COVER PAGE

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
REPORT TITLE	**:**	Water Conservation and Demand Management
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REPORT STATUS	**:**	Final Report
DWAF REPORT NO.	**:**	PB D000/00/4903
DWA NAMIBIA REPORT NO.	**:**	400/8/1P-12
LOR CONSULTANTS REPORT NO:		97331/3487
DATE	**:**	January 2005

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)
Main Report	PB D000/00/4703	400/8/1/P-13	3749/97331
Synopsis	PB D000/00/4703	400/8/1/P-13	3749/97331
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

PRE-FEASIBILITY STUDY INTO MEASURES TO IMPROVE THE MANAGEMENT OF THE LOWER ORANGE RIVER

WATER CONSERVATION AND DEMAND MANAGEMENT

EXECUTIVE SUMMARY

INTRODUCTION

General

The Orange River has the largest river basin south of the Zambezi. It rises in the Drakensberg Mountains in Lesotho at an altitude of about 3 300 m, from where it flows to the west for approximately 2 200 km to the sea. From 20^0 E longitude westwards it forms the nearly 600 km long international border between Namibia and South Africa. This common border area has an arid climate. It has been estimated that the natural runoff of the Orange River Basin is in the order of 11 300 Mm^3/a. The areas of natural runoff are indicated in Figure 1.

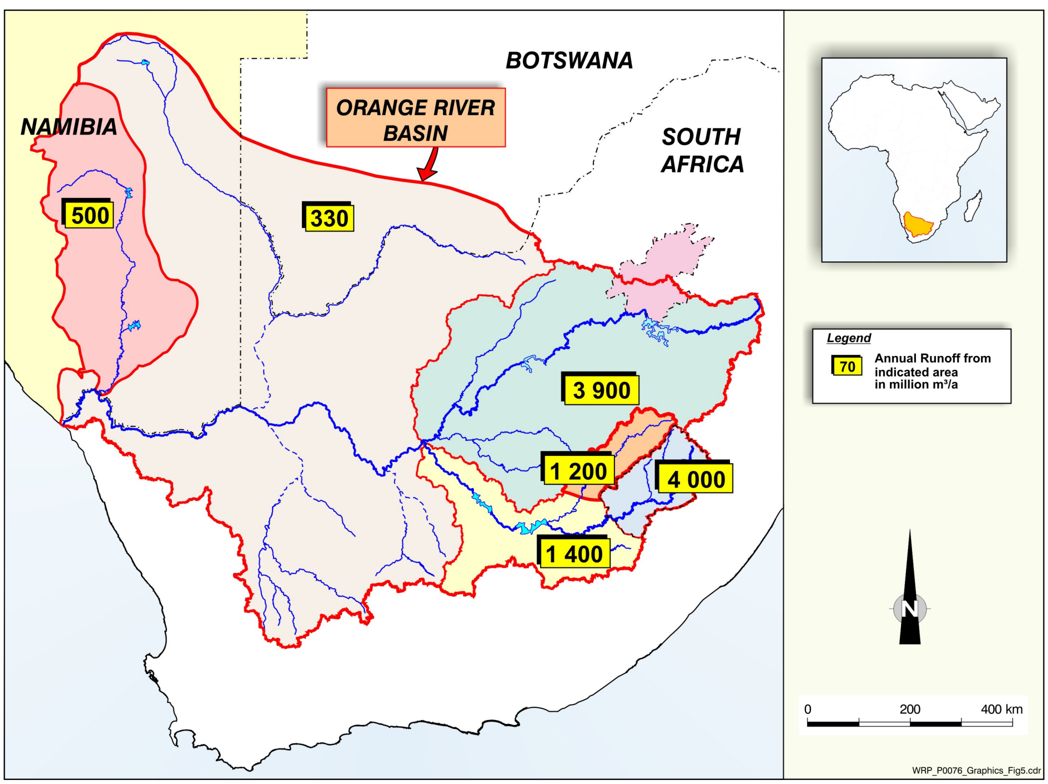

Figure 1: Sub-division of Areas of Natural Run-off in the Orange River Basin

Three important strategies that can be used to increase the water yield/use efficiency of the river system are:

- *Additional storage facilities in the Lower Orange River that can capture some of the 800 Mm^3 run-off that is contributed by the catchment downstream of the Orange / Vaal confluence, and spills from the dams in the middle and upper Orange River.*
- *Reduction of operating losses from the releases made at the Vanderkloof Dam.*
- *Water Demand Management (WDM) initiatives.*

Purpose of this Report

It is the objective of this study to investigate measures to improve the availability of water along the Lower Orange River. This report focuses mainly on Water Demand Management (WDM) initiatives and other demand side measures that can be implemented to improve water use efficiency especially in the irrigation sector.

The purpose of this report is to:

- *assess the potential for improvement in water use efficiency and water demand management both in the upstream area and in the common border area (CBA).*
- *make recommendations for improved efficiency.*
- *provide cost estimates to implement the identified measures.*

RIVER REQUIREMENTS AND OPERATIONAL LOSSES

Losses from the Orange River System represent important "demands" that must be taken into account.

The river requirements of the Orange River System represent an important "demand" that must be taken into account. River requirements are losses resulting from evaporation directly from the water in the river, evapo-transpiration from natural plant growth along the river and seepage that cannot be changed substantially through WDM initiatives.

Operating losses that occur as a result of the complexity of the system while trying to satisfy water needs along the 1 380 km downstream of Vanderkloof Dam were estimated to be approximately 270 Mm^3/annum. The operating losses in the Orange River can be regarded as a river conveyance loss. Reduction in these losses would be an efficiency improvement.

The total conveyance losses in canal systems are estimated at 88 Mm^3/annum for the Orange River downstream of the Vanderkloof Dam. A figure of similar magnitude may be lost in the Fish River in the Eastern Cape.

WATER DEMAND CENTRES AND WATER DEMAND

In a separate Lower Orange River Management Study (LORMS) report on the expected Water Requirements the major demand centres supplied from the Orange River System are defined as:

1. *Vaal River Catchment*
2. *Eastern Cape (transfers through the Orange / Fish Tunnel)*
3. *Upper Orange River (upstream of the Vanderkloof Dam)*
4. *Lower Orange Upstream Area (Vanderkloof Dam to 20^0 E longitude)*
5. *Common Border Area (Lower Orange, Downstream of 20^0 E longitude)*
6. *Fish River (Namibia)*

*The Lower Orange is further subdivided into irrigation areas and main urban/industrial water use centres as indicated in **Figure 2**.*

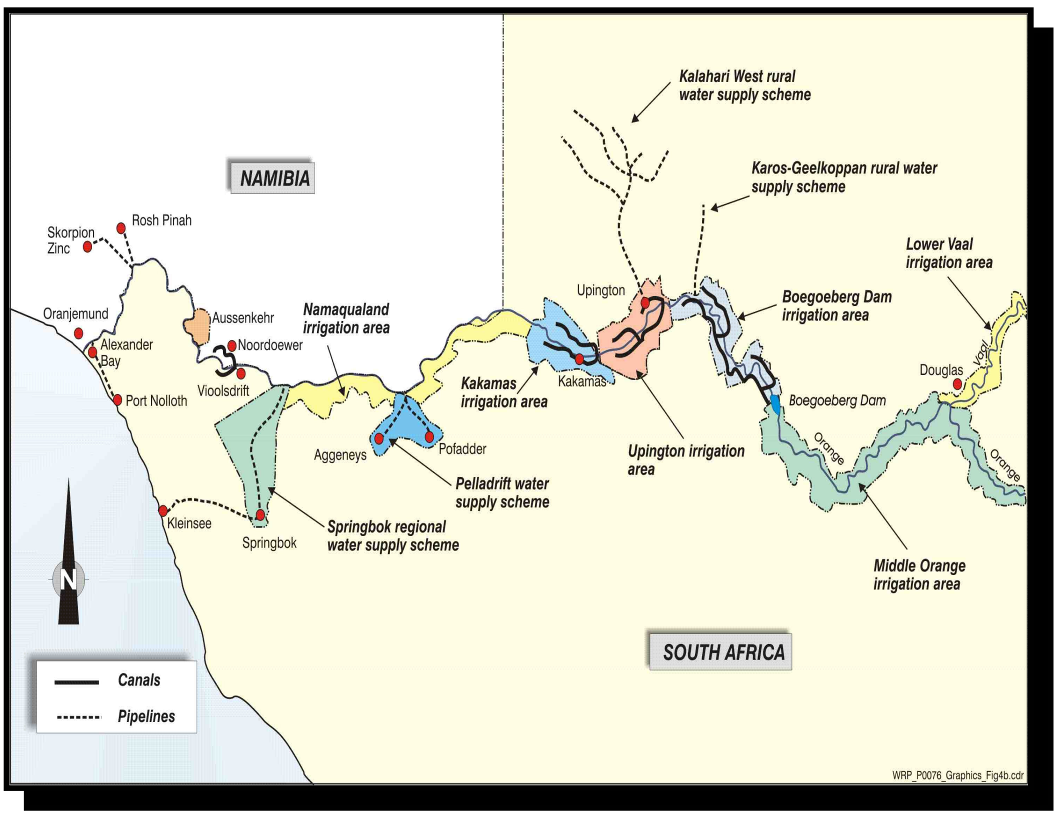

Figure 2: Irrigation Areas and Main Urban / Industrial Water Use Centres along the Lower Orange River

