Million m <sup>3</sup> /a)	Increase Yield (Million m <sup>3</sup> /a)	Cost (Million R/N\$) *	Unit Reference Value
New Boegoeberg Dam	163	90	62	192	0.35
Komsberg Dam	260	100	126	230	0.28
Vioolsdrif Dam	260	110	170	318	0.26

\* Excluding Engineering Design and Supervision, and VAT

The overall ecological assessment was that the impacts at Komsberg and Vioolsdrif are very similar and should not be used as the basis for selection. However, some of the impacts at Vioolsdrif can be more easily mitigated than those at Komsberg. The Vioolsdrif site was therefore agreed to be studied in more detail.

### Assessment of Storage Dams

The costs and benefits were determined for large storage dams, which would also fulfil the role of a regulating dam at the Vioolsdrif and New Boegoeberg Dam sites. Because of the significant storage provisions which must be made for sediment, the live storage in the first years will be significantly more than that available at the end of the 50-year period. Therefore, two yield values were determined for each dam size. The results are summarised in **Table 5**.

**Table 5: Results for Storage Dams at Vioolsdrif and Boegoeberg**

Description	Total Storage (Million m <sup>3</sup> )	Live Storage after 50 Years (Million m <sup>3</sup> )	Average Historic Firm Yield (Million m <sup>3</sup> /a)	Cost *(Million R/N\$)	Unit Reference Value
Large Vioolsdrif Dam – 44m spill height	1 100	500	183	691	0.44
54.6m spill height	2 100	1 500	297	946	0.52
62.6m spill height	3 000	2 400	365	1 181	0.62
New Boegoeberg Dam – 35.4m spill height	1 210	500	101	872	1.35
42.1m spill height	2 210	1 500	187	1 002	0.88
44.6m spill height	3 110	2 400	225	1 078	0.84

\* Excluding Engineering Design and Supervision, and VAT

Results from the economic analyses indicated that the Vioolsdrif Dam is the better option. The relative ecological impacts at Vioolsdrif and New Boegoeberg for a large dam are similar to those for a re-regulating dam.

### OPTIONS ASSESSMENT

An option assessment workshop was held at which the options, described in the preceding sections, were assessed against the criteria shown in **Table 6**.

**Table 6: Criteria Used to Evaluate Options**

Fundamental Criteria	Primary Criteria	Secondary Criteria
1. Yield and Capital Cost, combined with Operating Cost as URV	1. Opportunities for Joint Management and Operation	1. Confidence in Yield
2. Ecological Impacts	2. Improved Management of Water Resources	2. Confidence in Cost
3. Social Impacts	3. Promotion of International Co-operation	3. Temporary Social/Economic Benefits during Construction
4. Water Quality	4. Opportunities for Benefit-Cost Equity	4. Permanent Social/Economic Benefits
5. Implementation Flexibility	5. Political Acceptability	5. Capacity Building
6. Operational Flexibility	6. Promotion of Public Safety	
	7. Promotion of Efficiency of Use	

The conclusions from the options assessment workshop were:

- *Utilisation of the Vaal Surplus was conditionally recommended.*
- *Real time River Modelling was recommended to improve the management of the river, with the inclusion of the Vaal River.*
- *Utilisation of Vanderkloof Low Level Storage was conditionally recommended.*
- *Investigation of specific water conservation and demand management initiatives in the area downstream of Gifkloof, up to the Namibian border, was recommended.*
- *The Vioolsdrif site was recommended as the re-regulating dam option for which a pre-feasibility design should be completed and a Scope of Work prepared for a Feasibility Study.*
- *The Vioolsdrif site was also recommended as the best site for a large storage dam on the Orange River downstream of Vanderkloof Dam. It should only be implemented in parallel with or after the other recommended management and development options. The benefits and impacts of providing a new storage dam at Vioolsdrif should be considered in the context of the whole Orange River Basin and compared with the alternative dam sites in the Upper Orange, which have been considered and provisionally recommended in other studies.*

## **YIELD ANALYSIS OF RECOMMENDED OPTIONS**

The assurance levels, agreed for different user categories in the Orange River System, are shown in **Table 7**.

**Table 7: Water Use by User Categories and Priority Classifications for 2005**

User Category	Priority Classification & Assurance of Supply (% of water use and volume)						Total (Million m <sup>3</sup> /a)
	Low (1 in 20-year)		Medium (1 in 100-year)		High (1 in 200-year)		
	%	Million m <sup>3</sup> /a	%	Million m <sup>3</sup> /a	%	Million m <sup>3</sup> /a	
Urban	20	12	30	18	50	30	60
Irrigation	60	1 062	30	531	10	177	1 770
Losses	0	0	0	0	100	332	332
<b>Total</b>		<b>1 074</b>		<b>549</b>		<b>539</b>	<b>2 162</b>

The results of the historic yield analysis are shown in **Table 8**.

**Table 8: Comparison of Water Balance from Historic Yield Analysis (From Table 2)**

Development Level	Surplus Yield:
	Historic Firm Yield Analysis (Million m <sup>3</sup> /a)
2005	-47
2015	-308
2025	-418

Note the Total Yield from Gariep and Vanderkloof Dams is \*3200 million m<sup>3</sup>/a.

From "Orange River System Analysis – Yield analysis up to Vanderkloof Dam"

The Water Resources Planning Model was used to carry out a planning or operating analysis (for a Category D estuary). These indicated that the proposed curtailment levels will be exceeded from 2006 onwards. These results are regarded as the most reliable on which to plan. Thus, actions need to be taken to improve the supply situation in the Orange River System from 2006 onwards. However, in practice it will not be possible to have Vioolsdrif Dam in place until 2015 at the earliest. The proposed management and development actions to address the temporary shortfall are discussed in subsequent sections.



## **PRE-FEASIBILITY DESIGN AND COSTING OF VIOOLSDRIF RE-REGULATING DAM**

A pre-feasibility design and costing was carried out for a re-regulating dam at Vioolsdrif. The principle design parameters were:

· Total storage capacity	260 Million m <sup>3</sup>
· Allowance for sedimentation	150 Million m <sup>3</sup>
· Live storage capacity	110 Million m <sup>3</sup>
· Riverbed level	RL 176.4 m
· Non-overflow crest (NOC)	RL 211.5 m
· Wall height to NOC	35.1 m
· Wall height to FSL	25.1 m
· Total crest length	485 m
· Spillway Safety Evaluation Discharge	26 300 m <sup>3</sup> /s
· Spillway Recommended Design Discharge	14 250 m <sup>3</sup> /s
· The 1:10-year interval diversion flood	3 000 m <sup>3</sup> /s

Due to the large design floods a concrete gravity dam was considered to be the only type of dam suitable for the site and due to its inherent lower costs, a rollcrete dam was selected. The re-regulating dam was planned to be raised to become a storage dam by adding rollcrete on the downstream side. The total project cost, including engineering, administration, infrastructure and dam construction, but excluding possible hydropower installation, at April 2004 rates, was estimated to be R 561 Million.

The estimated capital cost of a hydropower station at the dam was R 30 Million, the maximum generating capacity 4.2 MW and the total annual power generation was estimated at 21.3 GWh. The estimated income is R 3.4 Million/a, based on a selling rate of R 0.12 per kWh and a carbon emission reduction subsidy of R 0.04 per kWh.

## **OPTIONS FOR BI-NATIONAL DEVELOPMENT AND MANAGEMENT INSTITUTIONS**

Bi-national management issues relating to the Lower Orange River system fall in the ambit of the South African/Namibia Permanent Water Commission (PWC).

In the scenario that a new dam (or dams) are required in the Lower Orange to augment the supplies, the following options, involving different levels of management, were considered:

- *Bi-National management of a specific portion of the Basin by the Permanent Water Commission.*
- *Water supply organisations (bi-national and national) under the auspices of the Permanent Water Commission.*
- *National (country) institutions.*

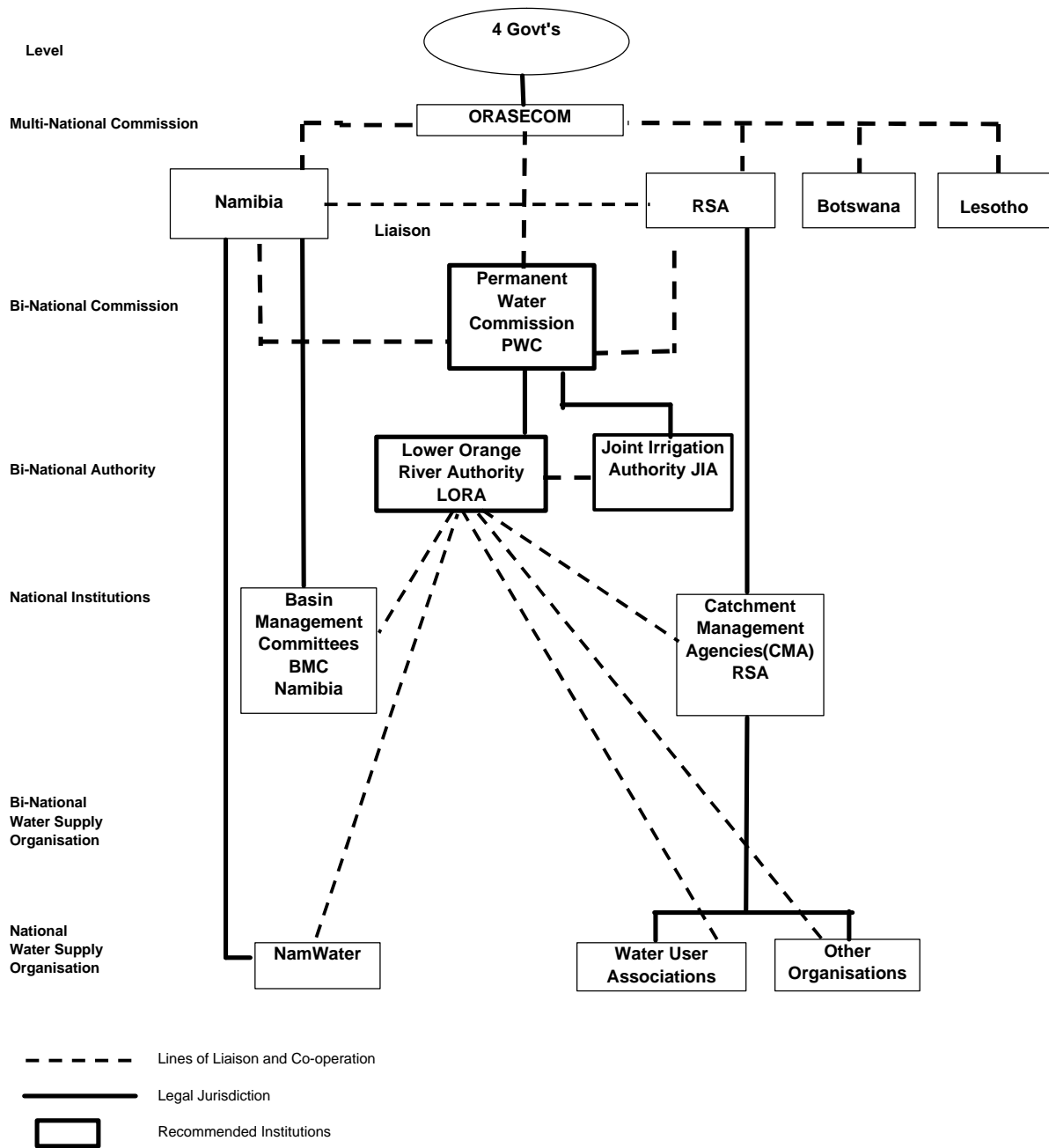
*The PWC agreement may require amendment to allow for matters such as building and operating a dam.*

*Alternatively, a second tier River Sub-system Management Agency/Authority could be considered for the Lower Orange River sub-system. The sub-system Agency/Authority would report to the Permanent Water Commission. The responsibilities of such a Lower Orange River Authority could include:*

- *The management and control of the water resource, ecological care in its area of jurisdiction and operation and maintenance of water resource infrastructure.*
- *Ensuring the agreed distribution of water to user groups.*
- *Implementation and financing of water resource development projects.*

*The joint management of a dam at Vioolsdrif will require an institution such as a Lower Orange River Authority that would manage the releases from the dam, monitor the use of water by the Parties and ensure that the environmental protection goals and conservation obligations are met.*

*The recommended institutions are shown, in the context of the broader institutional framework, including water supply organisations, in **Figure 3**. The existing institutional structures would be utilised, except that a new entity, the Lower Orange River Authority will be created. The powers of the Permanent Water Commission will require amendment to align it with its new functions and to provide for the Lower Orange River Authority. The area of jurisdiction of Lower Orange River Authority could be limited to the common border area or could be the whole reach from Vanderkloof Dam to the ocean. Once the principle of such an institution is accepted by the two Governments, the details of the roles, responsibilities, etc. can be developed further.*

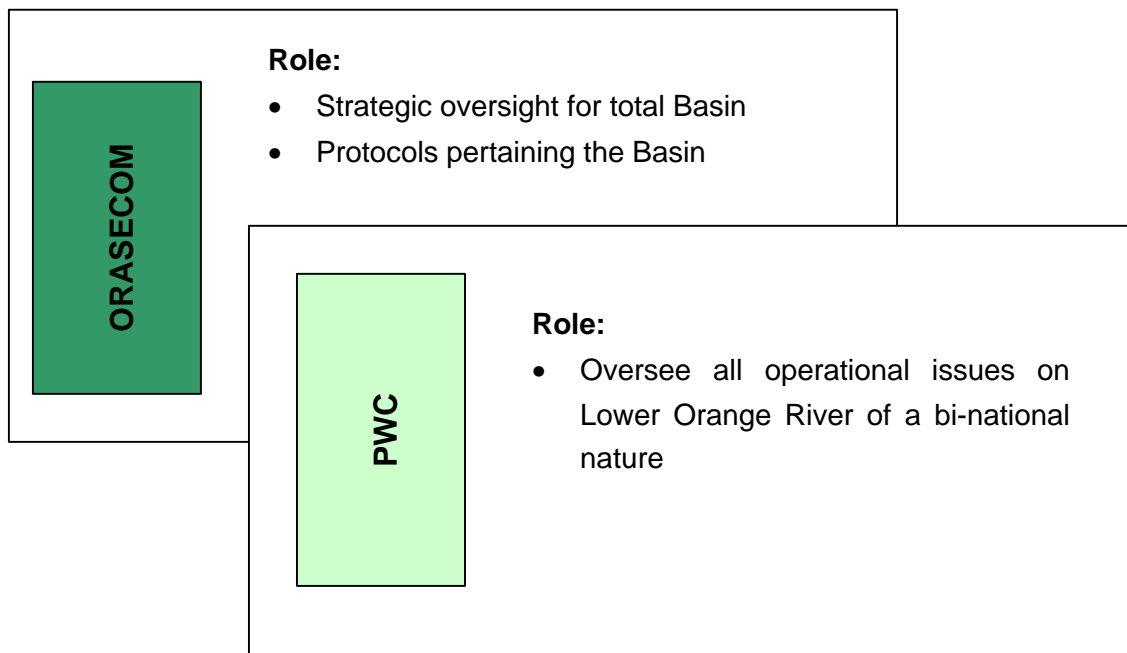


**Figure 3: Recommended Institutions for the Lower Orange River in the Context of the Broader Institutional Framework**

## OPTIONS FOR MULTI-LATERAL DEVELOPMENT AND MANAGEMENT INSTITUTIONS

The ORASECOM provides the strategic framework within which the countries, and bi-national institutions, are required to operate. The relationship between the Permanent Water Commission (PWC) and the ORASECOM is depicted in **Figure 4**. The PWC, as other bi-national commissions, operate separately from the ORASECOM, but has a reporting obligation to allow the latter to perform its monitoring function.

In the scenario that a large dam is required in the upper reaches of the Orange basin, a multi-lateral authority under the auspices of the ORASECOM should be considered as an option in addition to the bi-national options mentioned above.



**Figure 4: River Basin Management Roles of PWC and ORASECOM**

## WATER SHARING AND COST SHARING

### **Background for Water Sharing and Joint Management**

*In determining the practical sharing of allocable water and the cost of developing the resource, the following principles should be achieved:*

- *Water produced by an option should be able to be clearly defined with a known assurance and cost of supply, together with its point of delivery.*

- Water provided should be available at the point of delivery as modelled in the analysis.
- The anticipated benefits of the development option should be achieved in practice.

It was agreed that the cost sharing should be in relation to the sharing of benefits. Since both countries would, essentially, use the water for similar economic activities, irrigated agriculture and some mining, the sharing of benefits has, at this stage, been assumed to equate to the sharing of water. It was also clear that, in general, the management options will primarily result in benefits to one country, which would therefore carry the cost.

Three possible basic approaches to sharing the cost of implementing agreed measures between South Africa and Namibia were identified. For each option, the financial implications are illustrated for the development of a re-regulating dam at Vioolsdrif/Noordoewer, with a capital cost of R 561 Million and an allocatable yield of 170 Million m<sup>3</sup>/a and based on the following assumptions:

- At independence, it was agreed that Namibia would receive 50 Million m<sup>3</sup>/a from existing infrastructure and South Africa's equitable share of the water resources of the Orange River was 1 999,1 Million m<sup>3</sup>/a .
- The water demand in Namibia will be 75,5 Million m<sup>3</sup>/a in 2005 and 274,4 Million m<sup>3</sup>/a in 2025.
- The RSA demand on the Upper Middle and Lower Orange System, excluding the Vaal will be 1 973,6 Million m<sup>3</sup>/a in 2005 and 2 149,5 Million m<sup>3</sup>/a in 2025.
- The capital cost of the re-regulating dam, at April 2004 prices, amounts to R 561 Million.

**(i) Option 1 – Sharing of the Benefits of a Joint Development Compared with Independent Developments by South Africa and Namibia**

The benefits, due to the cost saving, by the development of a joint project, compared with the costs if each country were to develop its own project, are shared on a basis to be agreed. The calculations, based on estimated costs, indicate a total benefit of about R 232 Million. The result of sharing this benefit is shown in **Table 9**. The benefit to South Africa for the delayed expenditure when developing its own project was not included. This will decrease the benefit available for sharing by about R 50 Million and change the sharing ratio by about 3% to R 182 Million.

**(ii) Option 2 – Sharing of Costs in Proportion to Incremental Water Use**

The cost is shared in relation to the incremental water derived by each party from the joint development. The starting point for determining the increase in water use by each country is their equitable share. The increases in water use to 2025 are:

- Namibia : 224,4 Million m<sup>3</sup>/a
- South Africa : 150,4 Million m<sup>3</sup>/a

**(iii) Option 3 – Cost Sharing on the Basis of System Water Use and Total Development Costs**

The cost is shared in relation to water use from the entire Orange River System, by combining the cost of new developments into total system cost, including the cost of historic developments to get a total unit cost of water from the system. This approach may be considered in view of the fact that Namibia had been under the administration of South Africa when the existing Orange River System was constructed.

The percentage cost allocations, attributable to each country for each option, are shown in **Table 9**.

**Table 9: Percentage and Indicative Costs of Contribution to New Development**

	South Africa	Namibia
<b>OPTION 1</b>		
Capital Cost (R Million)	269	292
% Share of Cost	48%	52%
<b>OPTION 2</b>		
Capital Cost (R Million)	225.5	335.5
% Share of Cost	40%	60%
<b>OPTION 3</b>		
Capital Cost (R Million)	497.6	63.4
% Share of Cost	89%	11%

The obligation to meet the Ecological Water Requirements should be shared in proportion to the consumptive water utilization from the system.

**RECOMMENDATIONS FOR THE MANAGEMENT OF THE LOWER ORANGE RIVER**

**The following recommendations for Environmental and Water Quality Management are made:**

- Develop policies and strategies for agreeing and implementing required environmental flows for the whole Basin in collaboration with ORASECOM.
- Manage the river system to optimise the benefits to the river and estuary of the water available at the estuary.
- Remove or mitigate the impacts of the anthropogenic impacts on the river and estuary.
- Undertake comprehensive assessments of the riverine and estuarine Ecological Water Requirements.