*The water demand in the Orange River System is summarised in **Table 1**.*

Table 1: Water Demand in the Orange River System (2002)

Demand Area	Irrigation (Mm^3/a)	Urban/Ind/ Mining (Mm^3/a)	Total (Mm^3/a)
Vaal River System	796.0	1 840.0	2 636.0
Eastern Cape	607.0	18.9	626.2
Upper & Middle Orange	1371.0	101.3	1 472.3
Diffuse irrigation	397.3	0.0	397.3
Common Border Area	102.3	23.9	126.2
TOTAL			**5 258.0**

Note: The figure excludes irrigation demand in Lesotho

*It is clear from the information summarised in **Table 1** that the biggest opportunity for water use efficiency improvement is in the area upstream of the Common Border Area (CBA). In 2002 the CBA used only 2.4% of the water demand in the Orange River System (including the Vaal & Eastern Cape).*

SUMMARY OF THE WATER REQUIREMENTS

The water demand figures processed and collected as part of the Water Requirements Study (LORMS) is used as input to quantify the effect of water conservation/water demand management.

Vaal River System Water Requirements

*The Vaal River System water requirements are summarised in **Table 2.***

Table 2: Water Requirements in the Vaal River System

Sector	2002 (Mm^3/a)	2005 (Mm^3/a)	2010 (Mm^3/a)	2015 (Mm^3/a)	2020 (Mm^3/a)	2025 (Mm^3/a)
Irrigation	796.0	796.0	796.0	796.0	796.0	796.0
Urban, Industrial & Mining	1,840.0	1,968.2	2,038.6	2,088.1	2,162.6	2,270.0
Total	**5,208.4**	**5,412.2**	**5,564.8**	**5,647.2**	**5,729.4**	**5,868.8**

Water Requirements in the Eastern Cape

*The recently completed Algoa Pre-feasibility Study showed that with water demand management initiatives and the re-use of return flows, Port Elizabeth will only require augmentation by approximately 2017/18. The annual water requirements from the Orange River to the Eastern Cape are summarised in **Table 3**.*

Table 3: Water Requirements in the Eastern Cape

Sector	**2002 (Mm^3/a)**	**2005 (Mm^3/a)**	**2010 (Mm^3/a)**	**2015 (Mm^3/a)**	**2020 (Mm^3/a)**	**2025 (Mm^3/a)**
Irrigation	*607.3*	*626.3*	*651.3*	*651.3*	*651.3*	*651.3*
Urban, Industrial & Mining	*18.9*	*20.0*	*20.0*	*20.0*	*20.0*	*41.3*
Total	***626.2***	***646.3***	***671.3***	***671.3***	***671.3***	***692.6***

Water Requirements Upstream of the Common Border Area

The water requirements in the Orange River upstream of the Common Border Area are summarised in ***Table 4.***

Table 4: Water Requirements in the Orange River Upstream of the Common Border Area

Sector	**2002 (Mm^3/a)**	**2005 (Mm^3/a)**	**2010 (Mm^3/a)**	**2015 (Mm^3/a)**	**2020 (Mm^3/a)**	**2025 (Mm^3/a)**
Irrigation	*1,371.0*	*1,393.0*	*1,415.0*	*1,415.0*	*1,415.0*	*1,415.0*
Diffused Irrigation	*397.3*	*397.3*	*397.3*	*397.3*	*397.3*	*397.3*
Urban, Industrial & Mining	*101.3*	*110.1*	*121.9*	*134.0*	*143.5*	*153.4*
Total	***1,869.6***	***1900.4***	***1,934.2***	***1,946.3***	***1,955.8***	***1,965.7***

Water Requirements in the Common Border Area

The water requirements in the Orange River in the Common Border Area are summarised in ***Table 5.***

Table 5: Water Requirements in the Common Border Area

Consumer Category	**2002 (Mm^3/a)**		**2005 (Mm^3/a)**		**2010 (Mm^3/a)**		**2015 (Mm^3/a)**		**2020 (Mm^3/a)**		**2025 (Mm^3/a)**	
	NAM	*RSA*	*NAM*	*RSA*	*NAM*	*RSA*	*NAM*	*RSA*	*NAM*	*RSA*	*NAM*	*RSA*
Irrigation	*40.6*	*61.7*	*58.4*	*72.5*	*102.8*	*90.6*	*150.0*	*108.7*	*196.5*	*121.7*	*226.7*	*121.7*
Urban/Domestic	*7.1*	*14.8*	*8.5*	*16.6*	*8.7*	*23.0*	*9.0*	*23.7*	*9.4*	*21.9*	*9.5*	*22.7*
Mining/Industrial	*2.0*		*7.3*		*22.5*		*37.7*		*38.0*		*38.2*	
TOTAL	***49.7***	***76.5***	***75.5***	***89.1***	***134.0***	***113.6***	***196.7***	***132.4***	***243.9***	***143.6***	***274.4***	***144.4***

Water Requirements in the Fish River (Namibia)

The water requirements in the Fish River in Namibia will increase from 49.1 Mm^3/a in 2001 to approximately 51.3 Mm^3/a in 2025. The forecast growth is mainly related to expected growth in urban areas. Irrigation water use is expected to stabilise at 48.0 Mm^3/a as from 2005.

WATER DEMAND MANAGEMENT IN THE IRRIGATION SECTOR

The performance of the irrigation sector with respect to water management and conservation is not highly regarded in water management circles. Perceptions exist that:

- *the majority of farmers do not "schedule" correctly to fulfil the needed crop water requirements;*
- *water supplies are not well managed;*
- *distribution losses are high;*
- *existing systems, both on scheme and on farm, are not well maintained;*
- *few farmers are concerned about actual crop irrigation requirements,*
- *water wastage is excessive;*
- *water management has a low priority; and*
- *irrigation should be reserved for "high value" crops.*

"These are universal perceptions that are not only confined to Southern Africa, and may or may not be justified. Most developed countries, our competitors in global markets, are taking active steps to improve irrigation farming effectiveness and water use efficiency. In most developing countries, including Southern Africa very little support is given by Central Governments to improve irrigation farming practices and water use efficiency. There are, of course, individual outstanding exceptions, but they remain exceptions", (Crosby,2001).

WATER DEMAND MANAGEMENT IN THE VAAL RIVER SYSTEM AND EASTERN CAPE

A brief review was done of the Vaal River catchment and the Eastern Cape that receive water from the Orange River through the Lesotho Highlands Project and via the Orange - Fish transfer system respectively. Although the Vaal River System and the Eastern Cape abstract water upstream of the Common Border Area, they account for a significant portion of water use from the Orange River. In this study, it was assumed that any potential savings in the Vaal River System and the Eastern Cape would be used for expected future water requirements in those areas.

The potential savings that can be realised in the irrigation sector in these areas, if it is assumed that the same conditions exist as in the LORMS area, are summarised in ***Table 6.***

Table 6: Expected WDM Reductions in the Vaal River System and Eastern Cape

Demand Area	*Irrigation Water use (Mm³/a)*	*Management & Scheduling (% net savings)*	*Metering & Conservation tariffs (% net savings)*	*Improved Irrigation Systems (% savings)*
Vaal River System	*796*	*7%*	*7% on the reduced demand*	*10 to 15% on the reduced demand*
Eastern Cape	*607*	*7%*	*7% on the reduced demand*	*10 to 15% on the reduced demand*

Note: An allowance of 30% return flow was made to calculate net water savings

The percentage savings should be treated as an indication of potential savings. With the large Metropolitan Areas that exist in both catchments, improved irrigation efficiency could make more water available for urban and industrial growth. The example of Los Angeles, where the Metropolitan Area subsidised farmers to improve their irrigation systems to make more water available to the urban areas, could be worthwhile exploring in more detail.

The following issues need to be taken into account regarding the efficient use of water in the Vaal River System:

1. *Presently, the transfer volume for the implemented Lesotho Highlands Water Scheme is a fixed volume annually. Water use inefficiency in the Vaal catchment would impinge on the future availability of water in the Lower Orange River if further phases of the Lesotho Highlands Water Scheme need to be implemented as a result of higher water demand in the Vaal River System.*
2. *Deterioration of the water quality in the Vaal River and transfer of good quality water from the Senqu River may have a negative impact on the water quality below the Vaal/Orange confluence at Douglas. Although the operating rules on the Vaal River System strive to prevent spills from the Vaal River into the Orange River, the fixed transfer volumes in the upper catchments may create temporary spills.*

WATER DEMAND MANAGEMENT IN LORMS

The main focus of the study is the LORMS area with more emphasis along the Common Border downstream of 20^0 East Longitude. WDM initiatives in the catchment upstream of the Common Border were assessed from existing reports and information on the Vaal River and Orange River Systems upstream of the common border.

Reducing of River Operation Losses

The lowering of the river operation losses (270 Mm^3/a) is part of a separate component of the hydraulic modelling to determine the system yield. Reducing operation losses, is discussed in more detail in the Water Requirements Report, as well as the discussion of the system yield, and is not covered in this report.

Reducing of Conveyance Losses in Canals

According to the estimated net losses of 21.54 Mm^3/a (14.25%) the Orange/Riet Canal is a good candidate for a more detailed investigation by the Water User Association (WUA). It is not possible to quantify potential savings as part of this study due to a lack of more accurate information on the canal system.

Water Demand Management in Urban Areas

*The biggest potential to improve water use efficiency is in Oranjemund, Rosh Pinah and Alexander Bay. Residents in the towns get unmetered water free of charge that leads to wastage. The per capita water consumption is summarised in **Table 7.** It is suggested that a value of 350 ℓ/p/d be accepted as a norm.*

Table 7: Urban Water Consumption of Mining Towns

Consumer	Consumption (Mm^3/a)	Population	Consumption (l/p/d)
Oranjemund	6.45	5 451	3 239
Rosh Pinah Town	0.60	1 537	1 071
Alexander Bay Town	2.60	3 164	2 250

The following basic WDM instruments were identified as minimum requirements for implementation of WDM in Urban areas in the LORMS area:

- *Appropriate tariffs that enhance water conservation;*
- *Metering of water to all end users;*
- *Information and education of the water users;*
- *Regular water balances to establish non-revenue water with benchmarking;*
- *Good maintenance of reticulation and plumbing systems;*
- *Monitoring of night-flow measurement; and*
- *Pressure management.*

Water Demand Management in the Mining Sector

Most mines use water efficiently because they use high volumes of water and the total cost of water usage is relative high. Most mines in the Common Border Area (CBA) covered in the study have implemented various water saving measures.

To prevent future misuse of water in the mining industry in the common border area it is suggested that the following stipulations be made in permit applications and approvals:

- *mandatory recycling of water from slimes dams, including the minimisation of evaporation (paddock system) within one year after starting with production.*
- *metering and charging for water to households, no free water to residents in mining towns.*
- *strict application of water pollution criteria to prevent water pollution in the Orange River.*
- *strict adherence to closing down of mining activities to prevent negative effects pertaining to water pollution and use of land for irrigation purposes after termination of mining activities.*
- *If specific water intakes for the different types of mines are determined conservation tariffs could also be applied to the mines.*

Water Demand Management in the Irrigation Sector

The irrigation sector is the highest consumer of water in the LORMS area. The identified WDM initiatives concentrate on this sector since it has the biggest potential for savings. Except for irrigation scheduling in the Kimberley/Douglas area, it seems that very little progress has been made with the implementation of WDM in the Orange River System. The WUA in the Kimberley/Douglas area can serve as an example to other areas where satellite images are used to determine the extent of cash crop cultivation. The success is the result of the combined effort of the Department of Water Affairs and Forestry (DWAF), WUA, the Griekwaland West Cooperative and the local farmers. It shows what can be achieved through a partnership amongst all the role players.

Experience elsewhere in the world has demonstrated that WDM in the irrigation sector has been successful if the farmers benefited through the implementation. A good example is the "Water for Profit" scheme in Queensland (Australia) where farmers are supported by the Government to improve irrigation systems and farm management to save water and to increase crop production. With an investment of A$ 41 million by the Queensland Government, 180 Mm^3/a was saved and the value of crop yield improvement was A$ 280 million/annum. There are no similar examples documented in Southern Africa and the benefit to the farmers needs to be demonstrated before they will participate actively in WDM initiatives.

***Table 8** summarises the identified issues and expected timeframes that need to be addressed to realise WDM savings in the irrigation sector in the LORMS area.*

Table 8: Proposed actions to Improve Irrigation Water Use Efficiency

Water Authority (supplier)		
Timing	***WDM Measure***	***Expected Results***
Short-term *Immediate to five years*	***Support structures*** • *Establish WUA's in the common border area* • *Establish water use efficiency advisory group* • *Foster private sector involvement* • *Train farmers* ***Policies and control*** • *Volumetric allocation of water* • *Control abstraction through the metering of irrigation water* • *Develop and implement conservation orientated tariffs/rebates etc.* ***Technical & Planning*** • *Allocate quotas based on certified proper irrigation system planning on new schemes* • *Allocate quotas based on proper drainage systems on all schemes*	*Improved farm management and water productivity* *Estimated net water saving of 7%* *Higher water use efficiency & higher yields through water application & proper drainage*
Medium term *Five to ten years*	***Policies and Control*** • *Introduce water markets through legislative process* • *Introduce assurance-based supply mechanisms incorporated in the tariffs* ***Operational*** • *Lower conveyance losses*	*Would add more value to water consumed (R output/m³)* *Higher scheme water use efficiency*
Long term *Ten to fifteen years*	***Operational*** *Introduce demand-driven supply to canal based irrigation schemes*	*Higher crop yields*

Management of Farms		
Timing	***WDM Measure***	***Expected Results***
Short-term *Immediate to five years*	• *Acquire scheduling system* • *Increase financial returns/m³ (Ben, Is this a measure or a result?)* • *Improve maintenance of application systems, canals and storage facilities* • *Initiate proper drainage*	*7% net water saving. Higher value crops and higher crop yields /m³ water used.*
Medium term *Five to ten years*	• *Re-engineer existing irrigation systems* • *Install more efficient irrigation systems* • *Better matching of crops with climate, soil and water quality* • *Consider selling of water quotas*	*Net water savings up to 10.2% and increased crop yields.* *Lower uneconomic water uses.*
Long term *Ten to fifteen years*	• *Install more efficient irrigation systems* • *Cover soil to lower evaporation*	*Improve water use efficiency.*

It is suggested that the principle that WDM options in a specific country could only be used to satisfy requirements (instream flow requirements, increased demand, etc.) for the river system should be accepted. This implies that savings in the Orange River System may be used elsewhere in the system, like in the Eastern Cape, Vaal River System or in the Common Border Area. If the principle is accepted, an equitable share of water for Namibia cannot be dependent on the successful implementation of WDM upstream of the Common Border in South Africa.

The only way to implement certain of the WDM options like scheduling, where no capital investment or incentive is required, would be to lower the allocated irrigation quota, provided that the volume of water supplied could be measured accurately. Farmers may be very reluctant to invest in irrigation efficiency knowing that it would reduce their allocated quota and that savings would be utilised elsewhere in the Orange River System. If the developer (Government) carries the cost of scheduling and an improved irrigation system, and if the farmers get the benefits through improved yield, WDM initiatives will be successful ("Water for Profit").

Along the Common Border Area, both countries should strive for comparable levels of water use efficiency. If this desk study of the area upstream of the Common Border shows that the implementation of a specific WDM option is competitive, more detailed investigations will need to be done into the specific areas identified for improvement during the full Feasibility Study.

The potential saving in the Fish River in Namibia is limited to an estimated net saving of 7% through scheduling, and a further 7% net saving on the reduced consumption through tariffs and metering. Approximately 85% of all the irrigation fields are levelled through laser levelling, which limits future savings that could result from the installation of improved high technology irrigation systems.

*The figures in **Table 9** give a summary of what can be achieved through WDM initiatives, if implemented. The success of the measures will depend on:*

- *final conclusions after the yield modelling (reducing operation losses);*
- *clear policy guidelines pertaining to tariff policies and rebates;*
- *advice on scheduling; and*
- *training of farmers.*

Table 9: Summary of Expected Savings through WDM Initiatives

Activity and Location	Volume Mm³	Costs/ m³ saved (cent)	Remarks
Water Efficiency Unit *(Upington)*	*Unknown*	*Unknown*	*Improves water productivity.*
Scheduling* *Upstream Vanderkloof* *Downstream Vanderkloof* *Common border*	 *7.2* *63.9* *3.6*	 *6.95* *3.20* *10.24*	*Improves water productivity.* *7.0% net water saving* *5.0% net water saving* *3.5% net water saving*
Metering & Pricing* *Upstream Vanderkloof* *Downstream Vanderkloof* *Common border*	 *6.7* *84.3* *6.9*	 *5.13* *3.12* *2.88*	*Improves water productivity.* *7.0 % net water saving on the reduced consumption after the implementation of scheduling.*
Irrigation Systems* *Gifkloof/Neusberg*	 *53.4*	 *89.7*	*Improves water productivity by 24.1%.*
Conveyance losses *Orange Riet Canal*	 *Unknown*	 *Unknown*	 *Requires a detailed investigation.*
Urban *Oranjemund & Rosh Pinah* *Alexander Bay*	 *6.1* *Unknown*	 *0.37* *Unknown*	 *Lower water use.* *Water use to be verified.*
Mining	*Unknown*	*Unknown*	*Reuse to be controlled with permit conditions.*

** An allowance was made for 30% return flow in all the calculations to give net water savings*

The measuring of such improvements could also be difficult to quantify without detailed modelling because of variations in the climate and on-farm factors influencing efficiency. 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 for developing forecasting methods to support the evaluation of long-term and short-term demand management alternatives.