- *A separate study should be instituted to investigate the observed problems of algae blooms/nutrients and other related water quality problems in the Lower Orange.*

***It is recommended that River Monitoring and Operation be improved through:***

- *Making significant improvements to the flow monitoring network, with particular emphasis on low flow monitoring.*
- *Continuous real time modelling of the Orange River be implemented so that operational losses can be reduced and inflows from the Vaal can be utilised.*
- *Integrate the operations of the Orange and Vaal River Systems.*

***The following recommendations are made for the improved use of existing infrastructure:***

- *The surplus yield of 105 Million m<sup>3</sup>/a available in the Vaal River System in 2005, but reducing to 30 Million m<sup>3</sup>/a in 2010, be considered as a strategic reserve to be used to increase the assurance of supply of users in the Orange River until 2010 if required. If this source were to be used, the applicable charges for use of the water would have to be agreed in advance.*
- *Accessing the water stored in Vanderkloof Dam (below the canal inlets to the irrigation system) by pumping, should not at this time, be relied on for augmenting the yield of the Orange River System, but may be considered as a strategic reserve, a role it has fulfilled in the past.*

***The following recommendations for water conservation and demand management are made:***

- *The ongoing initiatives in the urban, industrial, mining and agricultural sectors should continue and be encouraged.*
- *The management systems and institutional support to promote water conservation and demand management in all sectors, and particularly the irrigation sector, should be strengthened or established in both countries.*

*The opportunities for more efficient water use are greatest in the agricultural sector, and this sector also has the largest water use, particularly in South Africa. It is recommended that, in addition to improved management and institutional support, the following Water Demand Management measures be implemented in the irrigation sector:*

- *a water efficiency unit to promote Water Demand Management in the sector;*
- *proper scheduling of irrigation on farms;*
- *metering and application of tariffs to promote conservation;*
- *the upgrading of irrigation systems; and*
- *a Pilot Study for two locations in the Gifkloof/Neusberg is to obtain a better understanding of costs and benefits.*

*It is uncertain what proportion of the water, which is saved, would become available to be re-allocated to other users. It is thus recommended that no reliance be placed on this water for making new allocations available to new developments.*

### **Timing of Interventions**

*The recommendations in the preceding sections should be implemented as soon as practical.*

*Based on the systems analysis carried out in this Study, the current system is approximately in balance in 2005 if the Lower Orange River Management Study Ecological Water Requirements to maintain the estuary in a Category D are implemented. Augmentation is required from 2006 onwards. It was found that a re-regulating structure, as well as additional storage is required in the system.*

*However, the system should be able to meet the projected water requirements until 2012 if the current allowance for Ecological Water Requirements (Orange River Re-planning Study Ecological Water Requirements) are maintained and the implementation of increased Ecological Water Requirements from this or future studies is delayed until a new development can be commissioned. The intervention could possibly be delayed until about 2018 if real time modeling is implemented.*

*However, when a new dam (a re-regulating or storage dam at Violsdrif) is commissioned, the then agreed Ecological Water Requirements will have to be implemented. At this point, agreement should have been reached between Namibia and South Africa regarding the international best practice for the Ecological Water Requirements that are to be applied. If these are similar to the Ecological Water Requirements for a category D estuary, as determined in this study, additional yield from additional storage, will be required. This yield will be equivalent to that which can be obtained from utilising the Vanderkloof low level storage and a small storage dam. This is illustrated in **Figure 5**.*



**Figure 5: Required Intervention Time for Various Options versus the Most Probable Demand Growth**

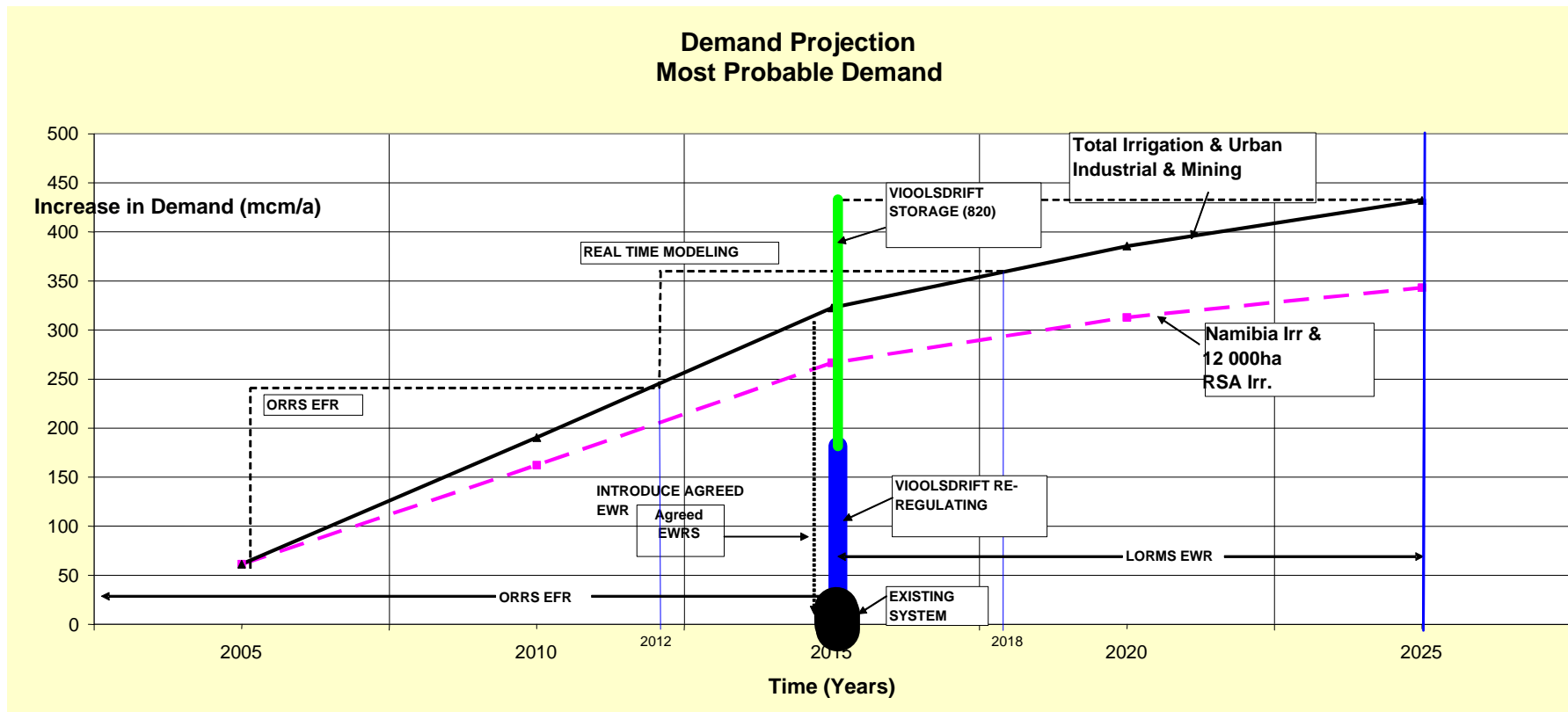


Figure 5: Required Intervention Time versus the Most Probable Demand Growth, excl. VdKloof low level storage

## **Development of New Infrastructure**

*It is recommended that, as a minimum, a re-regulating dam, but possibly a larger storage dam, be implemented at Vioolsdrif/Noordoewer. The recommended re-regulating dam at Vioolsdrif would be approximately 35 metres high with a gross storage capacity of 260 Million m<sup>3</sup>. If, as recommended, the Vanderkloof low level storage is excluded as a possible future option, then, in order to meet the projected demands up to 2025, a storage dam of at least 830 Million m<sup>3</sup> live storage is required, in combination with a re-regulating dam at Vioolsdrif. The actual storage capacity required will depend on the planning horizon, the decision on Ecological Water Requirements and demands the dam is to meet. This storage can be created either at Vioolsdrif or upstream of Gariep Dam.*

*The additional yield that can be obtained from a large Vioolsdrif Dam at 2005-development level varies from 280 Million m<sup>3</sup>/a (500 Million m<sup>3</sup> live storage) to 430 Million m<sup>3</sup>/a for a 2 400 Million m<sup>3</sup> live storage dam.*

*The projected increase in water requirements is significant and the currently estimated incremental yields are within the accuracies of hydrological assessments. The date when this additional yield will be required, is also very sensitive to the decision on the Ecological Water Requirements. It is therefore recommended that the necessary evaluation of the alternative locations for a yield (storage) dam on the Orange River System, such as at Bosberg or Mashai, and the planning for a re-regulating dam at Vioolsdrif, either with provision for raising or to be constructed as a re-regulating and yield dam in a single phase, proceed as soon as possible.*

## **Principles for the Appropriate Institutional and Financial Arrangements**

*The following will need to be agreed:*

- The appropriate framework of institutions for the management of the Lower Orange and implementing the proposed new infrastructure.*
- The roles and responsibilities of the institutions.*
- The arrangements for sharing the costs and benefits of the management and development of the Lower Orange River.*
- The appropriate sources of funding.*

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## **PROPOSED ACTIVITIES TO GIVE EFFECT TO THE RECOMMENDATIONS FOR RIVER MANAGEMENT**

*The following immediate and short-term activities are recommended as the first steps to give effect to the recommendations in the previous section.*

### **Recommended for Immediate Implementation**

*The following studies should be commissioned as soon as possible. These are listed approximately in order of priority.*

**(i) Improve the Operations of the Orange River Systems to Reduce the Losses**

*Commission a study to plan and coordinate the implementation, improved monitoring, real time modelling, and integrated operations of the Orange and the Vaal River systems.*

**(ii) Environmental and Water Quality Management**

*Commission a study to undertake:*

- *The feasibility of the removal or mitigation of the impacts of the anthropogenic impacts on the river and estuary and determine the Ecological Water Requirements for the river and estuary, including the required monitoring.*
- *The development of operating rules to optimise the benefits to the river and estuary of the water available at the estuary.*
- *The investigation of water quality issues.*

**(iii) Accelerate the Implementation of Water Conservation and Demand Management**

*Carry out a Pilot Study in two areas downstream of Gifkloof and develop an Implementation Plan to put in place the management and institutional support to promote water conservation and demand management in the irrigation sector.*

**(iv) Improve the Utilisation of Existing Infrastructure and Develop New Infrastructure**

- *Complete the current study (under the auspices of DWAF: RSA) into the economic viability of utilisation of the low level storage in Vanderkloof Dam.*
- *Commission a Reconnaissance Level Study to determine the best location and size for a dam in the Orange River to increase the system yield beyond which can be obtained by a re-regulating dam at Vioolsdrif.*
- *Commission a Feasibility Study for a new dam at Vioolsdrif.*

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*The determination of the best location for storage could be undertaken as an early task in the Feasibility Study for a new dam at Vioolsdrif. However, if the Feasibility Study is not commissioned soon this work should be commissioned as a separate study. This will be necessary as other studies will need to be commissioned without delay, in the event that Vioolsdrif is found not to be the recommended site for a yield dam.*

**(v) Agree on the Principles for the Appropriate Institutional and Financial Arrangements**

*The proposed first step is that the recommendations in the Legal, Institutional, Water Sharing, Cost Sharing, Management and Dam Operation Report are evaluated by the Parties and discussed by the Permanent Water Commission. Principles should be agreed and the subsequent steps defined.*

*If the recommendations from this study are implemented, they have the potential to improve the effectiveness of the management and development of the Lower Orange River. The benefits of improved availability of water resources for the environment and consumptive use will support the sustainable social and economic development of the region.*

# LOWER ORANGE RIVER MANAGEMENT STUDY

## MAIN REPORT

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## ABBREVIATIONS

BAS	:	Best Attainable State
BHN	:	Basic Human Needs
BMC	:	Basin Management Committee (Namibia)
BMP	:	Best Management Practice
CBA	:	Common Border Area
CMA	:	Catchment Management Agency (RSA)
DA	:	Directorate of Agriculture
DRWS	:	Directorate of Rural Water Supply
DW	:	Department of Works
DWA	:	Department of Water Affairs (Namibia)
DWAF	:	Department of Water Affairs and Forestry (RSA)
EWR	:	Ecological Water Requirements
FSL	:	Full Supply Level
IVRS	:	Integrated Vaal River System
JIA	:	Joint Irrigation Authority
LA	:	Local Authority
LHWP	:	Lesotho Highlands Water Project
LLS	:	Low Level Storage
LOR	:	Lower Orange River
LORA	:	Lower Orange River Authority (hypothetical)
LORC	:	Lower Orange River Consultants
LORMS	:	Lower Orange River Management Study
MAWRD	:	Ministry of Agriculture, Water and Rural Development (Namibia)
m.o.l.	:	minimum operating level
MRLGH	:	Ministry of Regional and Local Government and Housing
MWTC	:	Ministry of Works, Transport and Communication
NamWater	:	Namibia Water Corporation Ltd
NOC	:	Non-overflow Crest
NWA	:	National Water Act (36 of 1998)
NWRS	:	National Water Resource Strategy
ORASECOM	:	Orange-Senqu River Commission
ORRS	:	Orange River Re-planning Study
PES	:	Present Ecological Status
PP	:	Public Participation
PWC	:	Permanent Water Commission
RDD	:	Recommended Design Discharge
RMF	:	Regional Maximum Flood
RSA	:	Republic of South Africa
SADC	:	Southern African Development Community
SED	:	Safety Evaluation Discharge

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SoW	:	Scope of Work
TCTA	:	Trans Caledon Tunnel Authority
TDS	:	Total Dissolved Solids
URV	:	Unit Reference Value
VAPS	:	Vaal Augmentation Planning Study
WC&DM	:	Water Conservation and Demand Management
WDM	:	Water Demand Management
WMA	:	Water Management Area
WQT	:	Water Quality Trend
WRM	:	Water Resources Management
WRPM	:	Water Resources Planning Model (DWAF)
WRYM	:	Water Resources Yield Model (DWAF)
WUA	:	Water User Association

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## **1. BACKGROUND TO THE STUDY**

### **1.1 Introduction**

The Orange River with a catchment area of approximately 1 million km<sup>2</sup> originates in the highlands of Lesotho and flows west for approximately 2 200 km to the Atlantic Ocean.

The last 600 km of the Orange River forms the border between South Africa and Namibia, and any measure to improve the management of the water resources available in the Lower Orange River (LOR), will benefit both countries. It is therefore advisable that future management or development projects will probably be undertaken jointly by the two countries with due consideration of the equitable and reasonable requirements of the other Basin States.

Several important studies have been undertaken to investigate the water resources of the Orange River by the Republics of South Africa (RSA) and Namibia, often with the involvement of both Parties, but always funded and directed by only one Party.

### **1.2 Ministers Meeting**

In April 1999, the respective Ministers responsible for Water Affairs agreed that, for the first time, a Joint Study should be undertaken to develop agreed Strategies and Management Plans for the Orange River.

The Joint Study, under the control of the Permanent Water Commission (PWC) between Namibia and South Africa, investigated and made recommendations on the more efficient management and use of water resources in the LOR.

### **1.3 Project Consultants**

A Namibia / South Africa consortium, comprising Windhoek Consulting Engineers, Burmeister & Partners and Alexander & Becker of Namibia, and WRP (Pty) Ltd and Ninham Shand (Pty) Ltd of South Africa was appointed in November 2002. The consortium was supported by a multi-disciplinary team of specialist sub-consultants.

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## 2. STUDY OBJECTIVES

Namibia is the most downstream riparian user of the Orange River water and all existing storage structures on the Orange River are located more than 1 000 km upstream in South Africa and Lesotho. This situation is understandably of concern to Namibia, which has expressed a wish to secure an equitable and reasonable share of the Orange River water on a more viable and permanent basis.

The overall study objective was stated as “Investigate and report on the availability of water and options for improved management through the efficiency of water use and supply management measures to promote the strategic objectives of the countries involved”.

The key components of the study were thus:

- Assessment of Estuarine and Riverine Ecological Water Requirements (EWRs), using the latest accepted methodologies.
- Assess present and future water requirements.
- Identification of the opportunities for Water Conservation and Demand Management (WC&DM), and the potential costs and benefits.
- Review of the South African hydrological database by Namibia and the re-assessment of the Fish River hydrology to provide an agreed hydrological database.
- Selection of development scenarios in the Orange River Catchment (including the Vaal River System) for assessing the future water balance.
- Assessing the yields from potential dam sites, taking account of contributions from the Fish River.
- Assessment of the social and environmental impacts of all management options, including dams, and identify potential mitigation measures.
- Assessment of dam development costs and yields.
- Determination of the Unit Reference Values (URVs) of water from dams and the savings from water conservation measures.
- Consolidating the information on each management option, or combination of options, into management reports so that decision-makers from Namibia and South Africa can make informed decisions.
- Ensuring that the public and particularly the Stakeholders, who would be directly affected, are informed and that their opinions are recorded and taken into account.
- Assessment of the Institutional environment and identification of possible management approaches for management and operation of a new dam on the LOR.
- Assessment of alternative approaches to water and cost sharing.

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### 3. DEVELOPMENT AND MANAGEMENT OBJECTIVES

The countries' Strategic Objectives for the joint management of the LOR were agreed by the countries to be:

- Regional Economic Development;
- Poverty Alleviation;
- Job Creation;
- Food Security;
- Protection of the Environment;
- Ensuring Water Supply to Downstream Users; and
- Water Resources Management (WRM) aligned with National Policies, Objectives and Strategies for Water Resources.

The following hierarchy of strategies and plans were proposed and agreed to guide the development of a Management Strategy and Plan for the LOR:

- Strategic Objectives for the region served by the LOR.
- Specific Objectives to meet the strategic objectives, e.g., develop eco-tourism, increase subsistence agriculture, increase commercial agriculture and agro-industry, etc.
- Water Resources Objectives to support or meet Specific Objectives.
- Fundamental Water Resource Strategies (each strategy comprises groups of similar types of management or development options) to meet Water Resource Objectives.
- A Framework for Water Resources, with an Implementation Plan, programmes and projects to implement the Water Resource Strategy.

The Study Objective and Strategic Objectives were analysed to define Water Resources Objectives (See **Section 10**) and to allow a framework for a WRM Plan to be developed.

## 4. STUDY AREA

The water resources and use in the whole Orange River Basin, shown in **Figure 4.1**, were assessed. The river reach west of the 20° longitude, where the river forms the border between Namibia and South Africa, was subject to the most detailed study. The Vaal River System was not studied in any detail since the results of detailed studies recently completed on that river basin by South Africa were suitable for use in the Lower Orange River Management Study (LORMS).

It has been estimated that the natural runoff of the Orange River Basin is in the order of 11 300 Million m<sup>3</sup>/a. As shown on **Figure 4.2**, approximately 4 000 Million m<sup>3</sup>/a originates in the Lesotho Highlands, and approximately 800 Million m<sup>3</sup>/a from the contributing catchment downstream of the Orange/Vaal confluence. Extensive water resource developments have taken place upstream of the confluence, including several large dams and inter-basin transfer schemes. The remaining 6 500 Million m<sup>3</sup>/a originates from the areas contributing to the Vaal, Caledon, Kraai and Middle Orange Rivers. Much of the runoff originating from the Orange River downstream of the Orange/Vaal confluence is highly erratic and cannot be relied upon to support the downstream water requirements unless regulation is provided. The portion of runoff originating from the Fish River in Namibia can support some of the downstream demands, particularly the environmental demands at the river mouth.

There is extensive water utilization in the Vaal River Basin, most of which is for domestic and industrial purposes. Large volumes of water are used to support the extensive irrigation and some mining demands occurring along the Orange River downstream of the Orange/Vaal confluence. Irrigation in the Eastern Cape is also supplied, through the Orange/Fish tunnel.

The Basin of the Lower Orange River largely corresponds with that of the Northern Cape Province in South Africa and the South, Central and Eastern regions in Namibia. The largest primary contributions to the economy are made by mining and irrigated agriculture. Mining activities are centred around Alexander Bay and Oranjemund, while extensive irrigation occurs at locations along the Orange River, as shown on **Figure 4.3**. Demographic projections show a steady decline in the population in the region over the next 25 years. Economic activity is likely to remain dependant on mining and irrigation for the foreseeable future, with modest contributions from eco-tourism.



Several new potential developments have been identified, both in Namibia and South Africa, which may result in greater water demands from the LOR in future. In Namibia, such developments include the Haib copper mine, Skorpion lead and zinc mine, the Kudu gas-fired power station at Oranjemund and several irrigation projects for communal and commercial irrigation along the northern riverbank. Similar potential also exists on the South African side of the river, with particular need to develop irrigation for previously disadvantaged farmers.

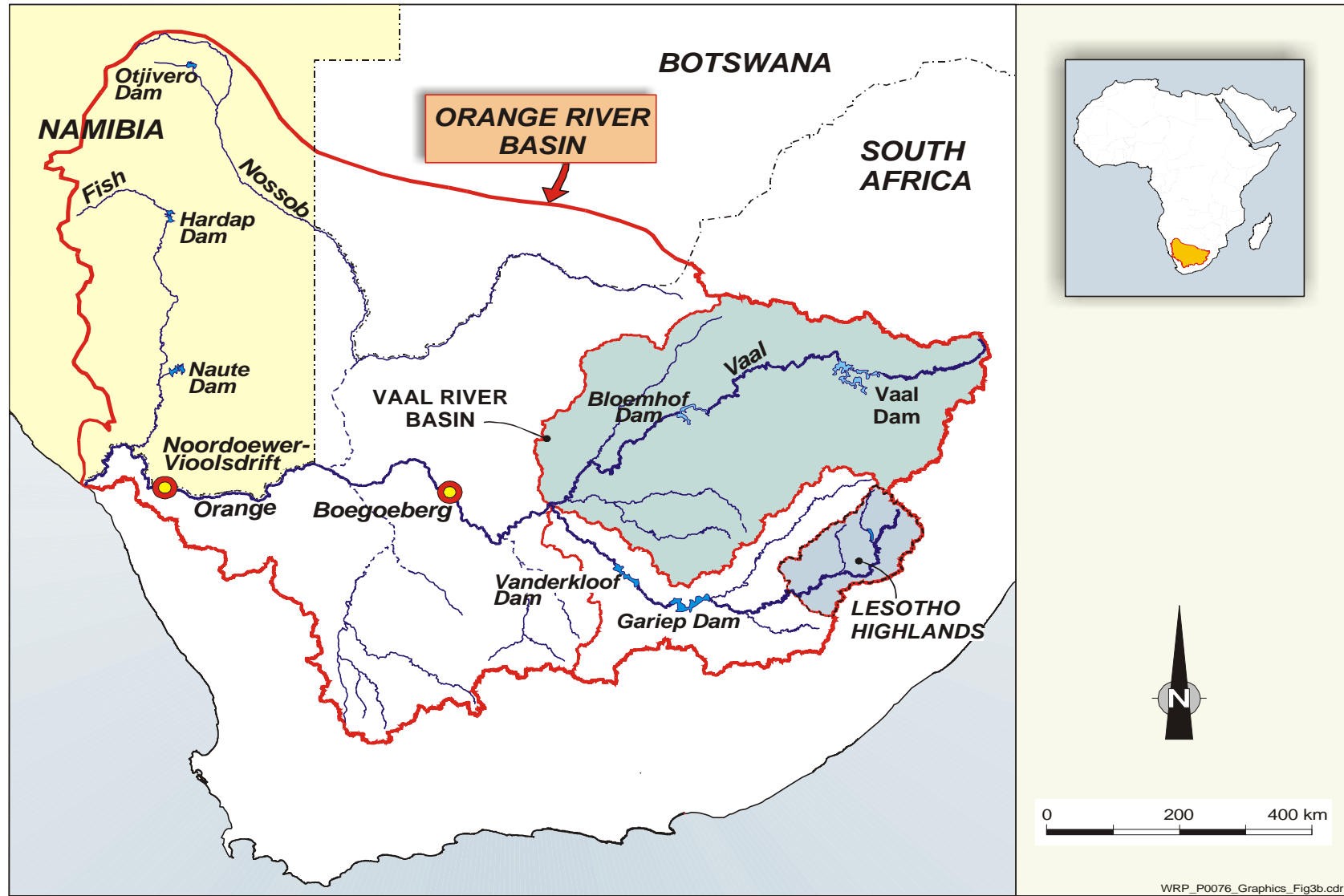


Figure 4-1: Orange River Basin

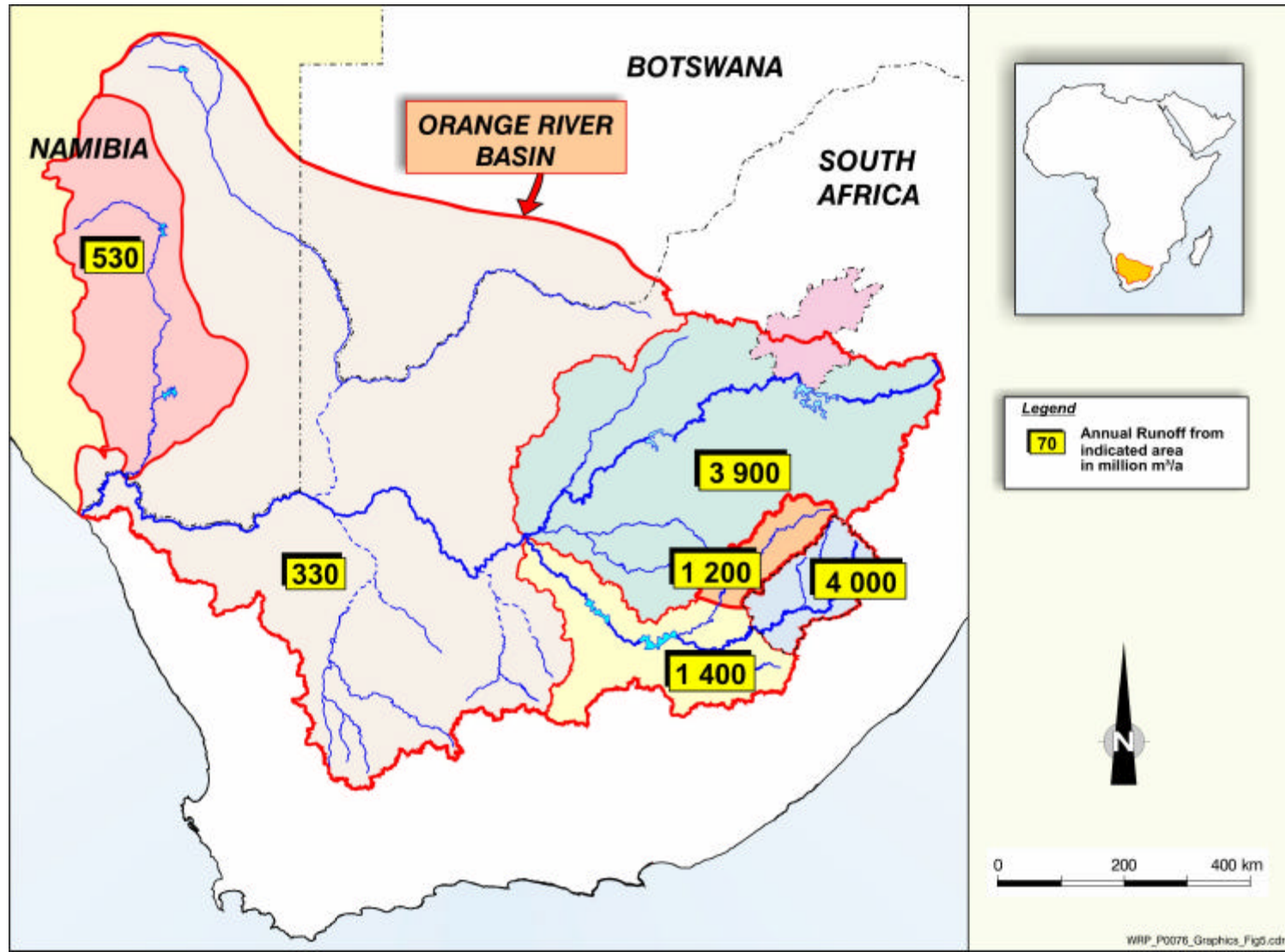


Figure 4-2: Approximate Distribution of Natural Runoff in the Orange River Basin

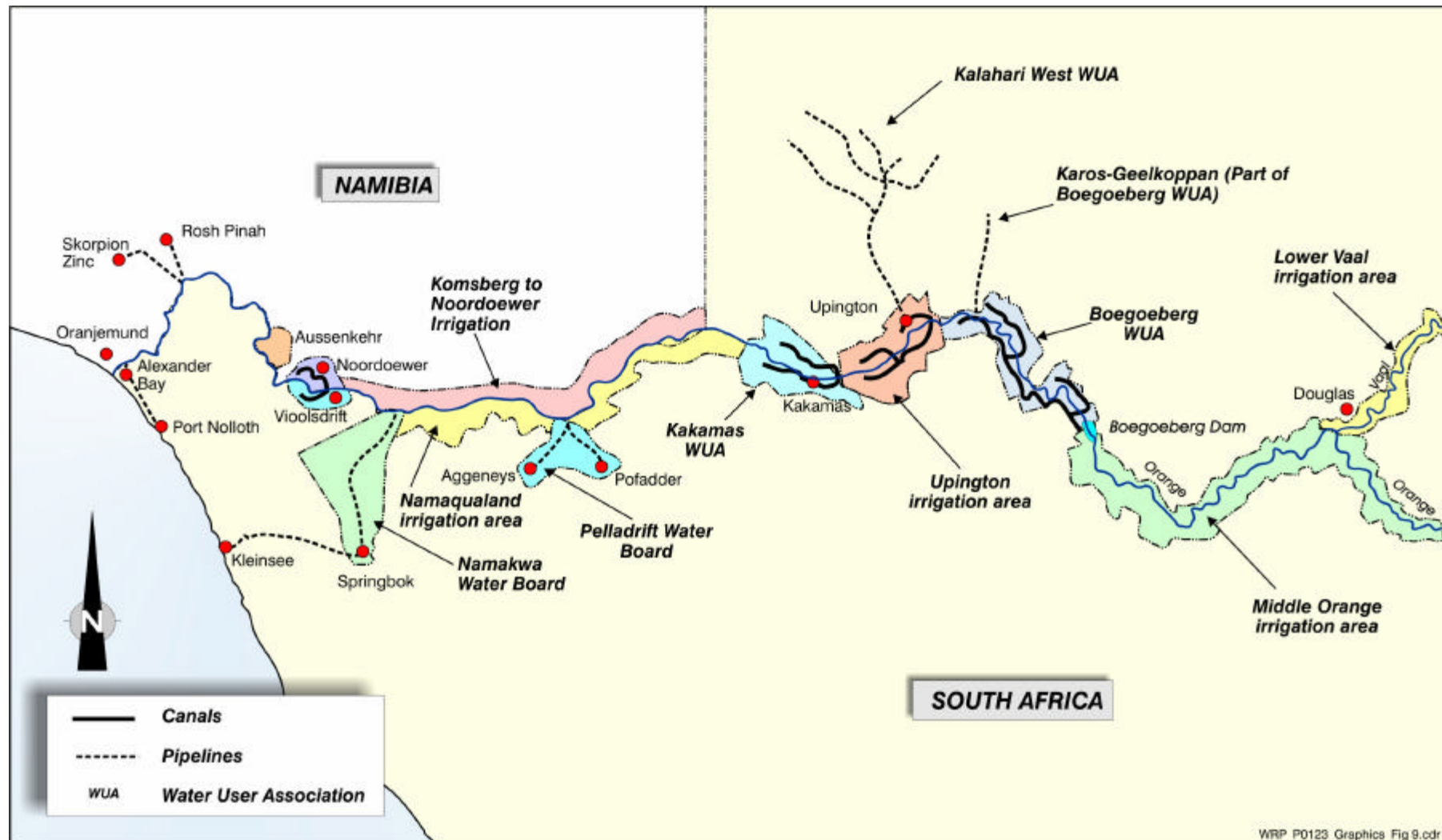


Figure 4-3: Major Water Demand Areas along the Lower Orange River

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## 5. POLICY, LEGAL AND INSTITUTIONAL BACKGROUND

### 5.1 International Background

Important international frameworks include the RAMSAR convention and the 1997 UN Convention on the Law of Navigational Uses of International Watercourses, which defines the status and principles for the management of International Watercourses. The Revised Southern African Development Community (SADC) Protocol is a regionally accepted and up-to-date instrument, which should be employed as a basis for negotiating agreements on the Orange River. It establishes comprehensive guidelines on water sharing principles and obligations.

Namibian/South African and other bi-lateral and multi-national agreements provide further background to the management of the LOR Basin.

Considerations for National and International Law requirements on the protection of eco-systems and the implications of the recently published Berlin Rules should be considered in further studies.

### 5.2 National Policy and Legal Environment

#### 5.2.1 *Namibia*

According to the Namibian constitution, all water in Namibia belongs to the State, which regulates and permits its use. Relevant Acts in the water sector are:

#### **Water Act 1956 (Act No. 54 of 1956) as amended**

Namibia's Water Act is being administered by the Department of Water Affairs (DWA) – Namibia, of the Ministry of Agriculture, Water and Rural Development (MAWRD) – Namibia. This Act provides mechanisms whereby International Treaties can be complied with. A new Water Act is presently being developed to be specifically aligned with the requirements of the Namibian Constitution and International Treaties and Agreements. In terms of this draft legislation, River Basin Management Committees will also be set up.

The Water Act also enacts an Advisory Water Board, which advises the Minister on matters concerning the protection and utilisation of water resources, and is responsible for the equitable allocation of and distribution of water between different consumer groups.

- **Namibia Water Corporation Act (Act No. 12 of 1997)**  
This Act establishes the Namibia Water Corporation (NamWater), which has taken over the bulk water supply function of the DWA.
- **Local Authorities Act (Act 23 of 1992)**  
The Local Authorities (LAs) Act spells out the functions and duties of LAs in rendering water supply and wastewater disposal services.
- **Other Acts that have a bearing on the water sector include:**
  - The Health Act of 1920.
  - A proposed Environmental Management Act, which is under preparation.
  - A proposed Pollution Control Act, which is under preparation.

### 5.2.2 South Africa

#### (i) The Constitution

Under the South African Constitution, all water belongs to the nation and is to be managed nationally. Relevant Acts in the Water Sector are:

#### (ii) The South African National Water Act of 1998

The Department of Water Affairs and Forestry (DWAF) is mandated by the National Water Act (NWA) (No. 36 of 1998): to ensure that South Africa's water resources are protected, used, developed, conserved, managed and controlled in a sustainable and equitable manner, for the benefit of all persons.

This Act incorporates important references to the International Law principles and deals with International Watercourses. Stated objective is to meet "international obligations".

#### (iii) The Water Services Act, 108 of 1997

This Act deals with the domestic regulatory framework with regard to basic water supply and sanitation.

#### (iv) Environmental Acts

- Environmental Conservation Act. (Act 73 of 1989.)
- National Environmental Management Act. (Act 107 of 1998.)

### 5.3 National Institutional Arrangement

The national and institutional arrangement in Namibia and South Africa, that will have a bearing on the management of and further development of water resources along the LOR, are summarised in **Table 5.1**.

**Table 5.1: Existing National, Institutional Arrangements for WRM**

Responsible Agencies – South Africa	Responsible Agencies - Namibia
<ul style="list-style-type: none"> <li>• <b>National Government</b> <ul style="list-style-type: none"> <li>- DWAF (National &amp; Provincial)</li> <li>- International Commissions</li> </ul> </li>   <li>• <b>Provincial Governments</b> <ul style="list-style-type: none"> <li>- Liaison</li> <li>- Co-ordination of planning</li> </ul> </li>   <li>• <b>Local Authorities (LAs)</b> (At District and Local Municipality Level) <ul style="list-style-type: none"> <li>- Water Supply &amp; Sanitation</li> </ul> </li>   <li>• <b>At the encompassing Watercourse level:</b> <ul style="list-style-type: none"> <li>• Catchment Management Agencies (CMAs)</li> </ul> </li>   <li>• <b>Bulk water suppliers:</b> <ul style="list-style-type: none"> <li>- DWAF &amp; Trans Caledon Tunnel Authority (TCTA) (raw water)</li> <li>- Water Boards</li> <li>- Water User Associations (WUAs) (Irrigation Boards)</li> <li>- Some LAs</li> <li>- Private</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>• <b>National Government</b> <ul style="list-style-type: none"> <li>- DWA &amp; Directorate of Agriculture (DA) (National)</li> <li>- International Commissions</li> </ul> </li>   <li>• <b>Regional Governments</b> <ul style="list-style-type: none"> <li>- Directorate of Rural Water Supply (DRWS): decentralizing responsibilities</li> </ul> </li>   <li>• <b>Local Authorities (LAs)</b> <ul style="list-style-type: none"> <li>- Water Supply &amp; Sanitation</li> </ul> </li>   <li>• <b>At the encompassing Watercourse level:</b> <ul style="list-style-type: none"> <li>- River Basin Management Committees (foreseen)</li> </ul> </li>   <li>• <b>Bulk water supplies:</b> <ul style="list-style-type: none"> <li>- DRWS (small scale rural)</li> <li>- NamWater (in terms of NamWater Act)</li> <li>- Some LAs</li> <li>- Private</li> </ul> </li> </ul>

There are thus similar arrangements for managing water resources and water supply, which should facilitate cooperation and appropriate joint management activity.

The present responsibilities for environmental management of Watercourses in Namibia and South Africa are divided between a number of organisations that include Environment Affairs, Water Affairs, Agriculture and Minerals and Energy. Arrangements for effective cooperative governance with common objectives should be established.

#### 5.4 Current Operating System

Two systems, the Integrated Vaal River System (IVRS) and the Orange River System are important in the management of the LOR. Although the IVRS is not used to support the Orange River System, it is operated to minimize spills into the Orange River. This is important as large volumes of water are transferred into the Vaal River from neighbouring catchments (e.g., from Lesotho Highlands Water Project - LHWP) at high cost.

The Gariiep and Vanderkloof Dams are the only resources currently used to supply the Lower Orange and stabilise water requirements along the Orange River from

the Gariep Dam to the Orange River Mouth. The two dams increased assurance of supply to water users in South Africa and are used to provide water requirements for irrigation, urban, mining, environmental needs, river evaporation and operational losses. The Gariep and Vanderkloof Dams are not supported by any upstream dams, but only receive the spills and environmental releases, mainly from the Katse and Mohale Dams. Releases from these two dams to supply downstream users are made directly into the Orange River, and are routed through turbines to generate hydropower.

Operating analyses for the Orange River System are done on an annual basis to determine available surplus or deficit in the system for the next year. Surpluses are allocated to generate additional hydropower over and above that generated by normal releases for downstream users. When there is a deficit in the system, curtailments are imposed.

## 5.5 Background for Water Sharing and Joint Management

The management of systems upstream of the LOR are important when water sharing, cost sharing and joint management structures are considered. Upstream development has altered the natural flow patterns and reduced annual average flows in the Lower Orange. Equitable sharing of benefits of the system to achieve a win-win situation for all involved, including the ecosystem, is therefore required. The sharing solutions should be such that vested interests and country sovereignty are not threatened.

In determining the practical sharing of allocable water, the following principles should be achieved:

- Water produced by an option should be able to be clearly defined with a known assurance and cost of supply, together with its point of delivery.
- Water provided should be available at the point of delivery as modelled in the analysis.
- Abstractions should be metered.
- The benefits of the development option should be achieved in practice, i.e., it should be ensured, that water assessed to be available, should in practice, reach the consumers for whom it is meant.

Management issues that need to be considered include:

- Determining, managing and monitoring of EWRs and conservation responsibility.
- Management arrangements and operating rules of the current Orange River water resource that may need to be adjusted or expanded to include new developments.



- Other developments in the Orange River System that may influence the LOR need to be agreed upon.

In addition to technical management issues, current and envisaged institutional arrangements in both Namibia and South Africa need to be considered. Each country is currently and should remain fully responsible for matters like control of anthropogenic impacts on LOR, pollution control, Water Demand Management (WDM) and monitoring and managing water quality in river courses upstream of the Common Border Area (CBA).

## 6. PHYSICAL AND ECONOMIC ENVIRONMENT

The Basin of the LOR largely corresponds with that of the Northern Cape Province in South Africa and the South, Central and Eastern regions in Namibia. Climate over the region is harsh semi-desert to desert. The minimal rainfall ranges from 400 mm to less than 50 mm per year, and is characterized by prolonged droughts. With the exception of sparse and highly intermittent runoff from local tributaries and occasional inflows from the Fish River in Namibia, the LOR is totally dependant on flow in the Orange River from upstream sub-catchments. As a result of the low rainfall, groundwater resources are also limited, although well used for rural water supplies. Important conservation areas include the Kgalagadi Trans-border National Park, the Au-grabies National Park, the Richtersveld National Park (the new Transfrontier Park), as well as a transboundary RAMSAR site at the Orange River Mouth.

The largest primary contributions to the economy are made by mining and irrigated agriculture. Mining activities, which are centred around Alexander Bay and Oranjemund, consist mainly of the extraction of alluvial diamonds and a variety of other mineral resources, mined at both inland locations and along the coast. A zinc mine has recently been established at Skorpion.

Extensive irrigation occurs at locations along the Orange River, where the tendency has increasingly been towards growing high value orchard crops. Sheep and other livestock farming are found where the climate is favourable.

Important irrigation development along the CBA include the Vioolsdrif/Noordoewer Joint Irrigation Scheme, which is managed by the Joint Irrigation Authority (JIA) and those at Aussenkehr in Namibia, and the Namaqualand and Pella irrigation areas in South Africa.

Demographic projections show a steady decline in the population in the region over the next 25 years. Economic activity is likely to remain dependant on mining and irrigation for the foreseeable future, with modest contributions from eco-tourism. There is considerable seasonal migration of labour. Outside the small towns along the CBA there are negligible infrastructure or community services. Any significant developments will make a meaningful contribution to the regional economy and this is a priority of the Namibian Government.

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## 7. ENVIRONMENTAL WATER REQUIREMENTS

Updated preliminary assessments were made of the EWRs for the Orange River, downstream of Augrabies, and the River Estuary, as the releases currently being made from Vanderkloof Dam for EWRs were determined before current methodologies were available.

### 7.1 Riverine Water Requirements

The Present Ecological Status (PES) of various river reaches was assessed (using the RSA methodology) for a suite of ecological disciplines and generally assessed to be a 'D' (largely modified) for each discipline, except for water quality a 'B/C' (largely natural/moderately modified) and geomorphology a 'C' (moderately modified). The ecological condition of the river is deemed to be on a negative trajectory, with all disciplines expecting one-category deterioration in condition in the next twenty years.

The flow-related factors contributing to the PES and negative trajectory were identified as:

- unseasonal winter releases;
- lack of very low flow periods;
- lack of the November freshet (small flood), which occurred in the natural system;
- reduction in water volume;
- reduction in wet and dry season inter-annual floods; and
- lack of flow variability.

The recommended category for the river from a comprehensive study of EWRs would most likely be a C-Category.

The most important aspects of the flow regime for maintaining or improving the current ecological condition are re-instating the winter lowflows (i.e., reducing current flows present during winter), and re-instating a November freshet.

### 7.2 Riverine Ecological Management

Controlling the present mechanical manipulation of the river bed, banks and floodplain is extremely important as these factors are major contributors towards the decline in the condition of the riverine ecosystem, which, together with the current manipulation of the flow regime, will eventually lead to its complete collapse.

Particular attention should be given to maintaining the few remaining and relatively undisturbed anastomosed sections, such as upstream of Onseepkans. These areas are considered to be ecologically very important.

The periodic emptying of the existing small dam at Boegoeberg for maintenance, which releases pulses of sediment-laden water, has detrimental downstream impacts, and should be managed to minimise the impact.

### **7.3 Estuarine Water Requirements**

The Orange River Estuary is ranked as the seventh most important system in South Africa in terms of conservation importance, and is considered to be an estuary of 'high importance'. The Orange River Mouth Wetland is a RAMSAR site, i.e. a wetland of international importance. In September 1995, this site was placed on the Montreux Record as a result of a belated recognition of the severely degraded state of the salt marsh on the south bank. According to the South African guidelines, the recommended Ecological Category should therefore be a Category A – if this is not possible, then the objective should be to achieve the Best Attainable State (BAS).

It was concluded that the PES of the Estuary is a D+ largely modified.

While acknowledging the importance of the estuary, the following factors were noted in recommending a BAS:

- Major dam developments in the catchment that have reduced river inflow to the estuary by more than 50% (considered to be irreversible), and it is unlikely that the estuary could be returned to a Category A.
- Anthropogenic (human) developments along the banks of the estuary (i.e., non-flow related modifications), such as the road across the salt marsh area, seepage of saline water from mining developments and human disturbance (of birds) also contribute largely to the PES of a Category D.

It is therefore not considered possible to reverse the flow modifications and anthropogenic development to the extent that would improve the Ecological Category to a Category A or B.

The BAS for the Estuary was therefore considered to be an Ecological Category C, with a strong recommendation that mitigating actions to reverse modifications caused by the non-flow related activities and developments in the estuary be investigated by the responsible authorities.

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Although the BAS is considered to be a Category C, which should be the long-term objective, the first step would be to achieve and maintain a Category D estuarine state. A number of anthropogenic impacts on the estuary would also have to be reversed if the negative trajectory of the estuarine category is to be halted and reversed.

#### **7.4 Conclusion**

The PES of the river is assessed to vary between a B/C and a D for various river reaches and disciplines, all of which have a negative trajectory.

The total volume of water required to maintain the estuary, either category D or C, would be sufficient to stop the negative trajectory of the river provided that the necessary variability in flow can be re-introduced and the non-flow related issues can be addressed.

In terms of water resource planning and yield analysis, it is the estuarine flow requirements which control the allocatable yield.

The Ecological Category of the estuary is very dependent on the flow patterns, particularly seasonality, and the removal of non-flow related impacts. To achieve an Ecological Category of a C or D and continue to supply existing irrigation, it would require re-regulation of the river flows and a concerted effort to address the anthropogenic development.

It is recommended that an extensive monitoring programme be implemented to improve the understanding of the ecology and flow regimes of the estuary and river. This will enable comprehensive ecological flow determinations on the Orange River and estuary, with a reasonable degree of confidence in the results.