It was agreed, in consultation with the Client, to carry out a Pilot Study in the Neusberg/Gifkloof area covering a group of twenty farmers (10 progressive farmers and 10 average farmers, using flood irrigation) to get updated water consumption figures, improved crop yields and even higher value crop yields to compare actual figures with the estimated figures used in the report. The estimated cost for the Pilot Study, including the upgrading of 20 farms, amounts to R 11.33 million, including capital investments on participating farms.

The estimated costs for the establishment of a Water Efficiency Unit from Upington downstream, including the Common Border Area, 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.

The cost sharing could be based on the respective areas under irrigation in the two countries.

RECOMMENDATIONS

The following recommendations and time frames are proposed to improve Demand Management in the LORMS area:

It is recommended that:

1. *That a Pilot Study be carried out (January 2005 to December 2009), covering approximately 20 farms in the Neusberg/Gifkloof area to verify expected water savings, cost of such savings and improved crop yields for farmers before any major WDM initiative are implemented in the two targeted areas identified in this study. The benefits and costs of specialised advice to farmers (Water Use Efficiency Group), scheduling, metering and tariffs (rebates) and improved irrigation systems needs to be established for the two farmer groups.*

2. *The proposed measures and time table to improve water use efficiency for the irrigation sector as summarised below be accepted:*

Water Authority (supplier)		
Timing	**WDM Measure**	**Expected results**
Short-term Immediate to five years	**Support structures** • Establish WUA's in the common border area • Establish water use efficiency advisory group • Foster private sector involvement • Train farmers **Policies and control** • Volumetric allocation of water • Control abstraction through the metering of irrigation water • Develop and implement conservation orientated tariffs/rebates etc. **Technical & Planning** • Allocate quotas based on certified proper irrigation system planning on new schemes • Allocate quotas based on proper drainage systems on all schemes	Improved farm management and water productivity Estimated net water savings of 7% Higher water use efficiency and higher yields through water application and proper drainage

Water Authority (supplier)		
Timing	**WDM Measure**	**Expected results**
Medium term *Five to ten years*	***Policies and Control*** • *Introduce water markets through legislative process* • *Introduce assurance-based supply mechanisms incorporated in the tariffs* ***Operational*** • *Lower conveyance losses*	*Would add more value to water consumed (R output/m³)* *Higher scheme water use efficiency*
Long term *Ten to fifteen years*	***Operational*** • *Introduce demand-driven supply to canal based irrigation schemes*	*Higher crop yields*
Management of Farms		
Timing	**WDM Measure**	**Expected results**
Short-term *Immediate to five years*	• *Acquire scheduling system* • *Improve maintenance of application systems, canals and storage facilities* • *Initiate proper drainage*	*7% net water saving. Higher value crops and higher crop yields /m³ water used. Increasing financial returns/m³*
Medium term *Five to ten years*	• *Re-engineer existing irrigation systems* • *Install more efficient irrigation systems* • *Better matching of crops with climate, soil and water quality* • *Consider selling of water quotas*	*Net water savings up to 10.2% and increased crop yields.* *Uneconomic water uses would be lower.*
Long term *Ten to fifteen years*	• *Install more efficient irrigation systems* • *Cover soil to lower evaporation*	*Improve water use efficiency.*

3. *The principle that WDM options in a specific country can only be used to satisfy requirements (instream flow requirements, increased demand, etc.) for the whole river, and that allocation of an equitable share for Namibia cannot be linked to the successful implementation of WDM in South Africa be accepted.*

4. *The principle that both countries should strive for comparable levels of water use efficiency within the irrigation sector along the Common Border Area be accepted.*

5. *A Water Use Efficiency Group for the area downstream of Upington (similar crop types), including the Common Border Area, be established at an estimated initial cost of R 2.5 million (R 1.5 million recurrent costs) and that the cost be shared annually in accordance with the irrigation areas between the two countries.*

6. *The high estimated net losses of the Orange/Riet Canal be investigated in more detail during the full Feasibility Study in order to determine the viability of lowering conveyance losses.*

7. *A more detailed investigation be carried out for the Gifkloof/Neusberg area to determine the viability of improved irrigation systems as part of the main Feasibility Study.*

8. *The principles and guidelines as discussed in the report relating to metering and conservation tariffs be developed further for finalisation between the two countries.*

9. *Permit allocations for the mining towns of Oranjemund, Rosh Pinah and Alexander Bay (after verification) be reduced to lower the excessive water consumption to approximately 350 ℓ/p/d with the condition that end-consumers are metered, and that they pay for water consumed within the next three years.*

10. *The following basic WDM instruments be approved as minimum requirements for implementation of WDM in Urban areas in the LORMS area:*

    - *Appropriate tariffs that enhance water conservation;*
    - *Metering of water to all end users;*
    - *Information and education of the water users;*
    - *Regular water balances to establish non-revenue water with benchmarking;*
    - *Good maintenance of reticulation and plumbing system;*
    - *Monitoring of night-flow measurement; and*
    - *Pressure management.*

11. *The following stipulations be added to permit applications and approvals pertaining to water use efficiency in the 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, no free water to residents in mining towns except for baseline water (6 kℓ/household/month).*

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LIST OF ABBREVIATIONS

a	:	annum
Aug-Blou	:	Augrabies-Blouputs
BMP	:	Best Management Practice
Boegoe	:	Boegoeberg
c	:	cent
CBA	:	Common Border Area
CMA	:	Catchment Management Agency
DAC	:	Direct Allocatable Costs
d/s	:	downstream
DWA	:	Department of Water Affairs (Namibia)
DWAF	:	Department of Water Affairs and Forestry (RSA)
ECSA	:	Engineering Council of South Africa
EWMPs	:	Efficient Water Management Practices
FAO	:	Food and Agriculture Organisation
GIS	:	Geographical Information System
GPS	:	Geographical Planning System
ha	:	hectare
IRP	:	Integrated Resource Planning
IUCN	:	The World Conservation Union
LA	:	Los Angeles
ℓ/p/d	:	litre/person/day
ℓ/c/d	:	litre/capita/day
LHWP	:	Lesotho Highlands Water Project
LOR	:	Lower Orange River
LORMS	:	Lower Orange River Management Study
Mm^3	:	million cubic metres
NamWater	:	Namibian Water Corporation Ltd
NDI	:	Net Disposable Income
NSW	:	New South Wales
ORRS	:	Orange River Development Project Replanning Study
P-D	:	Prieska- Douglas
RPL	:	Recognition of Prior Learning
RSA	:	Republic of South Africa
RW	:	Rand Water
SAII	:	South African Irrigation Institute
SWI	:	Special Water Intake
u/s	:	upstream
Up-Keim	:	Upington-Keimoes
VDKL-HT	:	Vanderkloof-Hopetown
VRSAU	:	Vaal River System Analysis Update
WC	:	Water Conservation
WDM	:	Water Demand Management
WRC	:	Water Research Commission (South Africa)

WUA	:	Water User Association

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MAIN REPORT

1. INTRODUCTION

1.1 General

The Orange River has the largest river basin south of the Zambezi. It rises in the Drakensberg Mountains in Lesotho at an altitude of about 3 300 m, from where it flows to the west for approximately 2 200 km to the sea. From 20^0 E longitude westwards, it forms the nearly 600 km long international border between Namibia and South Africa. This Common Border Area (CBA) has an arid climate. Here, the Orange River passes through some of the most rugged and isolated terrain, but with fertile soils in narrow corridors along its banks. A map of the Orange River catchment is included as **Figure 1.1**.