## **8. CONSUMPTIVE WATER REQUIREMENTS**

The current and future water requirements of the whole Orange River Basin were considered. Estimates of the total water requirement of the LOR, including water demand projections to the year 2025 were developed. These provide a basis for agreeing water allocations between South Africa and Namibia and undertaking the Orange River Systems Analysis. A proposed curtailment model for implementation during times of drought assigning different assurances of supply to different sections was developed.

The following consumer groups were analysed:

- Irrigation;
- Industrial/mining; and
- Urban/domestic.

Operating losses were also assessed.

### **8.1 Current and Future Water Requirements in Lesotho and Botswana**

Water requirements in Lesotho were not evaluated in this study, but the results of completed studies were used. It is anticipated that the results of the Lesotho Lowlands Feasibility Study will give a better understanding of the future water requirements in Lesotho. It is expected that these will be higher than the current estimates, but the increases are unlikely to materially affect the results of this Study.

Water requirements in Botswana are primarily met from groundwater and some local surface water sources. These do not influence the results of this study.

### **8.2 Current and Future Water Requirements in South Africa**

The current water use throughout the Orange River Basin was initially assessed from published information and currently available data. This was checked against the data from the current water use registration process in South Africa and anomalies were corrected.

Future water use in urban and industry was based on work done in the Orange River Re-planning Study (ORRS), which was updated with more recent information which was made available by the DWAF and other sources. Mining demands were assessed independently. The result is a predicted slow growth in demand from these sectors.

The study included a brief review of the water demands from the Upper Orange, the Vaal River Catchment and the Eastern Cape that receives water from the Orange River via the Orange/Fish Transfer System.

Provision has been made in South African Government Policy to allocate water from the Orange River to resource poor farmers for the following areas of irrigation:

- 4 000 ha in Lower Orange at 15 000 m<sup>3</sup>/ha;
- 4 000 ha in Eastern Cape at 11 000 m<sup>3</sup>/ha; and
- 4 000 ha in Upper and Middle Orange at 11 000 m<sup>3</sup>/ha.

No other new water allocations from the Orange River are envisaged for agriculture in South Africa.

This policy decision, to cap new water allocations for agriculture at 12 000 ha, was made, because it was anticipated that there was no surplus water in the system. However, there are more “resource poor” farmers and developable agricultural land in the Orange River Basin to whom water would be allocated if it is available. The full extent and timing of this potential allocation is unknown.

### **8.3 Current and Future Water Requirements in Namibia**

The same approach was followed in Namibia, as in South Africa. The majority of the present and future demands in Namibia are for irrigation, with some increase in demands by mining.

The Namibian water requirements, to be met from the Orange River, are all along the CBA and discussed in the following section.

### **8.4 Future Water Requirements along the Common Border**

The potential future agricultural water demand along the CBA, in both Namibia and South Africa, was assessed on the basis of potentially irrigable land, a percentage that might reasonably be developed and an annual application of water. The detailed analysis included visits to sites.

However, as described above, an increase of only 4 000 ha was included in the projected future demands on the LOR in South Africa.

The information on water consumption in the urban and mining sectors along the CBA was collected through questionnaires and directly from bulk suppliers of water, both in South Africa and Namibia.

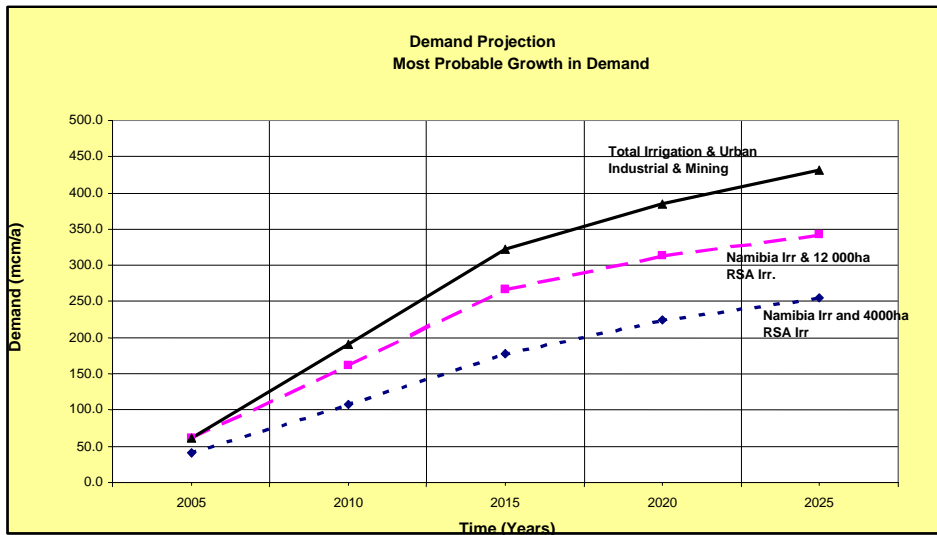
The combined current demand and future demand projections along the CBA are presented in **Table 8.1**. The Human Reserve is included in the domestic demand.

**Table 8.1: The Combined Water Demand Projection on the CBA**

Consumer Category	Expected Water Demands (Million m <sup>3</sup> /annum)											
	2002		2005		2010		2015		2020		2025	
	NAM	RSA	NAM	RSA	NAM	RSA	NAM	RSA	NAM	RSA	NAM	RSA
Irrigation	41	3 233	60	3 297	103	3 361	150	3 381	197	3 381	227	3 381
Urban, Industrial & Mining	9	1 890	16	2 115	31	2 204	47	2 266	47	2 348	48	2 487
<b>Total by Country</b>	<b>50</b>	<b>5 123</b>	<b>76</b>	<b>5 412</b>	<b>134</b>	<b>5 565</b>	<b>197</b>	<b>5 647</b>	<b>244</b>	<b>7 729</b>	<b>274</b>	<b>5 868</b>
<b>TOTAL</b>	<b>5 173</b>		<b>5 488</b>		<b>5 699</b>		<b>5 844</b>		<b>7 973</b>		<b>6 142</b>	

### 8.5 Total Current and Projected Future Water Requirements

The combined “most probable” projections of growth in water demand for the Orange River Basin are illustrated in **Figure 8-1** and given in **Table 8.2**.



**Figure 8-1: Most Probable Growth in Irrigation and Urban/Industrial Water Use within the Orange River System**



**Table 8.2: Summary of the Probable Water Demands on the Orange River System**

Category	Expected water demand (Mm <sup>3</sup> /a)					
	RSA					
	2002	2005	2010	2015	2020	2025
<b>Irrigation</b>						
Vaal <sup>1</sup>	796	796	796	796	796	796
Upper & Middle Orange <sup>2</sup>	1 371	1 381.2	1 398.1	1 415	1 415	1 415
Eastern Cape <sup>3</sup>	607	617.5	634.4	651	651	651
Diffuse Irrigation <sup>4</sup>	397	397	397	397	397	397
Lower Orange <sup>5</sup>	62	82	102	122	122	122
<b>Subtotal Irrigation</b>	<b>3 233</b>	<b>3 273</b>	<b>3 328</b>	<b>3 381</b>	<b>3 381</b>	<b>3 381</b>
<b>Urban, Industrial &amp; Mining</b>						
Vaal <sup>6</sup>	1 840	1 968	2 039	2 088	2 163	2 270
Upper & Middle Orange	101	110	122	134	143	153
Eastern Cape	19	20	20	20	20	41
Lower Orange	15	17	23	24	22	23
<b>Subtotal Urban, Industrial, Mining</b>	<b>1 975</b>	<b>2 115</b>	<b>2 204</b>	<b>2 266</b>	<b>2 348</b>	<b>2 487</b>
<b>TOTAL - South Africa</b>	<b>5 208</b>	<b>5 389</b>	<b>5 531</b>	<b>5 647</b>	<b>5 729</b>	<b>5 868</b>
		<b>NAMIBIA</b>				
Irrigation - Lower Orange <sup>7</sup>	41	60	103	150	197	227
Urban	9	16	31	47	47	48
<b>Total - Namibia</b>	<b>50</b>	<b>76</b>	<b>134</b>	<b>197</b>	<b>244</b>	<b>274</b>
		<b>Lesotho</b>				
Irrigation		9	9	9	9	9
Urban		11	12	14	15	17
<b>Total - Lesotho</b>		<b>20</b>	<b>21</b>	<b>23</b>	<b>24</b>	<b>26</b>
<b>TOTAL (RSA, Namibia &amp; Lesotho)</b>		<b>5 485</b>	<b>5 687</b>	<b>5 867</b>	<b>5 997</b>	<b>6 168</b>

## Notes:

1. The irrigation figures used for the Vaal are those used in the yield modelling and estimated by Loxton Venn.
2. Upper Orange Irrigation allows for 4000 ha development from present to 2010 @ 11 000 m<sup>3</sup>/ha/a.
3. Eastern Cape irrigation allows for 4000 ha development from present to 2010 @ 11 000 m<sup>3</sup>/ha/a.
4. The Diffuse Irrigation refers to irrigation from farm dams and from tributaries of the Orange. There are no irrigation allocations for these irrigators. The hectares under irrigation vary annually and are not known. Only the irrigation consumption has been estimated.
5. Lower Orange refers to the Common Border Area and RSA Irrigation allows for 4000 ha development @ 15 000 m<sup>3</sup>/ha/a by 2015.
6. 2025 Urban, industrial, mining demand of Vaal is an extrapolated figure.
7. Lower Orange refers to Common Border Area: Namibia Irrigation allows for 15115 ha irrigation by 2025.

## 8.6 User Categories and Priority Classifications

When managing the water resources and supply to users, all the demands are not supplied at the same assurance level and the assurance levels adopted for various percentages of the different user categories in the Orange River System, is shown in **Table 8.3**.

**Table 8.3: User Categories and Priority Classifications**

User Category	Priority Classification & Assurance of Supply		
	Low 1 in 20 year	Medium 1 in 100 year	High 1 in 200 year
Urban	20%	30%	50%
Irrigation	60%	30%	10%
Losses	0%	0%	100%

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## 9. WATER RESOURCES

### 9.1 The Current System

The river system analysed for this study is referred to as the Orange River System and the main focus was on the Middle and Lower Orange, downstream of Gariep Dam and excluding the Vaal System. Gariep and Vanderkloof Dams are the two resources used to regulate the supply to users along the entire Orange River from Gariep Dam to the Orange River Mouth. Gariep Dam also supports the irrigation and limited urban requirements in the Eastern Cape through transfers via the Orange/Fish Tunnel into the upper reaches of the Fish River. Water from Vanderkloof Dam is transferred via a canal system to the Riet/Modder Catchment, mainly to support irrigation.

Development in the Vaal System and upstream of Gariep Dam, such as the LHWP and various other dams and users, affects the yield available from Gariep and Vanderkloof Dams. None of the upstream dams are used to support Gariep and Vanderkloof Dams.

From the point of release at Vanderkloof Dam, water has to travel 1 400 km to the most downstream point of use and operational losses, estimated to be 270 Million m<sup>3</sup>/annum, and “transmission losses”, which are actually evaporation losses and water used by the riparian zone, must be released in addition to the user requirements.

There are large developments in the Vaal River System that affect the inflows from the Vaal into the Orange River downstream of Vanderkloof Dam. These inflows are not currently considered when making releases from Vanderkloof Dam to be used in the Orange River, downstream of the confluence of the two rivers because:

The Vaal River is operated to minimize spills into the Orange River and it is therefore mainly during floods that significant volumes of water enter the Orange from the Vaal.

Vanderkloof Dam is located approximately 200 km upstream of the confluence of the Orange and Vaal Rivers, but 1 400 km upstream of the river mouth. Releases from Vanderkloof Dam take approximately one month to reach the river mouth, and are made well in advance to supply the downstream users in time, making it very difficult to utilize inflows from the Vaal.

Local inflows from the catchment downstream of the Orange/Vaal confluence are sporadic and contribute less than 7% of the total runoff under natural conditions. The largest inflow downstream of the Orange/Vaal confluence is that from the Fish River (Namibia), which enters the Orange approximately 150 km upstream of the river mouth. These inflows are also sporadic and there are not many users located downstream of the confluence with the Fish River that can utilize spills from the Fish River.

## 9.2 Analysis of Water Resources Availability – Historic Yield Analyses

All the developments upstream and downstream of Gariep and Vanderkloof Dams are included in the water resources system model, as they will all affect the surplus yield available in the system.

A base scenario, a current scenario and additional scenarios with varying management and development options were defined and analysed to determine the benefit, in terms of incremental yield, for possible developments and the impacts on the system of supplying the projected water demands up to 2025. Sensitivity analyses were also undertaken to obtain an improved understanding of the system for each analysis. The reference code used to identify the analysis is given in brackets.

### 9.2.1 Base Scenario (RS1)

This scenario represents the current system with 2005-development level urban, industrial and mining demands and with the current (2002) irrigation demands imposed on the system. It was assumed that:

- The full Phase 1 of the LHWP is in place with the recently updated environmental requirements from the LHWP and the resulting reduced transfer to the Vaal of 780 million m<sup>3</sup>/a.
- The EWRs, recommended by this study, to maintain the estuary in Category D are provided.
- The minimum operating levels in Gariep and Vanderkloof Dams are the levels of the Orange/Fish tunnel and canal outlets, respectively.
- Hydropower is only generated at Gariep and Vanderkloof Dams with the water released into the river for downstream users below both dams.
- Spills from the Vaal, as well as any inflows from Lower Orange catchments, are not utilised by users along the Orange River.

Environmental requirements determined in the ORRS, and as currently released from Vanderkloof Dam, were included.

Using the base scenario, the effect of two projected future demand scenarios and a scenario with higher EWRs were analysed:

- urban/industrial and mining developments at 2015-development level (RS1a);
- urban/industrial and mining developments at 2025-development level (RS1b);  
and
- base scenario (2005-development levels), but with current EWRs from LHWP, EWRs provided to meet Rapid (Desktop) assessment for Category D Orange River and spills from the Vaal utilised to support the EWRs (RS2).

Results from the historic firm yield analyses are summarised in **Table 9.1**.

**Table 9.1: Yield Results for Base Scenario with Current and Projected Future Demands**

Scenario No. (RS)	Description	Units	Surplus/deficit Yield	Increase/Decrease
1	Base Scenario (2005-development level)	million m <sup>3</sup> /a	120	0
1a	Base Scenario (2015-development level)	million m <sup>3</sup> /a	67	-53
1b	Base Scenario (2025-development level)	million m <sup>3</sup> /a	34	-86
2	Base Scenario (2005-development level) with increased EWR for LHWP and Orange River	million m <sup>3</sup> /a	-299	-419

The surplus yield available in the system for the Base Scenario (RS1) is 120 Million m<sup>3</sup>/a, which indicates that the system is almost in balance as the 120 Million m<sup>3</sup>/a surplus represents less than 4% of the system yield of Gariep and Vanderkloof Dams, of approximately 3 250 Million m<sup>3</sup>/a.

The growth in urban/industrial and mining components have a relatively small impact on the system yield, reducing the system yield from 2005 to 2025 by only 86 Million m<sup>3</sup>/a (RS16).

The current situation (2005-development level), with Desktop 'D' EWR and current EWR releases from LHWP (Mohale and Katse Dams) (RS2), results in a deficit of almost 300 Million m<sup>3</sup>/a in the system, showing how significant the EWR are in assessing the water balance.

### 9.2.2 Current Scenario (RS3)

This scenario (RS3) has the same configuration as the Base Scenario (RS1), but was refined and updated to more closely reflect the current situation and uses the results of the LORMS studies into the EWRs for the initial target of a Category D Estuary. Thus, the following changes were made to the Base Scenario:

- The recommended environmental requirements to maintain the estuary in Category D, determined at the LORMS Estuarine Workshop, were included, instead of either the ORRS environmental requirements or the results of the rapid (Desktop) Class D analysis.
- Spills from the Vaal, including the effect of the operating losses in the Vaal, were utilised to support the environmental requirements in the Lower Orange.
- The recently updated environmental requirements from the LHWP and the resulting reduced LHWP transfer to the Vaal of 780 million m<sup>3</sup>/a for the full Phase 1 of the LHWP was used.

Analyses were also carried out with the most probable irrigation demands in 2005, 2015 and 2025, and the results are shown in **Table 9.2**.

**Table 9.2: Results for Historic Yield Analysis for Different Development Scenarios**

Scenario No. (RS)	Description	Units	Surplus/deficit Yield
3	2005-development level: - 2002 irrigation - 2005 irrigation	million m <sup>3</sup> /a	14 -47
3a	2015-development level: - 2002 irrigation - 2015 irrigation	million m <sup>3</sup> /a	-42 -308
3b	2025-development level: - 2002 irrigation - 2025 irrigation	million m <sup>3</sup> /a	-75 -418

Note: Growth in Urban/Mining Water Use is included

From this table it can be seen that for this current Scenario (RS3), with the 2002 irrigation water requirements, there is an estimated surplus of only 14 Million m<sup>3</sup>/a at 2005-development level.

When only the projected growth in the urban/industrial/mining water requirements is allowed, the surplus in the system will become zero between 2007 and 2008 with a

deficit of 42 Million m<sup>3</sup>/a in 2015 (RS3a) and a 75 Million m<sup>3</sup>/a deficit in 2025 (RS3b).

When the effect of the most probable irrigation growth is included, there will be a deficit in yield of 47 Million m<sup>3</sup>/a at the 2005-development level (RS3). This deficit will increase to 308 Million m<sup>3</sup>/a in 2015 (RS3a) and to 418 Million m<sup>3</sup>/a by 2025 (RS3b), with the projected irrigation demands for those years.

### 9.3 Effect of Environmental Flows on Current Water Balance

The historic firm yield of the system, available for allocation to consumptive use, is dependent on the EWR, which are controlled by the estuarine water requirements. This in turn is dependant on the agreed ecological category for the estuary, which must still be determined. At 2005-development levels and 2002 irrigation water use, it has been calculated that:

- To maintain the Estuary at a Category D: Surplus yield = 14 Million m<sup>3</sup>/a.
- To improve the Estuary to a Category C: Deficit of 500 Million m<sup>3</sup>/a will be experienced.

The reduction in yield from the system, which would be available for the consumptive water requirements, is thus very significant if the category of the estuary were to be improved from a 'D' to a 'C'.

### 9.4 Water Quality Trends

During the Vaal Augmentation Planning Study (VAPS) (DWAF, 1996), the Water Quality Trend (WQT) Model was calibrated on Total Dissolved Solids (TDS) data collected prior to 1987. One of the tasks of the LORMS was to determine whether the water quality (TDS) had changed significantly since 1987 and to decide if the WQT Model should be recalibrated with post 1987 data.

A statistical exercise was undertaken to establish whether the water quality data collected after the calibration period (1988 to 2002) differed significantly from that used to calibrate the WQT Model and those predicted by the Water Resources Planning Model (WRPM) for a 1995 level of development. Broadly, upstream of Upington, the predicted results are representative of the observed median values, while downstream of Upington, the predicted results are higher than the observed record. This indicates that the recalibration of the WQT Model can be postponed to a later date. However, it is strongly recommended that a separate study should be undertaken to investigate the nutrient levels, associated algal blooms and related water quality problems in the Lower Orange.

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## 10. DEVELOPMENT AND MANAGEMENT OPTIONS TO MEET THE OBJECTIVES

### 10.1 Water Resource Management Objectives

All the strategic objectives (See **Section 3**) were assessed to determine how the outcomes of this study (recommendations for management and development of the LOR) should be developed to meet the objectives. From this assessment, forty WRM objectives were developed, and grouped into 12 categories. All the objectives have been considered in this study.

The strategic objective “Protection of the Environment” is an overarching objective to which the assessment of the EWRs made a key contribution.

The two categories of WRM objectives, which provided the primary focus for the identification and assessment of WRM and development options, were:

- **Resource Assurance:**

- Provide increased assurance of supply for existing commercial and subsistence agriculture downstream of longitude 20°;
- Provide adequate water supply for secondary industries at high assurance of supply and affordable price; and
- Ensure sufficient water supply at agreed assurance of supply and affordable price to settlements for subsistence agriculture and stock watering.

- **Resource Quantity and Quality:**

- Provide increased volumes of water for mining in Namibia and RSA at agreed assurance of supply;
- Provide increased volumes of water for agricultural development in RSA and Namibia;
- Provide sufficient water for domestic and industrial use; and
- Provide water at a quality which is fit for its purpose.

The WRM objectives in the following four categories did not lead to WRM or development options, but were used to establish some of the criteria used for evaluation of options.



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The objectives in the last two of these four categories provided guidance to the Legal, Institutional, Water Sharing, Cost Sharing, Management and Dam Operation Report.

- **Resource Accessibility:**

- Provide access to the water required for Basic Human Needs (BHN);
- Provide access to supplies for economic activities; and
- Provide access to adequate water supply (quantity and quality) for subsistence agricultural activities.

- **Resource Protection:**

- Protect the Surface Water Resource;
- Protect the Groundwater Resource; and
- Follow appropriate environmental protection and management procedures in all operations and developments.

- **Resource Management and Control:**

- Effective management and control;
- Full Namibian participation in agreeing water allocations between RSA and Namibia;
- Namibian participation in the management decisions for Orange River System; and
- Joint South African/Namibian control of relevant water resources infrastructure.

- **System Operation:**

- Efficient operation of the Orange River to meet agreed reserve and water requirements and maximize benefits from the available resource.

The remaining six categories of water resource objectives, listed below, relate to distribution and affordability and will need to be considered in parallel and subsequent initiatives and studies by various levels of Government in both countries.

- **Resource Conservation and Use:**

- National and bi-national water use objectives;
- Policy to support and encourage economically beneficial use of water;
- National and bi-national guidelines to support WC&DM;
- Agricultural water use at or below benchmarks for efficient water use; and
- Domestic and industrial water use at or below benchmarks for efficient water use.

- **Public Safety:**

- Protect the public from flood risks;
- Protect the public from drought risks; and
- Protect the public from pollution risks.

- **Management Institutions:**

- Establish CMAs in each WMA in RSA and equivalent institutions in Namibia;
- Ensure effective bi-national management through appropriate and effective bi-national structure;
- Establish/support local Water Management Institutions (WUA, etc.); and
- Establish/support local Forums for public participation.

- **Financial Management:**

- Consistent national pricing guidelines, which are applied consistently to the shared resource;
- Pricing guidelines, which support the agreed priority objectives and strategies;
- Consistent and appropriate capital support mechanisms; and
- Consistent and appropriate operation support mechanisms.

- **Monitoring and Information:**

- Water use monitoring and information system;
- Water resource quantity monitoring and information system;
- Water resource quality monitoring and information system; and
- Environmental monitoring and information system.

- **Complimentary Strategies:**

- Capacity Building:
  - Management Institutions; and
  - Users.
- Public Participation:
  - Management objectives and strategies.
- Education and Awareness:
  - Politicians; and
  - Users.

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## 10.2 Management and Development Options

### 10.2.1 Introduction

Three Management Strategies were identified to meet the future water resource objectives. Within each strategy, a number of management and development options were identified and these are described in the following sections. Where possible, specific management and development options were defined in sufficient detail, to be able to determine the probable costs, benefits and impacts of the options.

The benefits of each of the management and development options, in terms of incremental yield and their ability to meet future demands were determined using the historic firm yield analysis. The system, as described in **Section 9**, was modified by adding each option, initially independently, and the historic firm yield compared with the current Scenario (RS3). The results are presented in **Sections 11, 12 and 13**. The development of costs is described in **Section 10.3**.

### 10.2.2 Strategy to Improve Benefits of Existing Infrastructure

Improvements can be made in the use of existing infrastructure of the Orange River to increase the allocatable yield. The improvements that can be made are highlighted below:

- Improved river operation to better match releases with requirements through real time modelling and integrated management of the Orange and Vaal River Systems. This will reduce the operational losses.
- There is currently a surplus of available yield compared with water requirements in the Vaal River. This could be utilised as an interim measure.
- Utilise Vanderkloof low level storage by installing new permanent pumps.

### 10.2.3 Water Conservation and Demand Management Strategy

The opportunities identified for more efficient water use were considered in the following four groups:

- **Opportunities for Management Control in all Sectors:**
  - Limit or cap new water allocations;
  - Monitor water use against allocations; and
  - Implement appropriate tariffs.

- **Urban Sector:**

- Maintained ongoing initiatives to reduce demands or limit projected increases in demand; and
- Review tariff structures and tariff levels to promote loss reduction and efficient use.

- **Mining Sector:**

- Mandatory recycling of water from slimes dams, including the minimisation of evaporation (paddock system) within one year after starting with production;
- Metering and charging of water to households in mining towns; and
- Appropriate tariff to enhance water conservation efforts.

- **Irrigation Sector:**

- The most significant opportunities are in this sector. Based on an overview of irrigation areas supplied from the Orange River, two large irrigation areas were selected for further study to evaluate the costs and benefits of three complimentary components of WC&DM;
- Scientific scheduling of water application;
- Metering and tariffs; and
- Efficient irrigation water application systems.

#### 10.2.4 *Strategy based on Infrastructure Development*

The options for meeting the water resource objectives through the development of infrastructure were grouped in two categories:

- Re-regulating dams to reduce the operational losses and improve the effectiveness of operation.
- Storage dams to increase the system yield.

### 10.3 **Development of Design and Cost Criteria for Options**

The planning and costing of each management option was derived from the particular circumstances around the option and past experience of the cost of various initiatives.

For the development options, requiring new infrastructure, the design criteria developed in the VAPS, modified where necessary, were used as a basis for the reconnaissance designs of each infrastructure development option. In particular, the sections on flood determination for the various dam types, and foundation grouting were revised to suit this study. The cost models were updated by utilising

contract prices, with appropriate escalation, for the recently constructed Maguga, Mohale, Inyaka and Paris (Bivane) Dams, and the Matsoku Weir.

#### **10.4 Assessment of Ecological and Social Impacts, and Benefits**

Each option was assessed by the ecologists, sociologists and other specialists on the team on the basis of published information, limited site visits to the general area and specific sites identified for development.

## 11. ANALYSIS OF IMPROVED USE OF EXISTING INFRASTRUCTURE

### 11.1 Utilise Vaal River Surplus (RS3c)

#### 11.1.1 Description

As a result of the LHWP and other transfers to augment the Vaal System, there is a temporary, conditional, surplus in the Vaal System, which can be utilised in several areas, including support to the Orange River System.

#### 11.1.2 Yield

The possible increases in system yield if all the surplus from the Vaal were supplied to the Orange, after allowing for some losses, are given in **Table 11.1**. The Vaal River surplus water might, however, be too expensive for the low to medium priority users, as the water needs to be pumped from the Tugela System to make the surplus available in the Vaal River.

**Table 11.1: Yield Results for Utilising Vaal Surplus (RS3c)**

Scenario No. (RS)	Description	Increase in Yield (Million m <sup>3</sup> /a)
3c	Vaal surplus	
	2005	94
	2010	28
	2015	10

Note: The effect of transfer losses is included.

#### 11.1.3 Costs

The direct costs of 20c/m<sup>3</sup> of this option arise from the cost of pumping from the Thukela System and some increase in operating costs.

However, new users on the Vaal System are required to pay the full Vaal water tariff, which is currently R1,46/m<sup>3</sup>.

#### 11.1.4 Social and Ecological Impacts

There are no social impacts specifically associated with using the surplus Vaal water in the Orange River System. The potential environmental impacts would be related to the ecological flow regime and how the system would be operated.

Although the water in the Vaal River is more polluted than that in the Orange, the release of this water into the Orange would have limited effect on the water quality in the Orange, which would still be acceptable for all users.

### 11.2 Hydraulic River Modelling and Improved System Operation (RS3d)

#### 11.2.1 Description

Results from the Water Resources Yield Model (WRYM) showed that at 2005-development level, on average, 1 680 Million m<sup>3</sup>/a enters the Orange River from the Vaal. The monthly flows vary from almost zero to extremely high flows during periods of high runoff when the major dams are spilling. Currently, these flows are not taken into account when releases are made from Vanderkloof Dam to supply downstream requirements.

Real time modelling will enable the operator at Vanderkloof Dam to reduce releases from Vanderkloof Dam at the required time to utilise the inflows from the Vaal for users in the Lower Orange.

#### 11.2.2 Yield

Results from a combination of hydraulic river modelling and the WRYM system modelling (RS3d) indicated that the surplus yield in the system can be increased by 80 Million m<sup>3</sup>/a when real time modelling is used to utilise inflows from the Vaal more effectively.

However, this additional 80 Million m<sup>3</sup>/a cannot be added to the surplus yield indicated for the current system (RS3) or any of the scenarios based on that scenario. When the most recent methodology is used to model the effect of the EWR on the system, it is automatically assumed that the required infrastructure and techniques are in place to utilise spills from the system, to support the EWRs. The benefit of the 80 Million m<sup>3</sup>/a is therefore already included in the current scenario (RS3), but not in the Base Scenario (RS1) where the ORRS' EWRs were modelled.

### 11.2.3 Costs

The estimated capital cost, primarily related to additional flow measuring stations, was estimated at R35 Million. The operating costs were estimated to be R100 000/annum.

### 11.2.4 Social and Ecological Impacts

There will be no social impacts. Implementation of this option will improve the operation of the river system and this can have benefits for the ecology through helping to meet the EWRs.

## 11.3 Utilisation of Vanderkloof Low Level Storage

### 11.3.1 Description

There is a significant volume of storage in Vanderkloof Dam below the level of the outlets to the irrigation systems. This storage can be accessed by installing a pumping system to lift the water into the irrigation canals. However, this will impact on the energy that can be generated by the hydropower plant at the dam.

### 11.3.2 Yield

The increase in yield of 143 Million m<sup>3</sup>/a can be achieved by the utilisation of the lower level storage in Vanderkloof Dam below the minimum operating level (m.o.l.) defined by the outlets to irrigation canals in the current scenario (RS3). However, if the yield from utilising the low level storage is determined on the basis of the system yield, determined when the m.o.l. is defined by the hydropower outlets, which are higher than the irrigation canal outlets, the incremental yield is expected to increase by approximately an additional 140 Million m<sup>3</sup>/a to 283 Million m<sup>3</sup>/a.

### 11.3.3 Costs

The capital costs were estimated at R85,4 million.

The operating costs were estimated at R2,8 Million/annum.

The economic impact of reduced hydropower generation is the subject of a separate study.

### 11.3.4 Social and Ecological Impacts

There will be very limited social and ecological impacts during construction and limited social benefits through temporary job creation during construction.



## 12. ANALYSIS OF WATER CONSERVATION AND DEMAND MANAGEMENT IN THE IRRIGATION SECTOR

### 12.1 Overview of Potential Water Savings and Costs

The irrigation sector is the highest consumer of water in the LORMS area and it also has the biggest potential for savings. Except for irrigation scheduling in the Kimberley/Douglas area, there has been very little structured implementation of WDM in the Orange River System.

**Table 12.1** gives a summary of what can potentially be achieved through WDM initiatives. The success of the measures will depend on:

- the creation of clear policy guidelines pertaining to tariff policies/rebates;
- advice on scheduling; and
- training of farmers.

**Table 12.1: Summary of Expected Savings through WDM Initiatives**

Activity and Location	Volume Million m <sup>3</sup> /a	Costs/ m <sup>3</sup> saved (cent)	Remarks
<b>Water Efficiency Unit</b> (Upington)	Unknown	Unknown	Improves water productivity.
<b>Scheduling</b>			Improves water productivity.
Upstream Vanderkloof	7.2	6.95	10.0% saving less 30% return flow
Downstream Vanderkloof	63.9	3.20	7.2% savings less 30% return flow
Common Border	3.6	10.24	5.0% savings less 30% return flow
<b>Metering &amp; Pricing</b>			Improves water productivity.
Upstream Vanderkloof	6.7	5.13	7.0% savings on the reduced
Downstream Vanderkloof	84.3	3.12	consumption after the implementation of
Common Border	6.9	2.88	scheduling.
<b>Irrigation Systems</b>			Improves water productivity by 24.1%.
Gifkloof/Neusberg	53.4	89.7	
<b>Conveyance losses</b>			
Orange Riet Canal	Unknown	Unknown	Requires a detail investigation.

Demand side management programmes cannot be designed, implemented and evaluated without the knowledge of present water uses and without an understanding of the important factors that influence these uses, both now and in the future. There is a need to develop forecasting methods to support the evaluation of long- and short-term demand management alternatives.

## 12.2 Gifkloof to Namibian Border

Given the potential benefits shown in **Table 12.1**, more detailed assessments of the costs and benefits of WC&DM measures in the area between Gifkloof and the Namibian border, were assessed in detail (RS3i) since this area was expected to provide the greatest benefits.

### 12.2.1 Yield

The potential water savings from the three main activities were assessed to be:

- Proper scheduling: 7% reduction in use.
- Metering and pricing of water use: 7% reduction in use after implementation of scheduling.
- Improvement of irrigation systems: 15% for Gifkloof to Neusberg; and 20% for Neusberg to Namibian border.

It was assumed that WC&DM could only start to be effective in 2006 or 2007, and that the benefits of scheduling and metering-pricing will only reach their full potential at the beginning of 2012 when a benefit of 55 Million m<sup>3</sup>/a could be achieved. These will be followed by the effect from improved irrigation systems with the full potential, a further benefit of 63 Million m<sup>3</sup>/a, only being achieved in at 2015. It was estimated that a significant saving of 118 Million m<sup>3</sup>/a can be obtained from WC&DM measures in these areas. The increase in yield takes account of the reduced return flows as a result of reduced application of water to irrigated areas.

### 12.2.2 Costs

The potential savings from scheduling and metering – pricing are estimated to have a capital investment cost of R 240.9 Million. The Gifkloof/Neusberg area may also have the highest potential for use of additional water, because most of the area can be utilised for high value crops like grapes.

The estimated costs for the establishment of a Water Efficiency Unit from Upington downstream, including the CBA, are estimated to be in the order of R 2.5 Million. The capital investment would be R 1.0 Million and the annual cost R 1.5 Million, depending on the size, method of operation and location of the unit.

### 12.2.3 Social and Ecological Impacts

No environmental impacts are anticipated.

Social impacts of WC&DM could be significant if the reduction in water use result in reductions of irrigated areas or crop yields. However, the anticipated reductions in water use as a result of more efficient use of the water, then no reductions in areas under irrigation or crop yields are anticipated.

While there will be social issues to be managed, there should not be any negative impacts.

The funding of the R 240,9 Million capital investment is problematic. The capital will be required for improved irrigation systems that are mostly privately owned.

## 13. ANALYSIS OF DAM DEVELOPMENT OPTIONS

### 13.1 Identification of Dam Sites

The potential dam sites identified in the ORRS were reviewed and a Desk Study undertaken to identify any new options.

#### 13.1.1 Options Upstream of the Common Border

The ORRS identified and evaluated the eight possible development options upstream of the common border listed in **Table 13.1**. No new sites were identified in the LORMS.

**Table 13.1: Dam Sites Identified in the ORRS Upstream of the Common Border within the LORMS Study Area**

Development Option	Location
Havenga Bridge Dam	~ 15 km downstream of Vanderkloof Dam
Elandsdraai Dam	~ 15 km upstream of Hopetown
Eskdale Weir	~ 15 km downstream of Hopetown
Hereford Weir	35 km downstream of Hopetown
Torquay Dam	~ 47 km downstream of Hopetown and ~ 35 km upstream of Vaal/Orange confluence
Lanyondale Dam	~ 60 km downstream of Douglas
Hospital Dam	~ 20 km upstream of Prieska
New Boegoeberg Dam	~ 1 km downstream of existing Boegoeberg Dam

#### 13.1.2 Options along the Common Border

The ORRS identified a number of options of which six merited further consideration in this study. A number of new locations were also identified in this study. Following an initial screening, the 15 sites listed in **Table 13.2** were selected for assessment in the pre-screening phase.

**Table 13.2: Dam Sites Identified along the Common Border**

Development Option	Approximate River Distances from the Mouth of the Orange River (km)	Comment
Kabies	148	Identified in ORRS
Grootpens A	173	
Grootpens B	177	
Aussenkehr	223	Identified in ORRS
Violsdrif A	303	Identified in ORRS
Violsdrif B	318	Identified in ORRS
Violsdrif C	322	Identified in ORRS
Violsdrif D	327	
Kambreek	433	Identified in ORRS
Coboop A	465	
Coboop B	475	
Coboop C	479	
Beenbreek	512	
Yas	542	
Komsberg	580	

### 13.1.3 Options on the Fish River

A site was selected at Koubis, immediately upstream of the Ai-Ais Nature Reserve, as being representative of typical sites in the area to provide reservoir characteristics for input into the yield model of the LOR. Initial runs of the hydrological model indicated that a dam on the Fish River would not be attractive in the regional context and no further investigations were carried out.

## 13.2 Pre-screening of Dam Sites

Each potential dam site was evaluated against the specified pre-screening criteria to identify the most favourable sites for further assessment.

- The only favourable site for the construction of a new dam upstream of the common border was confirmed as the New Boegoeberg site, approximately 1 km downstream of the existing small dam. The site is suitable for either a smaller re-regulating dam or for a large dam to improve the system yield.

- 
- Following the initial assessment, the Vioolsdrif, Yas and Komsberg Dam sites were assessed to be the most favourable options along the Common Border and were studied in more detail.
  - The Vioolsdrif A site was selected for this Study, because of the narrow cross section, but the B and C sites should also be considered in the further studies.

The Vioolsdrif A Dam site is situated upstream of the villages of Vioolsdrif and Noordoewer. The dam would inundate areas over which mining and prospecting licenses have been issued, over most of the length of the impoundment. This site is suitable either for a smaller re-regulating dam, or for large dam to improve the yield of the system.

- The Yas Dam site is situated approximately 54 km downstream of the border at 20° longitude. As in the case of the Komsberg site, much of the water stored by the dam will be on the South African side of the border and the dam would inundate parts of the Augrabies Falls National Park. The dam would not inundate much irrigable land, areas of mining and prospecting licenses, towns or villages, road infrastructure, or powerlines. A dam at this site would have a similar cost to a dam at Vioolsdrif.
- The Komsberg Dam site is situated approximately 7 km downstream of 20° longitude. Above a Full Supply Level (FSL) of RL 432 m, water would start to inundate parts of the Augrabies Falls National Park. The rapids downstream of the Falls will start to be inundated at levels above RL 450 m.

Inundation of the rapids and the river/gorge upstream of the rapids was agreed to be unacceptable, and this site would thus only be suitable for a smaller, re-regulating dam.

The results of those studies are summarised in **Table 13.3**.

**Table 13.3: Evaluation of Dam Sites against the Pre-screening Criteria**

Pre-screening Factor	Dam Site		
	Vioolsdrif A	Yas	Komsberg
<b>Site considerations</b>			
Topography of site and basin	Moderately good dam site	Good dam site	Very good dam site -narrow valley
Geological conditions	Only the Vioolsdrif Dam site was investigated (in the ORRS study) and geological conditions can therefore not be used as a factor for pre-screening purposes.		
Construction materials & borrow areas	Only the Vioolsdrif Dam site was investigated (in the ORRS study) and this pre-screening factor can therefore not be used as a factor for pre-screening purposes.		
Storage capacity potential	Potential storage capacities all exceed the maximum volume that can be utilized effectively		
Small re-regulating dam or large storage dam	All sites are suitable for either a small re-regulating dam, or a larger storage dam.		
Design floods & spillway arrangements	Design floods similar due to relatively great distance to main catchment areas		
	Mass concrete overflow	Mass concrete overflow plus possible by-wash	Mass concrete overflow
Seismic characteristics	All of the sites are situated in a low seismic risk area.		
River diversion during construction	For pre-screening purposes only mass concrete gravity dams were considered, and river diversion considerations are therefore identical.		
Considerations to site establishment	Not considered during pre-screening.		
Access roads	Access is difficult due to steep valley sides	1:50 000 maps do not indicate roads in the immediate vicinity of the dam sites	
<b>Contribution to the system yield</b>	Considered to be similar for all sites due to negligible additional inflow from catchment areas in the vicinity of these dams sites.		
<b>Social and environmental impacts</b>			
Potential social impacts	Social impacts of the individual sites for similar line storage capacities were not investigated, but the social impacts of the sites should not differ from one another significantly.		
Potential environmental impacts	Considered relatively low	Inundation of parts of the Augrabies Falls National Park	

Pre-screening Factor	Dam Site		
	Vioolsdrif A	Yas	Komsberg
Proximity / location to major centres	~ 20 km from Vioolsdrif / Noordoewer	~ 60 km from Onseepkans	~ 90 km from Onseepkans
International borders	Situated on the border between Namibia and South Africa.	The above dams and other dams constructed in the vicinity will have a lesser effect on international borders as water pushes up past 20° longitude.	
Possibility of hydro-power generation	There is the possibility of hydro-power generation at all sites investigated.		
Proximity to powerlines	20 km (line at Vioolsdrif / Noordoewer)	200 km (line on farm Kabis)	240 km (line on farm Kabis)
Flooding of existing infrastructure	No flooding of major infrastructure		
Flooding of irrigation areas: existing and potential	Potential flooding of irrigation areas in the vicinity of the river.		Smaller irrigation areas flooded
Flooding of mining and prospecting license areas	On Namibian side of border, all dams flood areas over which mining and prospecting licenses have been issued. Not much difference between one dam and the other.		Smaller areas flooded
Flooding of areas of archaeological importance	The conclusions of the desk study are that not many detailed investigations had been carried out to date and further investigations would have to be carried out for particular sites in the case of dam construction.		
Sedimentation rate	The difference in sedimentation rates between the different sites was not investigated but is not considered to be significant enough to influence a choice between the sites.		
Potential effects on water quality	The difference in the effects on the water quality between the different sites was not investigated, but is not considered to be significant enough to influence a choice between the sites.		
<b>Cost</b>	Moderate cost	Similar to Vioolsdrif	Lowest cost of all sites

The following conclusions were reached:

- The Yas Dam site does not offer any significant cost benefits over the Vioolsdrif site and will inundate parts of the Au-grabies Falls National Park. It was therefore excluded from further analysis.
- The capital cost of a dam at Komsberg is less than at Vioolsdrif for either a smaller re-regulating dam or a larger dam to improve the yield of the system. The allowable inundation of the Au-grabies Falls National Park by a dam at Komsberg, however, still had to be determined.

The net result of the pre-screening was that both the Vioolsdrif A and the Komsberg Dam sites were analysed in more detail and considered in the Options Assessment Workshop.



### 13.3 Assessment of Re-regulating Dams

#### 13.3.1 Yield and Costs

The benefits of a re-regulating dam at Vioolsdrif, Komsberg or a new dam at Boegoeberg, to reduce operating losses and therefore increase the allocatable yield of the system, were analysed using the hydraulic river modelling and yield analysis models. The costs of each were determined and the URVs calculated.

The results are given in **Table 13.4** and indicate that the Vioolsdrif option provides a significantly higher yield and lower URV than a re-regulating dam at either the New Boegoeberg or the Komsberg sites.

**Table 13.4: Yield Results for Re-regulating Dams**

Scenario No. (RS)	Description	Total Storage (Million m <sup>3</sup> /a)	Live Storage (Million m <sup>3</sup> /a)	Increase Yield (Million m <sup>3</sup> /a)	Cost (Million R/N\$)*	Unit Reference Value
3h	New Boegoeberg Dam	163	90	62	192	0.35
	Komsberg Dam	260	100	126	230	0.28
	Vioolsdrif Dam	260	110	170	318	0.26

\* Excluding Engineering Design and Supervision, and VAT

An important consideration is that there should be sufficient users downstream of the re-regulation dams, to utilise the saving in operational losses. The current demands downstream of the Vioolsdrif Re-regulating Dam are 193 Million m<sup>3</sup>/a (excluding estuary environmental requirement) and are therefore sufficient to utilise the indicated increase in yield of 170 Million m<sup>3</sup>/a.

#### 13.3.2 Social and Ecological Impacts

From the ecological assessment, it was concluded that:

- All of the proposed options will have a detrimental impact on the riverine ecosystem.
- A dam at New Boegoeberg site would have the least impact relative to the other options.

- 
- A dam site at the Vioolsdrif area would affect overall a less developed stretch of riparian landscapes and habitat than Komsberg, and stretches of the river are invaded by alien vegetation.
  - A dam site in the Komsberg area would affect large stretches of relatively pristine riparian woodlands, though interrupted by agricultural developments.