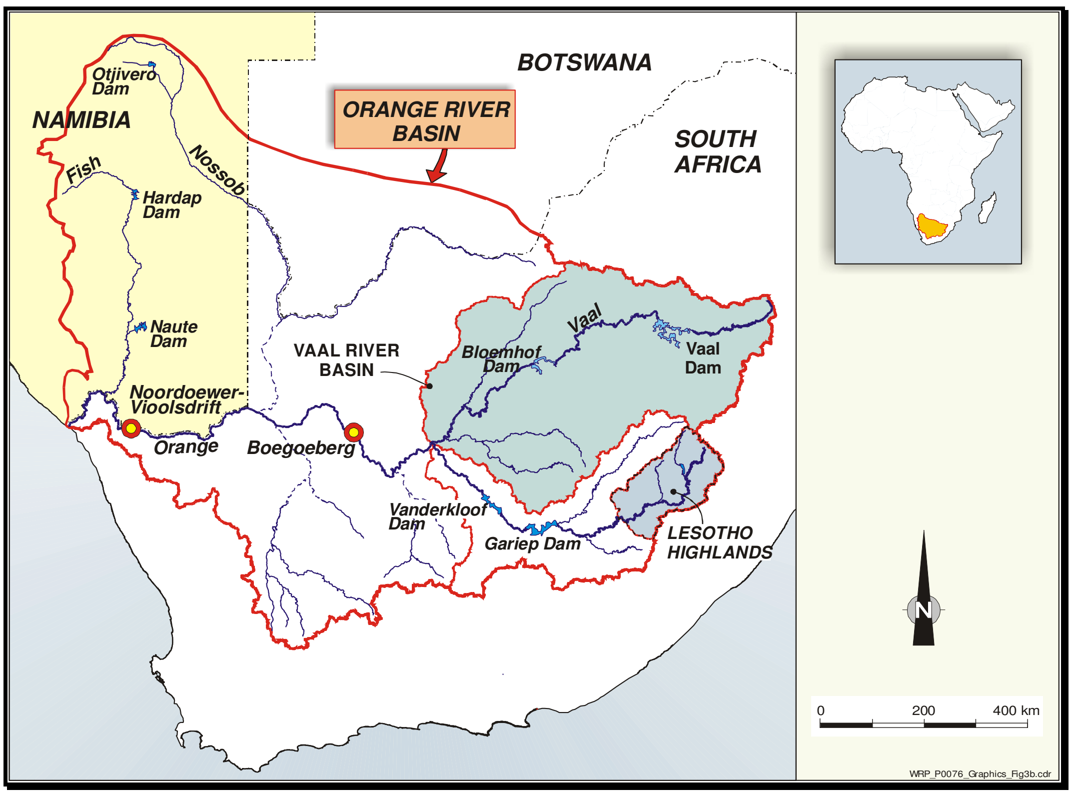

Figure 1.1: Orange River Basin

1.1.1 Runoff

It has been estimated that the natural runoff of the Orange River Basin is in the order of 11 300 Mm^3/a of which approximately 4 000 Mm^3/a originate in the Lesotho Highlands and approximately 800 Mm^3/a from the contributing catchment downstream of the Orange/Vaal confluence. The remaining 6 500 Mm^3/a originates from the areas contributing to the Vaal, Caledon, Kraai and Middle Orange Rivers (see **Figure 1.2**). 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 various downstream demands unless further storage is provided.

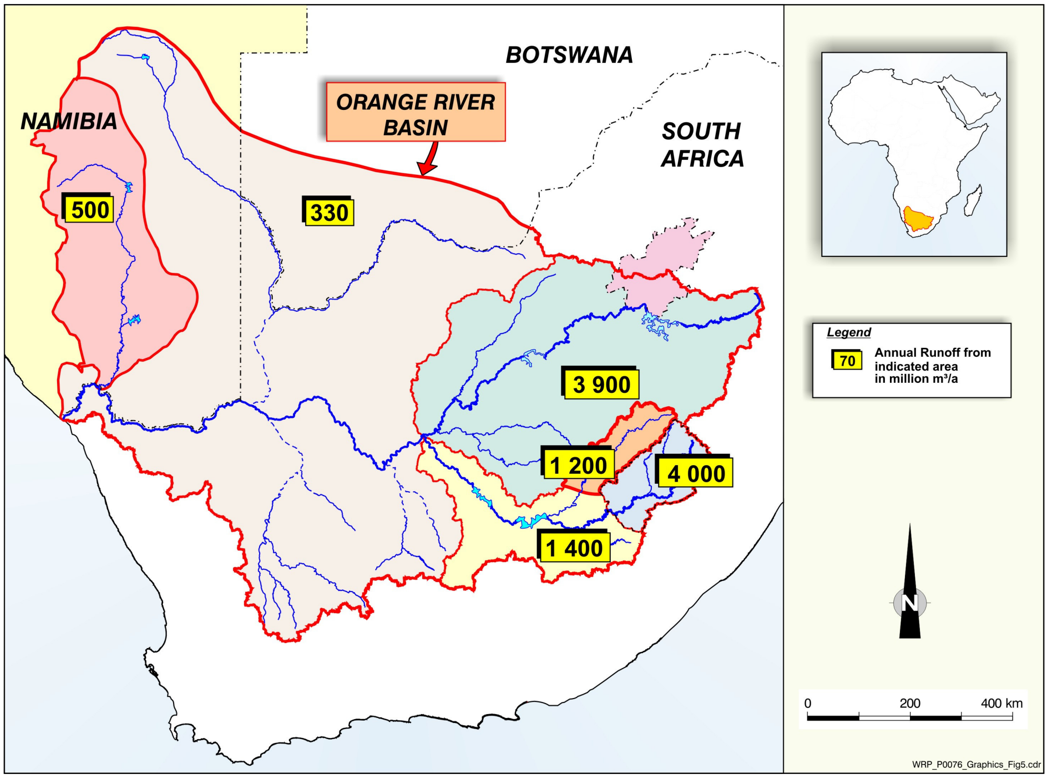

Figure 1.2: Sub-division of Areas of Natural Run-off in the Orange River Basin

Three important factors that will increase the water yield/use efficiency of the river system are:

- Storage in the Lower Orange to capture some of the 800 Mm^3 contributed by the catchment downstream of the Orange/Vaal confluence.
- Reduction of operating losses from the releases made at the Vanderkloof Dam.
- Water Demand Management (WDM) initiatives.

1.1.2 Major Demand Centres of the Orange River

In the report on the expected Water Requirements (LORMS), the major demand centres supplied from the Orange River System, are defined as:

1. Vaal River Catchment.
2. Eastern Cape (transfers through the Orange/Fish Tunnel).
3. Upper Orange River (upstream of the Vanderkloof Dam).

4. Lower Orange Upstream Area (Vanderkloof Dam to 20^0 E longitude).
5. CBA (Lower Orange, Downstream of 20^0 E longitude).
6. Fish River (Namibia).

The Lower Orange is further sub-divided into irrigation areas and main urban/industrial water use centres as indicated in **Figure 1.3**.

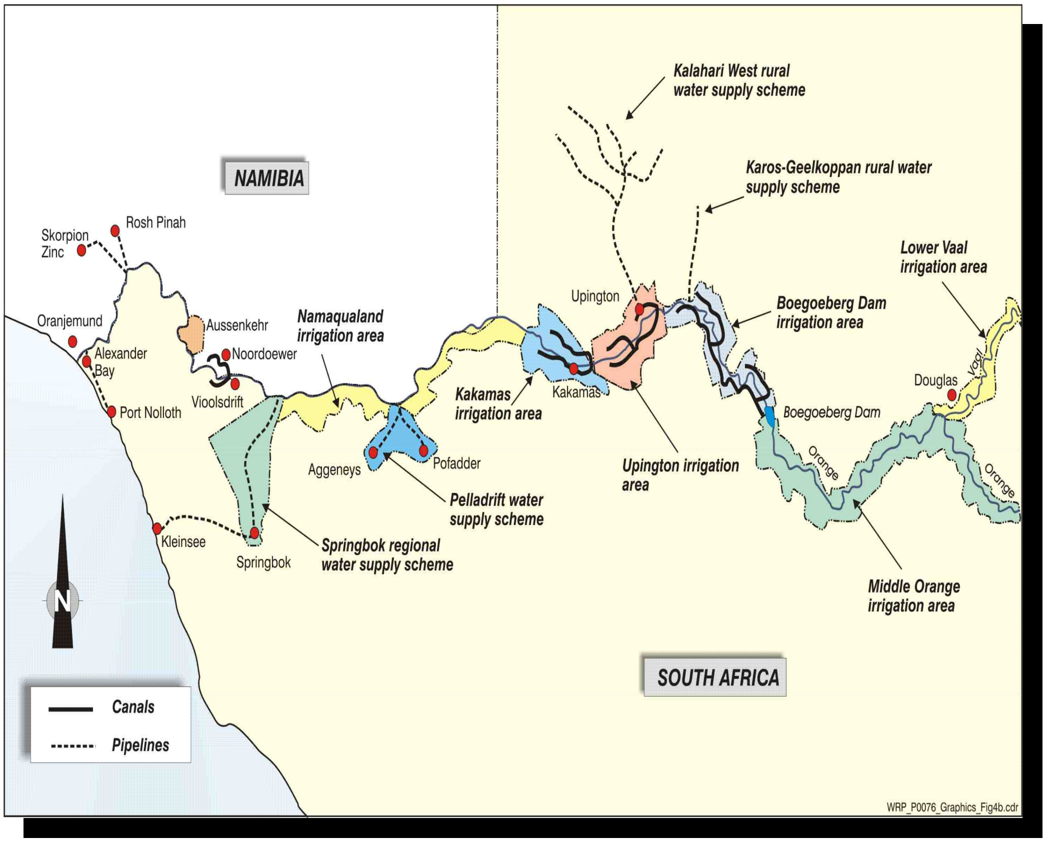

Figure 1.3: Irrigation Areas and other Water Use Centres along the Lower Orange River

The information processed and collected as part of the Water Requirements Study (LORMS) is used as input to quantify the effect of water conservation/water demand management (WC/WDM).

1.2 Objective of the Study

The objective of this study is to investigate measures to improve the availability of water along the Lower Orange River (LOR).

The options to be investigated as part of LORMS include both demand and supply side measures. This report focuses mainly on demand side measures that can be implemented to improve water use efficiency, especially in the irrigation sector. Improvement of water use efficiency in the irrigation sector can be measured through the change in water productivity i.e. crop yield/unit water used

The practical and financial viability of selected WDM options to improve the water use efficiency along the Orange River was assessed and the options prioritised. These options will be compared in the financial evaluation of the Lower Orange River Management Study (LORMS) with supply augmentation options and/or river control options. Although the reduction of operational losses in the Orange River can also be classified as a WDM activity, it is not discussed in detail in this report as it forms part of the river modelling exercise.

1.3 Purpose of this Report

The purpose of this report is to:

- assess the potential for improvement in water use efficiency and WDM, both in the upstream area and in the CBA;
- make recommendations for improved efficiency; and
- provide cost estimates to implement the identified measures.

Water demand forecasts compiled for the Water Requirements Report (LORMS) are summarised as background information.

Different consumer groups are as follows:

- Riverine requirements and operating losses.
- Urban/domestic and industrial/mining.
- Irrigation.

The potential savings through WDM were identified in accordance with the different demand centres with emphasis on the Orange River. An assessment was made, at a desktop level of detail, with respect to the following WDM aspects:

- Institutional requirements including private sector involvement.
- Flow measurement (urban and irrigation).
- Irrigation efficiency (scheduling, application systems and conveyance losses).
- Re-use of water by the mining sector.
- Other areas identified for improved efficiency and conservation.
- Current demand management practices.
- Effects that improved efficiencies may have on the availability of water.

A brief review was done of the Vaal River catchment and the Eastern Cape that receive water from the Orange River through the Lesotho Highlands Project and via the Orange-Fish Transfer System, respectively. The irrigation system efficiency and related factors along the Fish River in Namibia were also summarised.

Recommendations have been made with respect to the possible improvement of the points listed above.

2. METHODOLOGY

The main focus of the study is the LORMS area with more emphasis along the Common Border downstream of 20^0 East Longitude. WDM initiatives in the catchment upstream of the Common Border were assessed from existing reports/information on the Vaal River System and Orange River upstream of the Common Border.

2.1 Upstream of 20^0 E Longitude

For the purpose of this study, the area East of the Common Border, between the RSA and Namibia, was sub-divided into three main areas, the Vaal River catchment, the Eastern Cape area and the remaining Orange River catchment above the Common Border.

2.2 Downstream of 20^0 E Longitude (Common Border Area)

The area downstream of the Common Border was divided into the Orange River segment and the Fish River in Namibia.

2.3 Water Use Efficiency

2.3.1 Urban and Mining Water Use

The information on water consumption and water use efficiency for urban and mining consumers was collected through questionnaires and directly from bulk suppliers of water, both in South Africa and Namibia, where possible. The information was processed and verified for accuracy with information collected from other reports.

2.3.2 Irrigation Water Use

Various discussions were held with farmers along the CBA, as well as knowledgeable people in irrigation efficiency, both in South Africa and Namibia. In certain areas where there was a lack of detailed information in Southern Africa, international experiences were collected from literature.

The Consultants arranged a meeting in Kimberley where officials of the Department of Water Affairs and Forestry (DWAF) (Head Office, Northern Cape, Eastern Cape and Free State Regional Offices), Water User Associations (WUAs) and other key role players like the Douglas Cooperative, shared their views and knowledge.

The main objectives of the meeting can be summarised as follows:

- Provide the Regional Offices with background on the study and to share the perspectives from the Study Team with the DWAF representatives.
- Enable the Project Team (RSA & Namibian members) to better understand the current situation in the Lower and Upper Orange River water supply areas.
- Identify and discuss key success factors for WC/WDM options.
- Identify possible future actions that must take place for improved water use efficiency.

3. RIVER REQUIREMENTS AND OPERATION LOSSES

3.1 General

Losses from the Orange River System represent important "demands" that must be taken into account.

3.2 River Requirements

River requirements (losses as a result of evaporation directly from the water in the river, evapotranspiration from natural plant growth along the river and seepage) are described in detail in the Water Requirements Report (LORMS). For the purpose of this report, operation losses will only be discussed as a possible efficiency improvement alternative.

3.3 Operation Losses

Gariep and Vanderkloof Dams are used to support the demands along the LOR from Vanderkloof Dam to the Orange River mouth. These demand centres are located along a river length of approximately 1 380 km which, together with river requirements, and inflows from the Vaal and Fish rivers, contribute to the complexity of operating the system and determining how much water to release from Vanderkloof Dam. A further complication concerns releases from Vanderkloof Dam to generate hydropower, which are sometimes in excess of the downstream demands. The combined effect of all the releases contributes to the relatively high operation losses. In the study on the expected Water Requirements (LORMS), it was concluded that a realistic operation loss is 270 Mm^3/a. The operation losses in the Orange River can be regarded as a river conveyance loss, which can be reduced by better operation and the construction of more control structures in the Orange River.

3.4 Conveyance Losses in Canals

In the case of normal conveyance losses, the loss is expressed as a percentage of the upstream inflow to a specific system node and is generally used for canal losses and transfer losses in the system. Conveyance losses in canals are caused by leakage, seepage and evaporation losses. All the figures used in this report for conveyance losses are best estimates that were determined in consultation with DWAF personnel for the modelling exercise. The total conveyance losses are estimated at 88 Mm^3/annum for the Orange River downstream of the Vanderkloof Dam. A figure of similar magnitude may be lost in the Fish River in the Eastern Cape.

4. SUMMARY OF WATER REQUIREMENTS UPSTREAM OF 20^0 E LONGITUDE

4.1 Vaal River System

The total demand in the Vaal River System at the 2002-development level, is 3 065 Mm³/a with a total of 664 Mm³/a return-flow that flows back to the Vaal River System. The net system demand at the 2002-development level is therefore 2 401 Mm³/a and includes urban, industrial, mining and irrigation demands, as well as system losses. Approximately 230 Mm³/a of the return flows generated from the Rand Water supply area are returned to the Crocodile River catchment. The demand includes the total Vaal River System down to the confluence of the Vaal and the Riet Rivers. Demands within the Riet/Modder catchment are for the purpose of this study; included as part of the Orange River System as water from the Orange River is used to support demands in the Riet/Modder catchment.

The 2002 distribution of the Integrated Vaal River System Demand into various user groups is shown in **Figure 4.1**. From this figure, it can be seen that the urban/industrial user group represents 48% of the total demand and increases to 62% of the total demand if the large industries such as Sasol, ISCOR and ESKOM, are included.

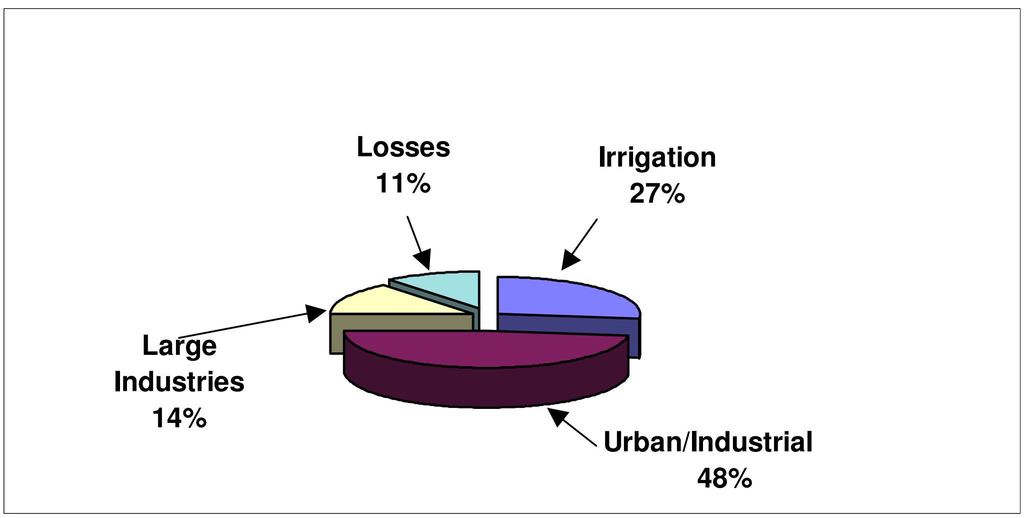

Figure 4.1: Distribution of the Integrated Vaal River System Demand

After discussions with the South African DWAF, it was decided to use two different demand projections for the Vaal River System, referred to as Scenario A and Scenario B. The scenarios are based on a demand forecast made by Rand Water (RW) in November 2001 (Scenario A), while Scenario B was adjusted for actual water consumption for 2000 (Scenario B). The demand projections for Scenario A and Scenario B are graphically compared in **Figure 4.2**. According to the latest annual update of the Vaal River System Demand in 2004, the water demand is expected to conform to Scenario B.