The overall ecological assessment was that the impacts at Komsberg and Vioolsdrif are very similar and should not be used as the basis for selection. However, some of the impacts at Vioolsdrif can be more easily mitigated than those at Komsberg.

The social impact assessment of the Komsberg and Vioolsdrif Dam sites concluded that:

- The construction of a regulating dam at Vioolsdrif will have the smallest negative socio-economic impact of the three options. This is largely due to the remoteness of the dam, and the limited settlement and agricultural development along the river banks in the area potentially inundated by the reservoir. Because of its remote location, the dam will also have the least benefit in terms of future socio-economic development in the immediate vicinity of the dam. Most of the benefits are likely to be felt downstream.
- The proposed regulating dam at Komsberg will have significant benefits, as well as negative socio-economic impacts. The negative impacts are largely related to the loss of land and infrastructure, and the disruption of communities. The scale of these impacts has not been accurately determined, but the modest size of the proposed reservoir indicates that the scale is relatively moderate. The potential for future socio-economic development associated with agriculture is good (around the dam and immediately downstream), but this will depend on the extent to which the dam improves the assurance of water supply.
- Agricultural development at Komsberg might be more cost effective than at Vioolsdrif, due to better access and the relative proximity of the dam to the infrastructure and marketing networks in and around Upington. However, potential for agricultural development is limited by the Augrabies National Park on the northern bank of the reservoir.

## 13.4 Assessment of Storage Dams

### 13.4.1 Yield and Costs

The costs and benefits were determined for large storage dams, which would also fulfil the role of a regulating dam at the Vioolsdrif and New Boegoeberg Dam sites.

Sedimentation is a serious problem, particularly for large dams located at the Vioolsdrif and New Boegoeberg Dam sites. The expected fifty-year sediment volumes for the two dams were estimated at 600 and 710 Million m<sup>3</sup>, respectively. Live storage volumes of 500, 1 500, and 2 400 million m<sup>3</sup> (after the 50-year sediment was included) were analysed for each of the possible dams. The applicable fifty-year sediment volume is therefore a substantial portion of the gross volume required for each reservoir. The live storage in the first number of years will be significantly more than that available at the end of the 50-year period. Two yield values were determined for each dam size.

Although estimates of the 50-year sediment volume can be made fairly easily, it is very difficult to know what the effect of the sediment will be on the area of evaporation from each dam. Evaporation from these two dams is significant, and the reason for the zero yield from a 500 Million m<sup>3</sup> New Boegoeberg Dam (50-year sediment included) is the large evaporation area. For the analyses, it was assumed that the evaporation area from the reservoir surface has not changed due to sedimentation over the years. With a dead storage of 600 and 710 Million m<sup>3</sup> for Vioolsdrif and New Boegoeberg Dams, respectively, the area of evaporation of the two dams at these storages is significant.

The yield results are summarised in **Table 13.5**.

**Table 13.5: Results for Storage Dams at Vioolsdrif and Boegoeberg**

Scenario No. (RS)	Description	Total Storage (Million m <sup>3</sup> )	Live Storage after 50 Years (Million m <sup>3</sup> )	Average Historic Firm Yield (Million m <sup>3</sup> /a)	Cost *(Million R/N\$)	Unit Reference Value
3f	Large Vioolsdrif Dam – 44m spill height	1 100	500	183	691	0.44
	54.6m spill height	2 100	1 500	297	946	0.52
	62.6m spill height	3 000	2 400	365	1 181	0.62
3g	New Boegoeberg Dam – 35.4m spill height	1 210	500	101	872	1.35
	42.1m spill height	2 210	1 500	187	1 002	0.88
	44.6m spill height	3 110	2 400	225	1 078	0.84

\* Excluding Engineering Design and Supervision, and VAT

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Results from the economic analyses indicated that the Violsdrif Dam is the better option, and it was decided to carry out a third analysis for each of the Violsdrif Dam sizes. In this analysis, it was assumed that the evaporation area at the dead storage volume of 600 Million m<sup>3</sup> would be the same as for the 100 Million m<sup>3</sup> dead storage and the yields for this scenario are given in brackets in **Table 13.5**.

#### 13.4.2 *Social and Ecological Impacts*

The relative ecological impacts at Violsdrif and New Boegoeberg for a large dam are similar to those for a re-regulating dam.

The yield dam at Violsdrif is in a sparsely populated area, so socio-economic impacts relative to other sites in South Africa and Namibia are small since the dam site is situated in a very poor and under-developed region, there is potential for any development to promote socio-economic development. At the higher full supply levels, the Violsdrif Yield Dam will have a significant socio-economic impact compared with the re-regulating dam due to the size of the reservoir and the area to be inundated. Significant loss of land and infrastructure will occur, together with the disruption of whole communities. It is important, however, to place these impacts in context.

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## **14. OPTIONS ASSESSMENT (Criteria, Process and Results)**

### **14.1 Criteria for Assessment**

The identified options described in the preceding sections, were assessed against each of the criteria, on a scale of 1 to 4, the results summarized and recommendations formulated. The recommendations are given below.

The project objectives and national water resource objectives formed the basis for the criteria used in the Options Assessment Workshop. The criteria were grouped into:

- Criteria that will be met equally by all options; and
- Criteria to be used to evaluate options.

### **14.2 Objectives and Criteria that will be met equally by All Options**

The following Strategic Objectives of both countries will be met equally by all options, because all the options can supply their yield at any agreed location and these objectives can be achieved by appropriate use of the water supplied:

- Regional Economic Development;
- Poverty Alleviation;
- Job Creation (from water supplied);
- Food Security; and
- Ensuring Water Supply to Namibian Users:
  - providing appropriate agreements and management and operation of the option are implemented.

The following criteria, developed from the Strategic and National Objectives and WRM Strategies cannot be achieved by a project, but require National Policies and Strategies to be implemented throughout the water sector.

- Resource Protection (flow related). All options will be planned to meet the EWRs.
- Agreed Water Use Objectives.
- Optimise economic benefits of water use (by users).
- Select economic developments for water use.
- Reduction of “losses” (by users).
- Appropriate Water Pricing Policy.
- Policy and mechanisms for financial assistance.
- Monitoring and information.

- Complimentary Strategies:
  - Public Participation (PP); and
  - Education and awareness.
  
- Water supply to downstream users.

The remaining Strategic Objectives and National Water Resource Strategies (NWRS) were developed into criteria to assess the options.

### 14.3 Criteria used to Evaluate Options

The criteria shown (**Table 14.1**), and classified as either fundamental, primary or secondary were used in the assessment.

**Table 14.1: Criteria Used to Evaluate Options**

Fundamental Criteria	Primary Criteria	Secondary Criteria
1. Yield and Capital Cost, combined with Operating Cost as URV	1. Opportunities for Joint Management and Operation	1. Confidence in Yield
2. Ecological Impacts	2. Improved Management of Water Resources	2. Confidence in Cost
3. Social Impacts	3. Promotion of International Co-operation	3. Temporary Social/Economic Benefits during Construction
4. Water Quality	4. Opportunities for Benefit-Cost Equity	4. Permanent Social/Economic Benefits
5. Implementation Flexibility	5. Political Acceptability	5. Capacity Building
6. Operational Flexibility	6. Promotion of Public Safety	
	7. Promotion of Efficiency of Use	

### 14.4 Process for Assessment

The possible options were evaluated at a workshop in September 2003 in Windhoek by a team comprising the Client, selected stakeholders and the Consultants. The workshop participants undertook the following activities:

- The current system yield, current water use and the implications of alternative EWRs on the water balance were examined.
- The two alternative future irrigation demand scenarios, which were agreed by the PWC, were confirmed for planning purposes.
- The criteria (see **Table 14.1**) for the evaluation of the management and development options were agreed.
- The results of the studies into the possible options for management and development of the water resources were presented by the Consultants and discussed.

- The options were evaluated in groups based on the strategic category in which they were identified. Where options are mutually exclusive, the preferred option was agreed. Where options could be pursued together with other options, concerns and areas for further study were agreed.
- The benefits and impacts of each option were evaluated by all the participants.
- The recommendations were made for the options to be studied further. In some cases, these recommendations are qualified.

## 14.5 Recommendations from the Assessment Workshop

The recommendations and proposed actions from the workshop, for each option, are summarized in the following sections.

### 14.5.1 Improve Benefits of Existing Infrastructure

#### **Vaal Surplus:**

This option was conditionally recommended subject to evaluating the results of the following investigations, which must be undertaken as soon as possible:

- Determine the costs which should be used in the economic evaluation.
- Analysis of water quality to assess the impact of the Vaal River inflows on the Orange River water quality.

#### **Real-time River Modelling:**

This option was recommended to improve the management of the river, with the inclusion of the Vaal River and a Scope of Work (SoW) for implementation should be prepared.

It was noted that this SoW must include the monitoring requirements.

#### **Utilise Vanderkloof Low Level Storage:**

This option was conditionally recommended subject to:

- Assessing the national impacts with respect to impact on hydropower generation in order to assess economic/financial viability of the option.
- The required information was expected to come from a parallel study, which was scheduled for completion in August 2004. However, the results of that study did not enable a decision to be made and more detailed investigations are envisaged.

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#### 14.5.2 Investigation of Specific Water Conservation and Demand Management Initiatives in the Irrigation Sector

The option to pursue specific initiatives in the area downstream of Gifkloof, up to the Namibian border, was recommended. The way forward was agreed as:

- Identify a small area, within one of the irrigation areas, for a Pilot Study.
- Prepare SoW for the Pilot Study. The study should evaluate costs, benefits impacts and requirements for implementation, including:
  - Legislation;
  - Licensing;
  - Technology; and
  - Capacity for effective implementation.

#### 14.5.3 Re-Regulating Dams

Three possible dam sites for a re-regulating dam, as described in **Section 13**, were evaluated at the Options Assessment Workshop.

Upstream of 20° Longitude (i.e., upstream of the Common Border):

- (a) New Boegoeberg Dam.

Downstream of 20° Longitude (i.e., along the Common Border):

- (a) Violsdrif Dam; and  
(b) Komsberg Dam.

The Violsdrif Dam site was preferred to the New Boegoeberg Dam site for the following reasons:

- (a) Significantly lower URVs;  
(b) Significantly larger saving in operational losses; and  
(c) Less impacts.

The Violsdrif and Komsberg sites initially appeared very similar. However, dams of all heights under consideration for the Komsberg Dam site would inundate parts of the Augrabies Falls National Park and a dam at this site could not be raised due to the proximity to the Augrabies Falls.

The Komsberg site was not recommended, unless improved cost estimates, using more detailed mapping make it competitive with Violsdrif and the ecological concerns prove unfounded.



After the workshop, these issues were investigated in more detail, including detailed mapping, revised cost estimates and field visits to assess the environmental impacts. The investigations showed that the site was less cost effective than shown by the initial assessment of the site, there are significant limitations on the storage capacity that could be developed without inundating the rapids. It was also concluded that the ecological impacts at Komsberg and Vioolsdrif were comparable and that they should not influence the recommendation.

The Vioolsdrif site was the recommended site for a re-regulating dam for which a pre-feasibility design should be completed and a SoW prepared for a Feasibility Study. The study should take particular note that:

- The dam may be raised.
- Sedimentation is a significant risk.

#### 14.5.4 Storage Dams

Two possible dam site options were investigated, as described in **Section 13**, in order to provide cost estimates, determine yields and assess benefits and impacts. The options were then evaluated at the Options Assessment Workshop.

Upstream of 20° Longitude (i.e., upstream of the Common Border):

- (a) New Boegoeberg Dam

Downstream of 20° Longitude (i.e., along the Common Border):

- (b) Vioolsdrif Dam

The Vioolsdrif site was also recommended as the best site for a large storage dam on the Orange River downstream of Vanderkloof Dam. It should only be implemented in parallel with or after the other recommended management and development options.

The benefits and impacts of providing a new storage dam at Vioolsdrif should be considered in the context of the whole Orange River Basin and compared with the alternative dam sites in the Upper Orange, which have been considered and provisionally recommended in other studies.

The Boegoeberg site was not recommended and no further study was proposed.

The timing for implementing additional storage will depend on the implementation and benefits of other options, which should be implemented first.

The following actions were recommended:

- Preliminary reconnaissance level designs should be carried out on the Vioolsdrif Dam site as part of the LORMS to provide improved cost estimates and consider alternative layouts (see **Section 16**).
- A SoW be prepared for a Feasibility Study to be undertaken when required.
- A single Feasibility Study for a phased development of a re-regulating dam followed by a storage dam may be most appropriate.

## 15. STOCHASTIC YIELD ANALYSIS OF RECOMMENDED OPTIONS

### 15.1 Water Resources Yield Modelling

The current scenario (RS3) was used as the basis for this analysis.

Results show that the historic firm yield has a recurrence interval of about 1 in 100-years and that if all the demands are supplied at a 1 in 100-year assurance of supply, there will be a small surplus of 56 Million m<sup>3</sup>/a available in the system.

In practise, however, all the demands are not supplied at the same assurance level and the assurance levels as required for different categories of users in the Orange River System is provided in **Table 15.1**.

**Table 15.1: Water Use by User Categories and Priority Classifications for 2005**

User Category	Priority Classification & Assurance of Supply (% of water use and volume)						Total (Million m <sup>3</sup> /a)
	Low (1 in 20-year)		Medium (1 in 100-year)		High (1 in 200-year)		
	%	Million m <sup>3</sup> /a	%	Million m <sup>3</sup> /a	%	Million m <sup>3</sup> /a	
Urban	20	12	30	18	50	30	60
Irrigation	60	1 062	30	531	10	177	1 770
Losses	0	0	0	0	100	332	332
<b>Total</b>		<b>1 074</b>		<b>549</b>		<b>539</b>	<b>2 162</b>

The results in this table show that almost 50% of the total demand needs to be supplied at a low assurance of 1 in 20-years because of the large irrigation component.

To assess the available surplus or deficit yield from the system, the total demand of 2162 Million m<sup>3</sup>/a was compared with the available yield at various recurrence intervals. The results are shown in **Table 15.2**. Results in this table indicates the surplus or deficit available when the total demand is supplied at either the 1 in 20-year, 1 in 50 year, 1 in 100 year or 1 in 200 year assurance levels.

**Table 15.2: Summary of Long-term Stochastic Yield Results for Current Scenario (2005-Development Levels)**

Scenario Description/Demand	Long-term Stochastic Firm Yield at Indicated Recurrence Intervals			
	1: 20-year (Million m <sup>3</sup> /a)	1: 50-year (Million m <sup>3</sup> /a)	1: 100-year (Million m <sup>3</sup> /a)	1: 200-year (Million m <sup>3</sup> /a)
Current Scenario (RS-P3)	2 825	2 450	2 218	2 000
Demand	2 162	2 162	2 162	2 162
Surplus/ Deficit (RS-P3)	663	288	56	(162)

The demands should however be imposed on the long-term stochastic yield curve at the required assurance levels as indicated in **Table 15.1**. When this is done the results show that there is a surplus of 480 Million m<sup>3</sup>/a available at a 1 in 20-year assurance level.

The available surplus in the system and therefore also the date when intervention is required, to ensure that the growing need of water users are met, as determined from the historic firm yield analysis and the stochastic analyses differ significantly.

The results are summarised in **Table 15.3**.

**Table 15.3: Comparison of Water Balance from Historic Yield Analysis (RS3) (from Table 9.2)**

Development Level	Surplus Yield:
	Historic Firm Yield Analysis (Million m <sup>3</sup> /a)
2005	-47
2015	-308
2025	-418

Note the Total Yield from Gariep and Vanderkloof Dams is 3 200 Million m<sup>3</sup>/a.

From "Orange River System Analysis – Yield analysis up to Vanderkloof Dam"

The Stochastic Analysis predicts that there will be a surplus until about 2015, with the current estimates of future water requirements, while the historic firm yield shows a deficit in 2005.

The two main reasons for the differences are:

- The historic firm yield is representative of a 1 in 100-year recurrence interval. This means that for the historic yield analyses all the demands are supplied at a 1 in 100-year assurance. For the stochastic analyses approximately 50% of the demands are allocated to a 1 in 20-year assurance, and the remaining to the 1 in 100 and 1 in 200-year assurances.
- Secondly, the demand growth curve for the Orange River System is relatively flat, so that a small difference in the calculated yield will make a significant difference in the timing required for intervention measures.

The Orange River System (Gariep and Vanderkloof Dams) has an extremely high system yield of approximately 3 200 Million m<sup>3</sup>/a and it should be noted that the estimated current surplus in the system is similar in magnitude to the 10% margin of error generally accepted for hydrology and systems analysis. That margin of error represents 320 Million m<sup>3</sup>/a, which is a large volume that could be utilised if it is actually available or a significant shortfall if the error is in the opposite direction.

To supply the projected increases in demand, one or more management and development options will have to be implemented.

If it is agreed that the estuary should be an Ecological Category D and based on the stochastic yield analysis and preliminary estimates of the ecological flows to achieve this, the new options should be implemented before 2015. However, based on the historic firm yield analysis, intervention is required in 2005. Given the sensitivity of the results to the analysis technique used, it was agreed that:

- various sensitivity analyses should be carried out; and
- more detailed analysis, using the WRPM, should be undertaken.

The results are presented below.

## 15.2 Sensitivity Analyses

The sensitivity analyses indicated that the stochastic yield results can be improved by means of the following:

- Analysing the inflow to the Orange from the Vaal stochastically and thereby producing Vaal inflow records, consisting of 501 flow sequences of 68 years each, instead of a single sequence from a historic analysis.
- Setting the river evaporation losses to zero and considering them as part of the system yield.
- Excluding the Lower Vaal operational losses from the Vaal inflow record.

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Results from the refined long-term stochastic analysis showed a surplus of 243 Million m<sup>3</sup>/a at a 1 in 20-year assurance level and this is regarded as the most accurate surplus indication from all the long-term stochastic analyses performed.

### **15.3 Water Resources Planning Modelling**

The WRPM was used to carry out a planning or operating analyses, using short-term stochastic yield characteristics, obtained from the WRYM as part of the operating rule. The growth projections of all the water requirements are also included in the WRPM, in order to determine when curtailments and, or, intervention measures will be required in future. Using the WRPM to determine the required intervention time results in a more conservative and realistic result than that obtained by means of the long-term stochastic yield analysis, as well as a more optimistic and realistic result than that from the historic firm yield analyses.

Results from this analysis, using the EWRs proposed in this Study for a Category D estuary, indicated that curtailment levels will be exceeded from 2006 onwards. This means that curtailments would then be imposed on the system more often than the given risk criteria.

From the results it is clear that actions need to be taken to improve the supply situation in the Orange River System from 2006 onwards, until such time as a Vioolsdrif Re-regulating Dam can be in place. However, in practice, it will not be possible to have Vioolsdrif Dam in place until 2015 at the earliest.

## 16. PRE-FEASIBILITY DESIGN AND COSTING OF VIOOLSDRIF RE-REGULATING DAM

### 16.1 Introduction

The preliminary design was based on the Vioolsdrif-A Dam site, which appears to be the most cost effective due to the smaller cross-sectional area, and similar stage capacity curves when compared with the other three sites.

The 1:50 000 mapping was used to compile the stage capacity curve for the site, but survey plans at a scale of 1:10 000 with 5 m contours were prepared from aerial photography for the dam site.

### 16.2 Flood Determination, Spillway and Diversion Works

In terms of the Guidelines for Sizing of Mass Concrete Dams, the flood magnitudes were based on the Regional Maximum Flood (RMF) concept. The Safety Evaluation Discharge (SED) was calculated to be 26 300 m<sup>3</sup>/s and the Recommended Design Discharge (RDD) 14 250 m<sup>3</sup>/s. Due to these large floods, the complete base width of the valley of 375 m will be used as spillway, and for the preliminary design, a total freeboard of 10 m was used.

The 1:10-year interval diversion flood to be used for a concrete dam was estimated to be 3 000 m<sup>3</sup>/s.

The first stage of the river diversion will consist of an approximately semi circular 8 m high rollcrete cofferdam that will be built on the left hand side of the river valley to close off 250 m of the river channel. Culverts will be installed in the rollcrete for diversion purposes during the second stage.

### 16.3 Embankment Planning and Design

#### Design Parameters:

The following parameters were used for the preliminary design:

- Total storage capacity 260 Million m<sup>3</sup>
- Allowance for sedimentation 150 Million m<sup>3</sup>
- Live storage capacity 110 Million m<sup>3</sup>
- Riverbed level RL 176.4 m
- Non-overflow crest (NOC) RL 211.5 m

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Due to the large design floods a concrete gravity dam was considered to be the only type of dam suitable for the site and due to its inherent lower costs, a rollcrete dam was selected.

#### **Access Roads and Site Establishment:**

Access to the site is difficult due to the steep valley sides. There is also no space available at the dam site for site establishment. For the purposes of the preliminary design, a gravel access road on the left bank was costed. The access road will be prone to frequent flooding unless it can be located at least 10 m above the river bed level.

#### **Outlet Works:**

The estimated monthly demands on this re-regulating dam vary from a minimum of 2.3 m<sup>3</sup>/s in June to 11.8 m<sup>3</sup>/s in January and the outlet works are sized to discharge 25 m<sup>3</sup>/s to meet the demands and wet season EWRs base flows.

However, the estimated maximum EWR is 400 m<sup>3</sup>/s in February. Whilst it can be expected that the dam would normally overflow during this time, allowance has been made for the installation of two 3.0 m wide by 3.5 m high radial gates to act as bottom outlets to make releases of up to 400 m<sup>3</sup>/s.

#### **Dam Raising:**

One of the development options is to construct the re-regulating dam and then to raise it to operate as a storage dam. If the storage dam is sized to meet the projected future downstream demands, it would require a total storage volume of 2 100 Million m<sup>3</sup>, requiring a NOC level at RL 241.0 m and a wall height to NOC of 64.6 m. This would require a 29.5 m raising of the re-regulating dam.



The re-regulating dam was planned to be raised to become a storage dam by adding rollcrete on the downstream side. To accommodate this, the proposed Outlet Works would be located 24 m downstream of the dam wall. During the raising, the intake tower would be extended vertically.