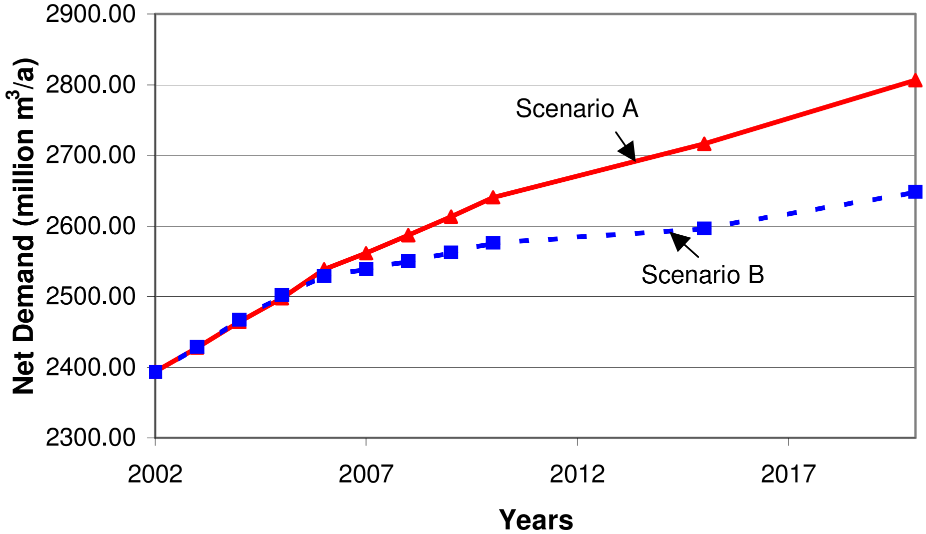

Figure 4.2: Integrated Vaal River System Demand Projections

4.2 Eastern Cape

4.2.1 Urban, Industrial and Mining

Transfers from Gariep Dam through the Orange/Fish tunnel are mainly utilised to support irrigation developments in the Eastern Cape, while the Port Elizabeth supply area gets approximately 20 Mm^3/a on average. The growth in urban demand would then be supplied from the development of local resources until 2020, where after further growth will be supplied from the Orange River Project. The Algoa Pre-feasibility Study, which was recently completed, showed that with WDM initiatives and the re-use of return flows, Port Elizabeth will not require augmentation before approximately 2017/18. According to the Water Requirements Report, it is expected that the water demand on the Orange River System will increase from 20 Mm^3/a to 41.3 Mm^3/a between 2020 to 2025.

Return flows from the urban/industrial areas in the Eastern Cape sub-system will not contribute to any flow in the Orange River System and are therefore not included.

4.2.2 Irrigation Water Requirement

The irrigation water requirement of the Eastern Cape is summarised in **Table 4.1**.

Table 4.1: Irrigation Water Requirements Eastern Cape (Orange/Fish Transfer)

River	River Reach	Scheduled Irrigation (ha)	Water Quota (m^3/ha/a)	Water Allocation (Mm^3/a)
Orange 6a	Orange/Fish transfer (Eastern Cape) Irrigation	19 329.9	13 500	260.95
6b	Orange/Fish transfer (Eastern Cape) Irrigation	14 732.6	12 500	184.16
6c	Orange/Fish transfer (Eastern Cape) Irrigation	15 980.5	9 000	143.82
6d	Orange/Fish transfer (Ciskei) Irrigation	1 470.0	12 500	18.38
	Sub-Total	**51 513.0**		**607.31**

Reliable information about irrigation return flows is not available. However, if the same conditions as for the Orange are also applicable here, 10% to 15% of the irrigation applied will be return flow. As a result of an additional 4 000 ha water allocation, it is expected that the irrigation water requirement will increase from 607 Mm^3/a to 651.3 Mm^3 by 2010 according to the demand projection in the Water Requirements Report. .

4.3 Orange River System

4.3.1 Urban, Industrial and Mining Water Requirements

A summary of the urban/industrial and mining water requirements demand is given in **Table 4.2**.

Table 4.2: Urban, Industrial and Mining Water Requirements for the Orange River Upstream of the Common Border

Description	Demand (Mm^3/a)					
	2000	2005	2010	2015	2020	2025
Area 1 Upstream of the Gariep Dam	67.0	77.5	86.6	95.6	103.5	111.3
Lesotho	(9.8)	(11.0)	(12.3)	(13.7)	(15.2)	(17.0)
Area 2 Gariep to Orange -Vaal confluence	5.4	5.6	5.9	6.2	6.5	6.8
Area 2 Orange Fish Transfer (Urban)	(18.5)	(20)	(20)	(20)	(20.0)	(41.3)
Area 3 Riet / Modder catchment	4.5	4.9	5.1	5.2	5.3	5.4
Area 4 Orange Vaal confluence to 20^0 Longitude	18.5	22.1	24.4	27.0	28.3	29.9
Total (excluding Eastern Cape & Lesotho)	**95.4**	**110.1**	**122.0**	**134.0**	**143.6**	**153.4**
Senqu/Vaal transfer (LHWP)	492.4	804.0	804.0	804.0	804.0	804.0
Total including Senqu/Vaal transfer	**587.8**	**914.1**	**926.0**	**838.0**	**947.6**	**957.4**

The figure for the Senqu/Vaal River transfer (LHWP) in **Table 4.2** is in accordance with the Treaty between South Africa and Lesotho.

4.3.2 Irrigation Water Requirements

A summary of the irrigation water requirements for 2002 is given in **Table 4.3**. The figures provided are in accordance with the registration information.

Table 4.3: Present Allocation of the Irrigation Sector in the Orange River Upstream of the Common Border

River reach no.	River	River Reach	Scheduled Irrigation (ha)	Water Quota ($m^3/ha/a$)	Water Allocations (Mm^3/a)
1& 2	Caledon	Welbedacht Dam u/s Gariep	6 215.1*	7 620	47.3
3& 4	Orange	u/s Aliwal North, d/s Aliwal North	4 134.3	8 000	33.1
5	Kraai	u/s Aliwal North	See table 4.4 for diffuse irrigation		
6	Orange	u/s Vanderkloof, d/s Gariep Dam	1 990.5	11 000	21.9
7	Orange	Canals from Vanderkloof Dam	17 803.8	11 000	195.8
8	Orange	Vanderkloof Dam + Riet River	4 583.6	11 000	50.4
9	Orange	Vanderkloof to Marksdrift	15 545	11 000 & 10 000	166.1
10	Modder	u/s Tweerivier, d/s Krugersdrift	3 499.3	8 130&8 640	29.4
11	Riet	u/s Kalkfontein, d/s Tierpoort	708.0	9 000	6.4
12	Riet	u/s Riet River Settl, d/s Kalkfontein	3 046.3	11 000	33.5
13	Vaal	Harts-Vaal Conf/Douglas			
14	Vaal	Douglas weir to Orange-Vaal confl,	8 608.0	9 140	78.7
15	Orange	Marksdrift to Boegoeberg	15 434.0	10 000	154.3
16	Orange	Boegoeberg to Gifkloof weir	9 804.0	15 000	147.1
17	Orange	Gifkloof weir to Neusberg	15 563.6	15 000	233.5
18	Orange	Neusberg - Namibian border (20° E)	11 571.9	15 000	173.6
		TOTAL*	**119 566.4**		**1 371.1**

* This figure exclude a 1 150 ha irrigation area in Lesotho and the water transfers to the Eastern Cape.

There are also diffuse irrigation developments upstream of the major dams to which no specific allocation was given. These irrigation areas are private developments and are therefore not supported by any of the major dams. These irrigators obtain water directly from the river (mainly tributaries), as well as from farm dams on the tributaries. These irrigation developments are usually referred to as diffuse irrigation and a summary of the current development (2002) is given in **Table 4.4**.

Table 4.4: Diffuse Irrigation Developments

Description	Annual Requirement (Mm^3/a)
Total for Upper and Middle Orange River	397.3

4.3.3 Urban, Industrial & Mining Return Flows

Urban and industrial return flows in the Orange River System are minimal compared to the irrigation return flows. Only the return flows from the major consumers in the catchment were therefore included and summarised in **Table 4.5**.

Table 4.5: Urban/Industrial Return Flows in the Orange River Upstream of the Common Border

Description	Return Flow (Mm³/a)					
	2000	2005	2010	2015	2020	2025
Botshabelo - High Projection	4.8	6.3	8.1	9.8	11.6	13.5
Botshabelo - Most Probable Projection	4.9	6.5	8.2	9.9	11.5	13.1
Bloemfontein - High Projection	22.4	26.2	30.7	35.2	41.2	47.1
Bloemfontein - Most Probable Projection	21.5	24.3	26.3	28.2	29.6	31.0
Thaba Nchu - High Projection	1.6	1.9	2.3	2.6	3.2	3.8
Thaba Nchu - Most Probable Projection	1.5	1.6	1.6	1.7	1.7	1.6
Upington - High Projection	4.5	5.8	6.7	7.7	8.4	9.2
Upington - Most Probable Projection	4.5	5.6	6.2	6.9	7.1	7.4
Upington - Low Projection	4.5	4.9	5.5	6.0	6.5	7.0

The bulk of the return flows from Bloemfontein are used for irrigation purposes. The volume of the Bloemfontein return flows, which do enter the main river system, is unknown.