**Cost Estimate:**

The total project cost, including engineering, administration, infrastructure and dam construction, but excluding possible hydropower installation, for a rollcrete re-regulating dam with provision for raising at the Vioolsdrif A site at April 2004 rates was estimated to be R 561 Million.

**16.4 Hydropower Potential**

The available flow rate for hydropower generation was taken as the monthly demand figures, plus the minimum EWR. The average flow rate over a full year was estimated at 15.4 m<sup>3</sup>/s. The minimum available head is 20.3 m.

The estimated capital cost of a hydropower station at the dam was R 30 Million, which allows for all civil and mechanical/electrical works up to and including the switchgear at the dam site. No allowance was made for the cost of any distribution lines.

The maximum generating capacity is 4.2 MW. The total annual power generation was estimated at 21.3 GWh.

The estimated income is R 3.4 Million/a, based on a selling rate of R 0.12 per kWh and a carbon emission reduction subsidy of R 0.04 per kWh.

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## **17. OPTIONS FOR BI-NATIONAL DEVELOPMENT AND MANAGEMENT INSTITUTIONS**

### **17.1 Introduction**

Various models exist for the co-operative management, operation and maintenance of particular water schemes. Internationally, establishment of such an institutional arrangement is accepted as good practice. The format of such arrangement can differ, depending on a number of factors, but mainly relating to the autonomy granted to such an institution. On the one end of the scale, such body can be granted extensive powers to determine the utilisation of works, obtain funding, set charges and recover costs from consumers. On the other end, the countries may delegate limited powers to such institution related only to the physical operation and maintenance of works.

The proposed structures must be practical and capable of implementation within the constraints of available human resource and institutional capacity, as well as financial constraints.

A core consideration will be whether RSA and Namibia will need this institution to function on an independent budget and recover costs from the consumers and thus be able to raise own funding. Alternatively, it could be funded directly by the two Governments.

A key issue, which must be considered in the institutional assessment, is the boundary between national sovereignty and joint/co-operative management of a shared Watercourse. It is essential that duplication of activities and overlap of functions of organisations be reduced to the absolute minimum.

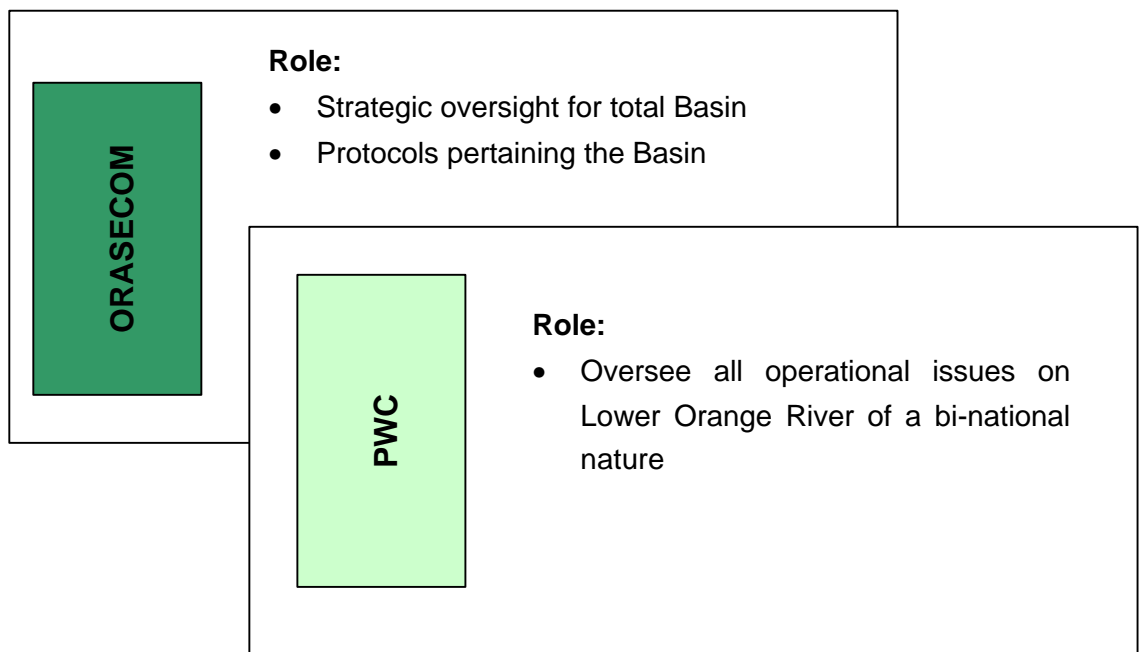
The following levels should be considered:

- Basin wide strategies and co-ordination.
- Bi-National management of a specific portion of the Basin by the PWC.
- Water supply organisations (bi-national and national) under the auspices of the PWC.
- National (country) institutions.

## 17.2 Basin-Wide Strategies and Co-ordination

The ORASECOM provides the strategic framework within which the countries, and bi-national institutions, are required to operate. The relationship of the Permanent Water Commission (PWC) with respect to the ORASECOM is depicted in **Figure 17.1**. The PWC, as other bi-national commissions, operate separately from the ORASECOM, but has a reporting obligation to allow the latter to perform its monitoring function.

In the scenario that a large dam is required in the upper reaches of the Orange basin, a multi-lateral authority under the auspices of the ORASECOM should be considered as an option in addition to the bi-national options discussed below.



**Figure 17-1: River Basin Management Roles of PWC and ORASECOM**

## 17.3 Bi-National Sub-System Management

The existing PWC between Namibia and South Africa was formed in the 1980s and has a liaison function with ORASECOM.

There are certain bi-national management issues relating to the LOR system that could or currently do fall in the ambit of the RSA/Namibia PWC. These issues need to be agreed, and management mechanisms designed for the PWC to implement.

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Matters that will typically be part of the functions and responsibility at this level will include water allocations, water rationing, and disaster management measures for droughts and floods, financial matters, policies and approaches, monitoring of lower level institutions, general overseeing and coordination functions, etc.

It may be appropriate to expand the powers and functions of the PWC to take on some or all of these responsibilities and oversee the joint development of future joint developments.

If it were to exercise these functions, an amendment to the PWC Agreement would be required.

A second tier River Sub-system Management Agency/Authority could be considered for the LOR sub-system. The sub-system Agency/Authority would report to the PWC. The responsibilities of such a Lower Orange River Authority (LORA) could include:

- The management and control of the water resource, ecological care in its area of jurisdiction, and operation and maintenance of water resource infrastructure.
- Ensuring the agreed distribution of water to user groups.
- Implementation and financing of water resource development projects.
- Monitor of water resources information (in close co-operation with other agencies/authorities) and analysis of data to produce management reports.
- Co-ordination with other bi-national and national bodies, as well as users and stakeholders in both countries.

The metering of abstractions from the river by the water users and effective monitoring is an essential component of sound WRM.

The joint management of a dam at Violsdrif will require an institution such as a LORA that would manage the releases from the dam, monitor the use of water by the Parties and ensure that the environmental protection goals and conservation obligations are met.

The area of jurisdiction of LORA needs to be considered in the context of other institutional structures and particularly the national Basin Management Committees (BMCs) in Namibia and the Upper and Lower Orange CMAs in South Africa. The jurisdiction of LORA could be either:

- The “river reach” along the CBA and the estuary/river mouth with a total river length of about 600 km.

Or

- The whole “river reach” below the Vanderkloof Dam to the estuary. The distance from the Vanderkloof Dam to the start of the CBA is some 700 km. The water flows through two South African CMAs (Upper Orange) (for 150 km) and Lower Orange (for the remaining 550 km) to the beginning of the CBA. The implications of this regarding issues of national sovereignty and communication with national bodies will have to be investigated.

The inclusion of this additional river reach from Vanderkloof Dam to the CBA would provide Namibia with valuable insights in the operation and planning of this South African portion of the Orange River System, and is recommended.

In this and other options, mechanisms whereby Namibia could participate in South African Water Resources Planning structures, dealing with the Orange River, should be considered as this will increase international co-operation and trust.

#### **17.4 Water Supply Organisations**

The water supply organisations in existence and needed in future, comprise two major categories:

- Those responsible for joint international water supply systems, i.e., Bi-national water supply organisations; and
- National water supply organisations.

The JIA is an example of a Bi-national water utility or scheme management organisation responsible to operate and maintain a particular water supply scheme such as the current Vioolsdrif/Noordoewer Irrigation Scheme.

The JIA could be made responsible for the development and/or operation of proposed water resources infrastructure such as the proposed Vioolsdrif Dam. This is, however, not considered to be advisable as the JIA serves a particular water use sector and may experience a conflict of interest.

Placing this development responsibility with LORA will ensure that all user sectors will be treated equitably and that care will be taken to ensure that EWRs for the river and estuary are met.

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There are a number of national water supply organisations in the two countries:

**Namibia**

NamWater Rosh Pinah  
Aussenkehr Irrigation  
Oranjemund

**South Africa**

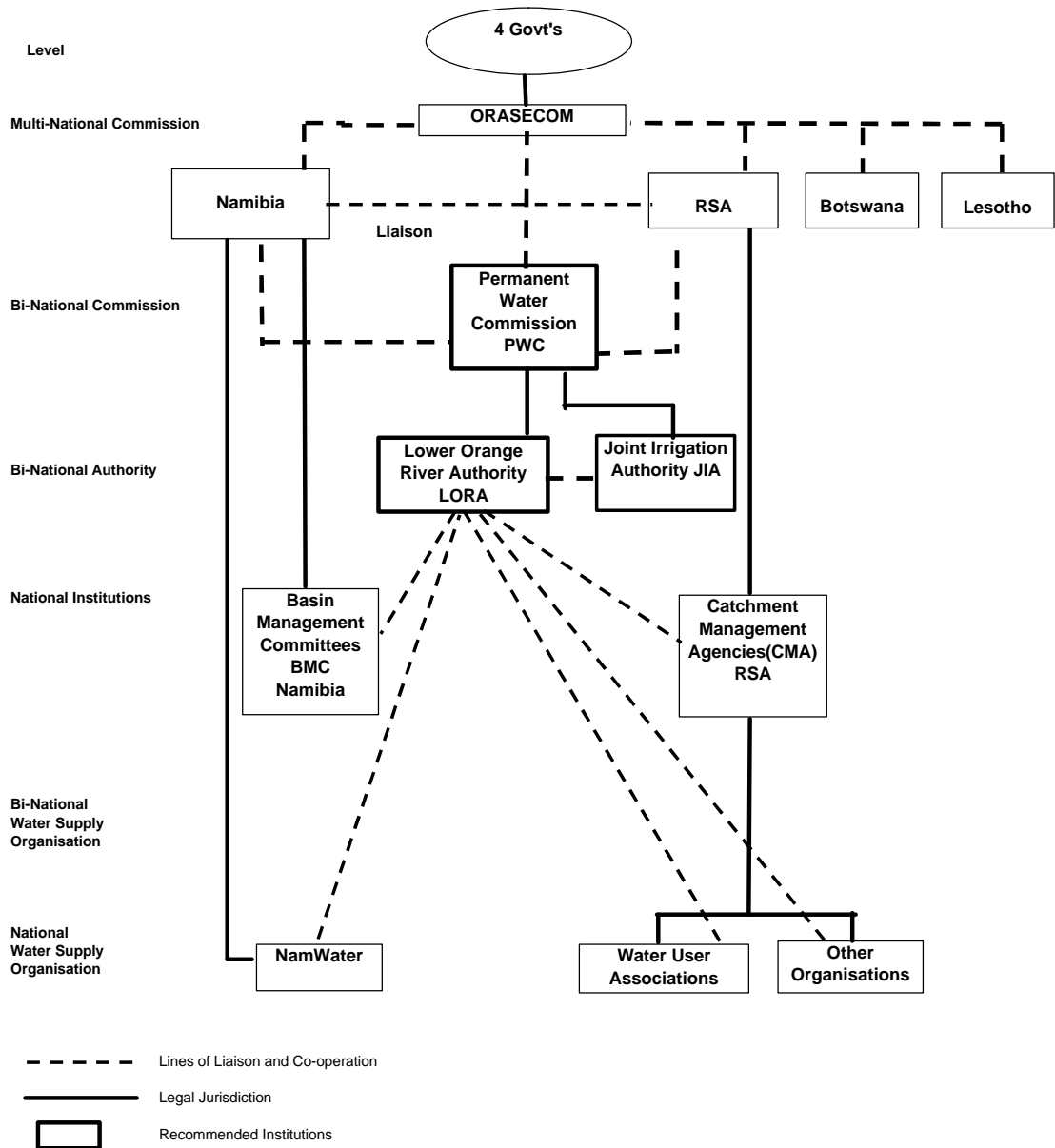
Pelladrift Water Supply Scheme  
Springbok Regional Water Supply Scheme  
Alexcor

### **17.5 Recommended Institutional Framework**

The recommended institutions are shown in the context of the broader institutional framework, including water supply organisations in **Figure 17.2**. The existing institutional structures would be utilised, except that a new entity, the LORA will be created. The powers of the PWC will require amendment to align it with its new functions.

LORA is a key to communication and co-operation with existing and proposed national and bi-national organisations in its area of interest.

The broad functions of the different institutions are set out in the discussion above. Once the principles of such an institution are accepted by the two Governments, then the details of the roles and responsibilities, etc. can be developed further.



**Figure 17-2: Recommended Institutions for the Lower Orange River in the Context of the Broader Institutional Framework**

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## 18. WATER SHARING AND COST SHARING

### 18.1 Introduction

The Orange River Basin has four co-basin states, each of which has obligations to the ecology, generates virgin flows in the Basin, has implemented water resources development and management, and is planning future developments. These are illustrated diagrammatically in **Figure 18-1**.

Each of the management and development options have costs associated with making water available, either through investment of capital in further infrastructure development or resources for improved management. Given the principles for water sharing and cost sharing described in **Section 17**, it was proposed that the cost sharing should be in relation to the sharing of benefits. Since both countries would, essentially, use the water for similar economic activities, irrigated agriculture and some mining, the sharing of benefits has, at this stage, been assumed to equate to the sharing of water. It was also clear that, in general, the management options will primarily result in benefits to one country, which would therefore carry the cost.

This section focuses on the water and cost sharing for infrastructure development. The sharing of the costs between the countries should be in accordance with an agreement to be worked out between the two countries.

### 18.2 Options for Cost Sharing

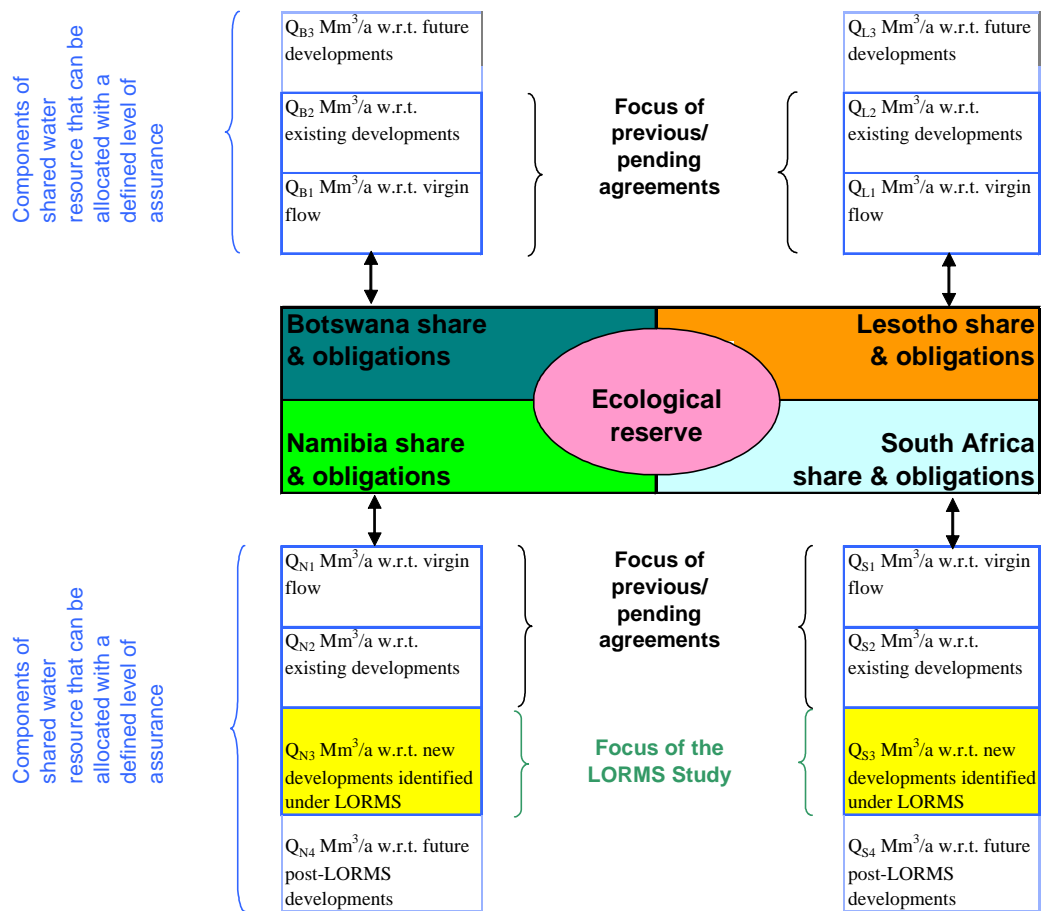
The options discussed here are for agreeing the cost sharing between the countries. Thereafter, each country would have to decide whether it will absorb the costs as a national investment or recover the costs from users and set appropriate water tariffs to be charged to various users on the river system.

The four identified options for South Africa and Namibia to share the capital and operating costs of new developments are discussed below. Arguments for and against Options 3 and 4 should be pursued as a subsequent action, if so desired by the two countries. For each option, the financial implications are illustrated for the development of a re-regulating dam at Vioolsdrif/Noordoewer, based on the following assumptions:

- At independence, it was agreed that Namibia would be entitled to receive 50 Million m<sup>3</sup>/a from the existing infrastructure of the Orange River.
- The water demand in Namibia will be 75,5 Million m<sup>3</sup>/a in 2005.



- The water demand in Namibia will be 274,4 Million m<sup>3</sup>/a in 2025.
- The RSA demand on the Upper Middle and Lower Orange System, excluding the Vaal will be 1 973,6 Million m<sup>3</sup>/a in 2005.
- The RSA demand on the Upper Middle and Lower Orange System, excluding the Vaal, will be 2 149,5 Million m<sup>3</sup>/a in 2025.
- The capital cost of the re-regulating dam, at April 2004 prices, amounts to R 561 Million. This re-regulating dam can add 170 Million m<sup>3</sup>/a to the yield of the system after provision for losses and EWRs.



**Figure 18-1: Simplified Orange River Share Diagram**

The identified options for South Africa and Namibia to share the cost of implementing agreed measures are discussed in the following sections:

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### 18.2.1 Option 1 – Sharing of the Benefits of a Joint Development Compared with Independent Developments by South Africa and Namibia

In this option, the benefits, due to the cost saving by the development of a joint project, compared with the costs if each country were to develop its own project, are shared on a basis to be agreed. Assumed to be 50:50 in this report. The calculations, based on estimated costs, indicate a total benefit of about R 232 Million. The benefit to South Africa for the delayed expenditure when developing its own project was not included. This will decrease the benefit available for sharing by about R 50 Million (about 3%) to R 182 Million.

If it is accepted that either country could, on its own, develop a dam on the Orange River along the common border, then the following options exist.

- South Africa can construct a re-regulating and storage dam at either Vioolsdrif or Boegoeberg to supply their requirements.
- Namibia could potentially construct either the Vioolsdrif Dam or a dam on the Fish River to supply their requirements.

However, this study has shown that:

- The Vioolsdrif Dam is better economically, than a dam at Boegoeberg; and
- That a dam on the Fish River in Namibia is not as economically attractive as Vioolsdrif and, because of its downstream location, cannot meet many of the demands.

It may thus be concluded that both countries would, independently select Vioolsdrif as their best stand-alone option. In this case, the benefit of a joint development is limited to the benefits of scale.

The implications of this are illustrated in **Table 18.1**.

**Table 18.1: Option 1 - Equal Sharing of Benefits of Joint Development**

	Total	Namibia	South Africa
<b>Yield Requirement (in 2025)</b>			
- Million m <sup>3</sup> /a	374,8	198,9	175,9
- % of Total	100	53,1	46,9
<b>Estimated Development Cost of Independent Dams</b>			
- R Million	1 173	603	570
<b>Joint Dam Development</b>			
- Yield Million m <sup>3</sup> /a	374,8		
- Cost R Million	941*		
- Cost Saving = Total Benefit R Million	232		
<b>50/50 Share of Total Benefit</b>		<b>116</b>	<b>116</b>
<b>Contribution to Joint Development</b>		Own cost less benefit (603-116)	Own cost less benefit (570-116)
- R Million	941	487	454
- % Share of Cost		52%	48%

\* Note: This is the estimated cost of a storage to meet the total required yield of 374,8 Million m<sup>3</sup>/a.

### 18.2.2 Option 2 – Sharing of Costs in Proportion to Incremental Water Use

The cost is shared in relation to the incremental water derived by each party from the joint development. If the starting point for determining the increase in water use by each country is their equitable share. The increases in water use to 2025 are:

- Namibia : 224,4 Million m<sup>3</sup>/a
- South Africa : 150,4 Million m<sup>3</sup>/a

The result is shown in **Table 18.2**.

**Table 18.2: Option 2: Sharing of Costs on the Basis of Incremental Water Use – Starting Point: Equitable Share of Water Resource**

	Total	Namibia	South Africa
2025 Incremental Water Use (Million m <sup>3</sup> /a)	374.8	224.4	150.4
Ratio	100%	59,8%	40,2%
Yield (million m <sup>3</sup> /a)	170		
Capital Cost (million)	R 561	R 335.5	R 225.5
O&M Cost (million/a)	R 2.1	R 1.26	R 0.85

If the starting point for determining the increased water use were to be the water use in 2005, when the system is approximately in balance, the effects is shown in **Table 18.3**.

**Table 18.3: Sharing of Costs on the basis of Incremental Water Use – Starting Point: Water Use in 2005**

	Total	Namibia	South Africa
2025 Incremental Water Use (Million m <sup>3</sup> /a)	374.8	198.9	175.9
Ratio	100%	53,1%	46,9%
Yield (Million m <sup>3</sup> /a)	170		
Capital Cost (million)	R 561	R 297.9	R 263.1
O&M Cost (million/a)	R 2.1	R 1.1	R 1.0

### 18.2.3 Option 3 – Cost Sharing on the Basis of System Water Use and Total Development Costs

In this option, the cost is shared in relation to water use from the entire Orange River System, by combining the cost of new developments into total system cost, including the cost of historic developments to get a total unit cost of water from the system. This is the approach commonly adopted by a country when developing the water resources of a basin within its borders. This approach may be considered in view of the fact that Namibia had been under the administration of South Africa when the existing Orange River System was constructed. A current South African

example is the Berg River Project. This option would not normally be pursued by two independent countries, but may be a relevance when considering that:

- Namibia used to be part of the RSA when the existing water supply systems were developed.
- Measures are sought to maximise overall benefits from the system and not only to meet the water requirements of the two countries.

#### 18.2.4 Option 4

This option would be the same as Option 3, but limiting the system under consideration to the sub-system from Gariiep Dam and downstream, excluding the Vaal System.

The implications for this approach are shown in **Table 18.4**.

**Table 18.4: Option 4: Sharing of Costs on the Basis of Share of System Water Use and Costs**

	Total	Namibia	RSA
2025 System Water Use (Million m <sup>3</sup> /a)	2 423.9	274.4	2 149.5
Ratio	100%	11,3 %	88,7%
Yield (Million m <sup>3</sup> /a)	170		
Capital Cost (R million)	561	63.4	497.6
O&M Cost (R million/a)	2.1	0.2	1.9
Historical Capital Expenditure Annuity (R million/a)	80.0	9.04	70.96
O&M Cost of Existing Works (R million/a)	9.13	1.03	8.10

### 18.3 Responsibilities for Meeting Ecological Water Requirements

The obligation to meet the EWRs should be shared in proportion to the consumptive water utilization from the system. The sharing of this cost is based on the assumption that the upstream systems such as the Upper Orange and Vaal both meet their obligations to the LOR System. That is a RSA responsibility and the sharing for the LORMS EWRs is thus independent of RSA's arrangements with the upstream systems/countries.

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## **19. RECOMMENDATIONS FOR THE MANAGEMENT OF THE LOWER ORANGE RIVER**

### **19.1 Environmental and Water Quality Management**

The following recommendations are made:

- Develop policies and strategies for agreeing and implementing required environmental flows for the whole Basin in collaboration with ORASECOM.
- Manage the river system to optimise the benefits to the river and estuary of the water available at the estuary.
- Remove or mitigate the impacts of the anthropogenic impacts on the river and estuary.
- Undertake comprehensive assessments of the riverine and estuarine EWRs.
- A separate study should be commenced to investigate the observed problems of algae blooms/nutrients and other related water quality problems in the Lower Orange.

### **19.2 Improve the Efficiency of Use and Effectiveness of Existing Infrastructure**

#### *19.2.1 Improve Efficiency of Operation through River Monitoring and Operation*

To achieve this, it is recommended that river monitoring and operation be improved through:

- Making significant improvements to the flow monitoring network, with particular emphasis on low flow monitoring.
- Continuous real time modelling of the Orange River be implemented so that operational losses can be reduced and inflows from the Vaal can be utilised. It is estimated that this would increase the yield of the system by approximately 80 Million m<sup>3</sup>/a.
- Integrate the operations of the Orange and Vaal River Systems.

Before the construction of Vioolsdrif Dam, the existing gauging structures should be improved and where required, new ones built to be able to measure low flow accurately. This is required for the effective implementation of real time modeling, which will improve the timing of releases and reduce losses. It will also help the operators to meet the ecological objectives of minimising high flows in winter months, and providing the desired EWR, particularly at the river mouth.

The implementation real time modeling and integrated operation of the Orange and Vaal River Systems will enable the operators of the Orange River System to utilize spills from the Vaal, and therefore, save on the releases from Vanderkloof thus increasing the surplus yield of the system.

#### 19.2.2 Use of Vaal River Surplus and Vanderkloof Low Level Storage

The following recommendations are made for the improved use of existing infrastructure:

- The surplus yield of 105 Million m<sup>3</sup>/a available in the Vaal River System in 2005, but reducing to 30 Million m<sup>3</sup>/a in 2010, be considered as a strategic reserve to be used to increase the assurance of supply of users in the Orange River until 2010, if required. If this source were to be used, the applicable charges for use of the water would have to be agreed in advance.
- Accessing the water stored in Vanderkloof Dam (below the canal inlets to the irrigation system) by pumping, should not at this time, be relied on for augmenting the yield of the Orange River System, but may be considered as a strategic reserve, a role it had fulfilled in the past.

Although the yield of the system can be increased by a further 143 Million m<sup>3</sup>/a if this water is accessed, the parallel study undertaken by the DWAF and Eskom, concluded that:

- While the direct costs and yields made this option attractive, the impacts on the electricity generation were significant.
- With Eskom's current generation system, the economic impact of loss of this peaking capacity was significant.
- The scheme should not be implemented until alternative peaking energy sources are available.
- A detailed Feasibility Study would be required.

### 19.3 Water Conservation and Demand Management

The following recommendations for WC&DM are made:

- The ongoing initiatives in the urban, industrial, mining and agricultural sectors should continue and be encouraged.
- The management systems and institutional support to promote WC&DM in all sectors, but particularly the irrigation sector, should be strengthened or established in both countries.

The opportunities for more efficient water use are greatest in the agricultural sector, and this sector also has the largest water use, particularly in South Africa.

The current (2002) agricultural water use from the Lower Orange, downstream of Vanderkloof Dam, (excluding the Vaal), is 1 375 Million m<sup>3</sup>/a and it is estimated that up to 20%, i.e., 277 Million m<sup>3</sup>/a could be saved and used for irrigating new areas.

In South Africa, the success of WC&DM measures is largely dependent on adequate incentives to farmers, the legislative and administrative regime in South Africa, as well as on significant education and training and acceptance amongst numerous private sector irrigators.

It is recommended that, in addition to improved management and institutional support, the following WDM measures be implemented in the irrigation sector:

- a water efficiency unit to promote WDM in the sector;
- proper scheduling of irrigation on farms;
- metering and application of tariffs to promote conservation; and
- the upgrading of irrigation systems.

In order to obtain a better understanding of costs and benefits, a Pilot Study is proposed for two locations in the Gifkloof/Neusberg area. It should cover twenty farmers (10 progressive farmers and 10 average farmers, using flood irrigation) to get updated water consumption figures, improved crop yields to compare actual figures with the estimated figures used in this report.

The estimated time to realise the full benefits of WC&DM, including the time required for the pilot study, is approximately 15 years. It is uncertain what proportion of the water, which is saved, would become available to be re-allocated to other users.

It is thus recommended that no reliance be placed on this water for making new allocations available to new developments, although some transfers of water rights between different areas may take place within the Orange River System.

#### **19.4 Timing of Interventions**

The recommendations in **Sections 19.1, 19.2 and 19.3** should be implemented as soon as practical and specific actions are discussed in **Section 20**.

Based on the systems analysis carried out in this Study, the current system is approximately in balance in 2005 if the LORMS EWRs to maintain the Estuary in a



Category D are implemented. Augmentation is required from 2006 onwards. It was found that a re-regulating structure, as well as additional storage is required in the system.

However, the system should be able to meet the projected water requirements until 2012 if the current allowance for EWR (ORRS EWRs) are maintained and the implementation of increased EWRs from this, or future studies, is delayed until a new development can be commissioned. The intervention could possibly be delayed until about 2018 if real time modeling is implemented.

However, when a new dam (a re-regulating or storage dam at Violsdrif) is commissioned, in say 2015, the then agreed EWRs will have to be implemented. At this point, agreement should have been reached between Namibia and South Africa regarding the international best practice for the EWRs that are to be applied. If these are similar to the EWRs for a Category D estuary, as determined in this study, additional yield from additional storage will be required. This yield will be equivalent to that which can be obtained from utilizing the Vanderkloof low level storage and a small storage dam.

This is illustrated on **Figure 19-1**, with the yield from Vanderkloof low level storage being accessed.

However, the economic viability of accessing this storage has not been demonstrated and it may not be viable. The implications of this scenario are shown in **Figure 19-2** without the yield from Vanderkloof low level storage being accessed. If the storage dam were to be at Violsdrif and the yield required from the dam is to meet the projected demands in 2025, the required storage capacity would increase from 280 Million m<sup>3</sup>/a to 820 Million m<sup>3</sup>/a.

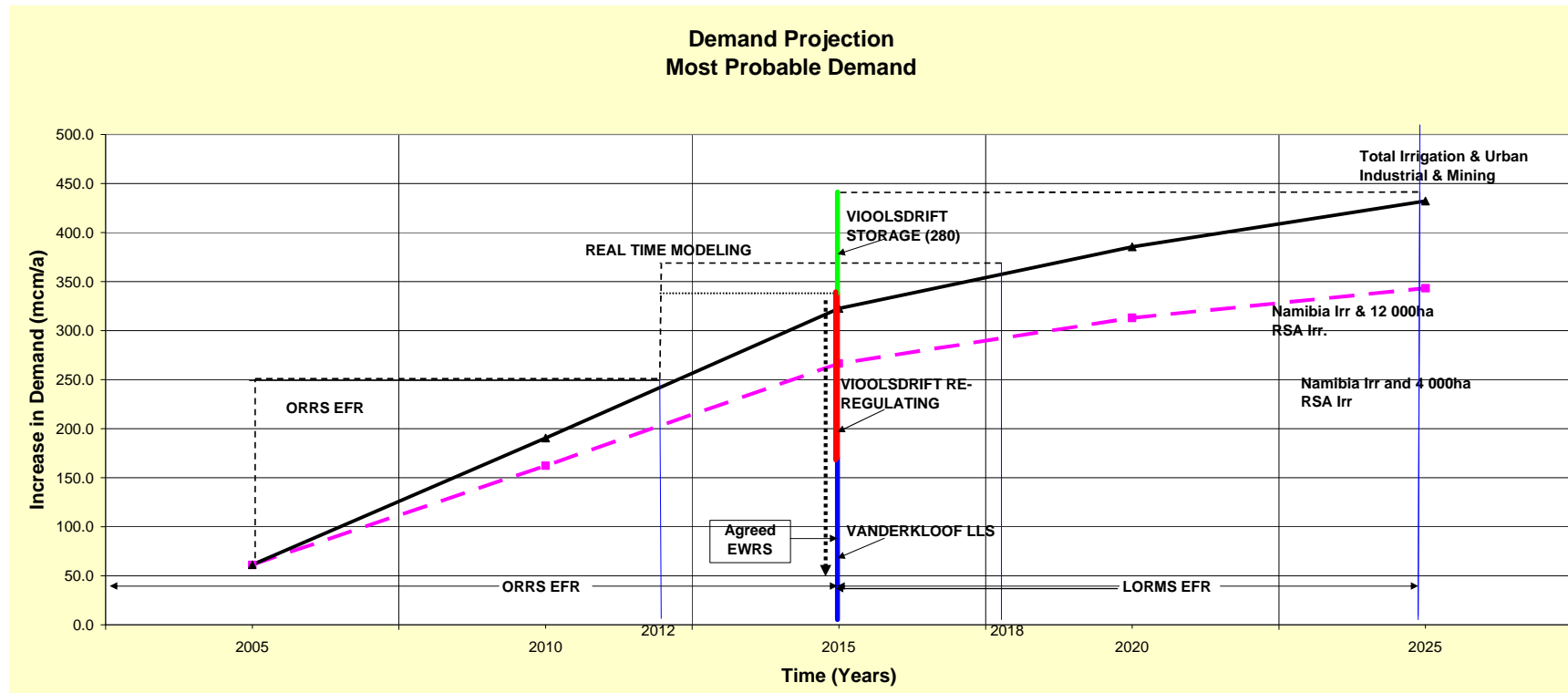


Figure 19-1: Required Intervention Time versus the Most Probable Demand Growth, incl. VdKloof Low Level Storage

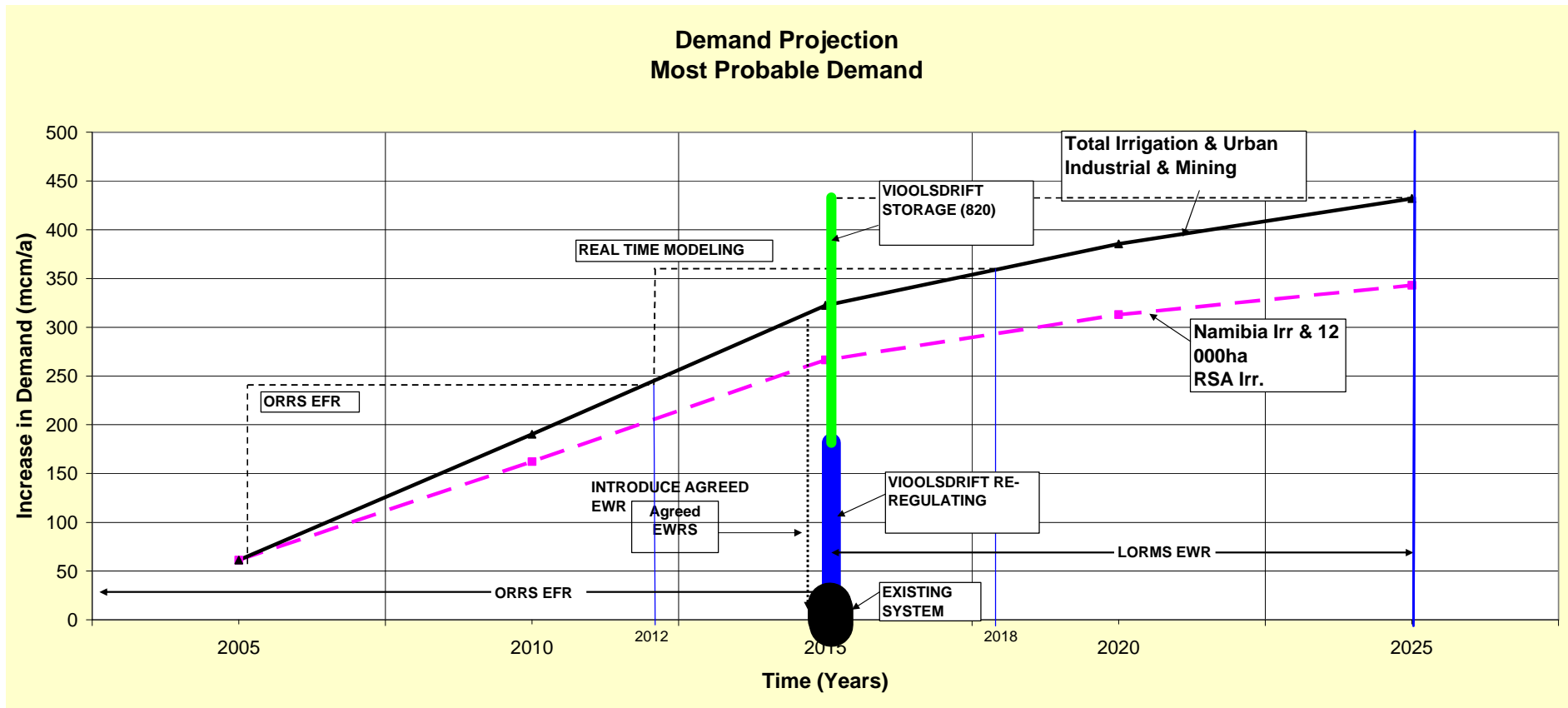


Figure 5: Required Intervention Time versus the Most Probable Demand Growth, excl. VdKloof low level storage

Figure 19-2: Required Intervention Time for Various Options versus the Most Probable Demand Growth, excl. VdKloof Low Level Storage

In summary:

- Management options can be used to meet the projected water requirement with the current releases for environment until 2012 or possibly 2018.
- When a new dam (at least a re-regulating dam at Vioolsdrif) is commissioned, the then agreed EWRs will have to be released and if they are similar to the LORMS EWRs for a category D estuary, additional yield, equivalent to that which can be obtained from utilising the Vanderkloof low level storage and a small storage dam to increase the yield, or low level storage is not to be used then a large storage dam at Vioolsdrif, or other location, will be required.

## 19.5 Development of New Infrastructure

It is recommended that, as a minimum, a re-regulating dam, but possibly a larger storage dam, be implemented at Vioolsdrif/Noordoewer.

The provision of a dam on or near the CBA will re-regulate the releases from Vanderkloof Dam and reduce the current operating losses by about 170 million m<sup>3</sup>/a. The re-regulating dam will also increase the yield through the regulation of incremental runoff downstream of Vanderkloof Dam. In the evaluation of the options the Vioolsdrif site was the preferred alternative. The recommended re-regulating dam at Vioolsdrif would be approximately 35 metres high with a gross storage capacity of 260 Million m<sup>3</sup>.

If, as recommended, the Vanderkloof low level storage is excluded as a possible future option, then, in order to meet the projected demands up to 2025, a storage dam of at least 830 Million m<sup>3</sup> live storage is required, in combination with a re-regulating dam at Vioolsdrif. The actual storage capacity required will depend on the planning horizon, the decision on EWRs and demands the dam is to meet. This storage can be created either at Vioolsdrif or upstream of Gariep Dam.

The additional yield that can be obtained from a large Vioolsdrif Dam at 2005-development level varies from 280 Million m<sup>3</sup>/a (500 Million m<sup>3</sup> live storage) to 430 Million m<sup>3</sup>/a for a 2 400 Million m<sup>3</sup> live storage dam.

It should, however, be noted that due to the limited water use downstream of Vioolsdrif Dam, the maximum live storage, which it is anticipated can be utilised for a storage dam at Vioolsdrif, is between 1 500 to 2 000 Million m<sup>3</sup>, depending on where future developments will take place (downstream or upstream of Vioolsdrif Dam). The maximum downstream use will also be affected by the actual river mouth environmental requirement that will be used in future, as well as the extent to which flows from the Fish River (Namibia) can be utilized to supply the environmental requirements.

The projected increase in water requirements is significant and the currently estimated incremental yields are within the accuracies of hydrological assessments. The date when this additional yield will be required, is also very sensitive to the decision on the EWRs. It is therefore recommended that the necessary evaluation of the alternative locations for a yield (storage) dam on the Orange River System, such as at Bosberg or Mashai, and the planning for a re-regulating dam at Vioolsdrif, either with provision for raising or to be constructed as a re-regulating and yield dam in a single phase, proceed as soon as possible.

Sedimentation has a major impact on the yield from dams in the Lower Orange and there is a lack of relevant data for this area. The processes should be put in place to collect and store the necessary data.

## **19.6 Principles for the Appropriate Institutional and Financial Arrangements for Management**

It is recommended that the following be agreed on:

- The appropriate framework of institutions for the management of the Lower Orange and implementing the proposed new infrastructure.
- The roles and responsibilities of the institutions.
- The arrangements for sharing the costs and benefits of the management and development of the LOR.
- The appropriate sources of funding.

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## **20. PROPOSED ACTIVITIES TO GIVE EFFECT TO THE RECOMMENDATIONS FOR RIVER MANAGEMENT**

### **20.1 Immediate Actions**

The following immediate and short-term activities are recommended as the first steps to give effect to the recommendations in **Section 19**.

### **20.2 Recommended for Immediate Implementation**

The following studies should be commissioned as soon as possible. These are listed approximately in order of priority.

**(i) Improve the Operations of the Orange River Systems to Reduce the Losses**

Commission a study to plan and coordinate the implementation, improved monitoring, real time modelling, and integrated operations of the Orange and the Vaal River systems.

**(ii) Environmental and Water Quality Management**

Commission a study to undertake:

- The feasibility of the removal or mitigation of the impacts of the anthropogenic impacts on the river and estuary, and determine the EWRs for the river and estuary, including the required monitoring.
- The development of operating rules to optimise the benefits to the river and estuary of the water available at the estuary.
- The investigation of water quality issues.

**(iii) Accelerate the Implementation of Water Conservation and Demand Management**

Carry out a Pilot Study in two WUA areas in the Neusberg/Gifkloof irrigation area and to develop an Implementation Plan to put in place the management and institutional support to promote WC&DM in the irrigation sector.

**(iv) Improve the Utilisation of Existing Infrastructure and Develop New Infrastructure**

- Complete the current study (under the auspices of DWAF: RSA) into the economic viability of utilisation of the low level storage in Vanderkloof Dam.
- Commission a Reconnaissance Level Study to determine the best location and size for a dam in the Orange River to increase the system yield beyond which can be obtained by a re-regulating dam at Vioolsdrif.
- Commission a Feasibility Study for a new dam at Vioolsdrif.

The Study should proceed as soon as possible. However, particularly if the dam is to be built as, or raised to become, a large yield dam, the study will require results from the EWR studies before it can be completed.

If the dam at Vioolsdrif/Noordoewer is only to be a re-regulating dam, then the EWR studies will not affect the Feasibility Study and it should proceed immediately.

- Commission a Reconnaissance Level Study to determine the best location and size for a dam in the Orange River to increase the system yield.

The determination of the best location for storage could be undertaken as an early task in the Feasibility Study for a new dam at Vioolsdrif. However, if the Feasibility Study is not commissioned soon this work should be commissioned as a separate study. This will be necessary as other studies will need to be commissioned without delay, in the event that Vioolsdrif is found not to be the recommended site for a yield dam.

**(vi) Agree on the Principles for the Appropriate Institutional and Financial Arrangements**

The proposed first step is that the recommendations in the Legal, Institutional, Water Sharing, Cost Sharing, Management and Dam Operation Report are evaluated by the Parties and discussed by the Permanent Water Commission. Principles should be agreed and the subsequent steps defined.

If the recommendations from this study are implemented, they have the potential to improve the effectiveness of the management and development of the Lower Orange River. The benefits of improved availability of water resources for the environment and consumptive use will support the sustainable social and economic development of the region.

## **21. CONCLUSIONS**

If the recommendations from this study are implemented, they have the potential to improve the effectiveness of the management and development of the Lower Orange River. The benefits of improved availability of water resources for the environment and consumptive use will support the sustainable social and economic development of the region.