4.3.4 Irrigation Return Flows

Substantial volumes of water from irrigation, urban and industrial developments are returned to streams and are then available for re-use. Based on the updated demands as used in this study, the return flows from the irrigated areas and relevant canal distribution systems from the Orange River are estimated as 224 million m³/a. This excludes the Vaal River, Fish/Sundays (Eastern Cape) and the Fish River in Namibia.

5. SUMMARY OF WATER REQUIREMENTS ALONG THE COMMON BORDER AND FISH RIVER (NAMIBIA)

This chapter is a brief summary of the combined current water demands and future demand projections of both countries, as summarised in the Water Requirements Report (LORMS).

5.1 Water Demand in the Common Border Area

Table 5.1 presents the current demand (2002) along the LOR. The Human Reserve (baseline water consumption for communities) is included in the domestic demand.

Table 5.1: Combined Water Demand for Namibia and South Africa along the Common Border Area (2002)

Consumer Category	Namibia		South Africa		Total	
	Mm³/a	% NAM	Mm³/a	% RSA	Mm³/a	% Total
Irrigation	40.55	78.4	61.72	77.5	102.27	25.8
Urban/Domestic	7.12	13.8	14.80	18.6	23.93	6.0
Mining/Industrial	2.01	3.9				
River losses [1]					264.60	66.8
Conveyance losses[2]	2.03	3.9	3.09	3.9	5.12	1.3
TOTAL	**51.71**		**79.61**		**395.92[3]**	

Notes:

1: River requirements along the Common Border.

2: Most of the irrigation water is pumped directly from the river into pressurised systems where leakages influence irrigation efficiency. The conveyance losses are estimated at approximately 5% of irrigation use, which include possible canal losses, pipeline breaks, backwashing of filters, etc. Accurate figures are not available.

3: The total operation losses from Vanderkloof Dam to the river mouth are 270 Mm^3/a and are not included in the Table.

The expected future water demand for irrigation is summarised in **Table 5.2**.

Table 5.2: Combined Water Demand Projections for Namibia and South Africa in the Common Border Area

Consumer Category	2002 (Mm³/a)		2005 (Mm³/a)		2010 (Mm³/a)		2015 (Mm³/a)		2020 (Mm³/a)		2025 (Mm³/a)	
	NAM	RSA	NAM	RSA	NAM	RSA	NAM	RSA	NAM	RSA	NAM	RSA
Irrigation	40.6	61.7	58.4	72.5	102.8	90.6	150.0	108.7	196.5	121.7	226.7	121.7
Urban/Domestic	7.1	14.8	8.5	16.6	8.7	23.0	9.0	23.7	9.4	21.9	9.5	22.7
Mining/Industrial	2.0		7.3		22.5		37.7		38.0		38.2	
TOTAL	**49.7**	**76.5**	**75.5**	**89.1**	**134.0**	**113.6**	**196.7**	**132.4**	**243.9**	**143.6**	**274.4**	**144.4**

5.2 Fish River Namibia

Table 5.3 presents the current water demand (2001) for the Fish River in Namibia.

Table 5.3: Total Current Demand from the Fish River (Namibia)

Consumer Category	Consumption (Mm³/a)
Irrigation	46.34
Urban / Industrial	2.72
TOTAL	**49.06**

The medium water demand scenario is summarised in **Table 5.4.**

Table 5.4: Water Demand Requirements for the Fish River (Namibia)

Consumer Category	2001 (Mm³/a)	2005 (Mm³/a)	2010 (Mm³/a)	2015 (Mm³/a)	2020 (Mm³/a)	2025 (Mm³/a)
Irrigation	46.4	48.0	48.0	48.0	48.0	48.0
Urban / Industrial	2,7	2,9	3,0	3,1	3,2	3,3
TOTAL	**49.1**	**50.9**	**51.0**	**51.1**	**51.2**	**51.3**

6. BACKGROUND ON WATER CONSERVATION AND DEMAND MANAGEMENT

6.1 Introduction

Water Conservation is defined as: *"The minimisation of loss or waste, the preservation, care and protection of water resources and the efficient and effective use of water"* (DWAF, RSA 1999).

Water Demand Management is defined as: *"Measures that improve efficiency by reducing water use or altering patterns of water use after abstraction".* (Van der Merwe, 2001).

Examples of demand management include conservation-oriented pricing, water-efficient irrigation, scheduling, changes in water use practices, efficient distribution systems, water-fixture plumbing standards, retrofitting and public education

Integrated Resource Planning (IRP) is defined as: "*A process for determining the appropriate mix of demand-side and supply-side resources, which is expected to provide long-term, reliable service to utility customers at the lowest reasonable cost and which maximises benefits to the society. This will require considerations of the impacts of various resource management options on water prices, system reliability, financial stability of the water utility, environmental quality, security of sources, economic development, water use efficiency, social equity and other social goals deemed important by government policy makers. The IRP process should identify and assess the various demand- and supply-side options available to utilities and outline a flexible plan for fulfilling the country's water needs".* (Van der Merwe, 2001)

Most of the water in the Orange River catchment is used upstream of the CBA. Most previous investigations did not try and quantify potential savings upstream of the Common Border through WDM. Although the detailed investigation of WDM upstream of the Common Border is not the main purpose of this report, savings upstream of the Common Border make water available for other uses, in-stream flow requirements and possible shortages in the whole Orange River System.

6.2 Urban and Industrial

Water use in the Urban and Industrial sector is very low (less than 10%) in the LORMS area. WDM in urban areas is well documented and there are several good examples within the Southern African region. The Water Services Act (Act No. 108 of 1997) and the Draft Model Bylaws (August 2000) in South Africa cover many of these requirements. In Namibia, WDM initiatives in urban areas depend mainly on initiatives from a few local authorities.

The following basic WDM instruments were identified as minimum requirements for implementation of WDM in urban areas in the LORMS area:

- Appropriate tariffs that enhance WC.
- Metering of water to all end users.
- Information and education of the water users.
- Regular water balances to establish non-revenue water with benchmarking.
- Good maintenance of reticulation and plumbing systems.
- Monitoring of nightflow measurement.
- Pressure management

6.3 International and Local Perspectives on Irrigation Efficiency

The agricultural sector uses more than 92% of the consumptive demand (excluding river requirements and environmental requirements) in the LORMS area upstream of the Common Border. This excludes volumes of water transferred to the Eastern Cape and the Vaal River. Along the Common Border area, approximately 81% of the water is used for irrigation in both countries. The discussion on WDM will concentrate mainly on the irrigation sector. The major water demand and expected increase in future water demand occurs in this sector in the LORMS area, especially along the Common Border.

The irrigation sector is not highly regarded in water management circles. There are perceptions, amongst others, that:

- the majority of farmers do not "schedule";
- water supplies are not well managed;
- distribution losses are high;
- existing systems, both on-scheme and on-farm, are not well maintained;
- few farmers are concerned about actual crop irrigation requirements;
- water wastage is excessive;
- water management has a low priority; and
- irrigation should be reserved mainly for "high value" crops.

"These are universal perceptions that are not only confined to Southern Africa, and may or may not be justified. In most developed countries, our competitors in global markets are taking active steps to improve irrigation farming effectiveness and water use efficiency. In most developing countries, including Southern Africa, very little support is given by Central Governments to improve irrigation farming practices and water use efficiency. There are, of course, individual outstanding exceptions, but they remain exceptions." (Crosby, 2001).

According to the final draft document for WC and WDM in the Agricultural Sector (DWAF, February 2001 Version), water losses of between 30 and 40% occur. Irrigation losses are often quite significant and it is estimated that less than 60% of water abstracted from water resources, is correctly placed in the root systems of plants. Approximately 35% of irrigation system losses return to the river systems by overland flow and return seepage. In certain areas, this return water can be nutrient enriched and polluted with herbicides, pesticides and other pollutants that could affect the water quality of rivers and streams.

Most of the above statements are general statements and are based on perceptions. In many cases they may be true of individual farmers or even river catchments. Along the Common Border between Namibia and South Africa there is a tendency to develop high value crops with advanced and efficient irrigation systems.

According to Seregelden (1999) the irrigation efficiency of the world needs to be improved from approximately 40 to 70% within the next twenty-five years to prevent food shortages. It is expected that the total water allocation to irrigation will drop from 70% of the total water consumption to 56%, as a result of growth in industrial consumption. (Headlines in Brief, Efficiency is the Key to Irrigation Crises. World Water and Environmental Engineering, August 1999).

In the World Conservation Union (IUCN Water Demand Management Country Study (South Africa) on farm management practices, Haasbroek and Harris (1999) reported that there is an acute need to improve irrigation management practices.

The following are necessary:

- **Irrigation scheduling:** Irrigation scheduling is the application of the correct amount of water at the correct time, considering all relevant factors. Over-irrigation is often a problem, mainly out of fear of applying too little water, and the lack of knowledge and expertise by the irrigator in scientific irrigation scheduling.
- **Proper irrigation system operation and maintenance:** Wear and tear and the improper use of a system (not using it exactly for what it was designed for) account for much of the inefficiency. Knowledge of the different types of irrigation systems available must be made available to farmers, as well as guidelines to choose the system most suited to their specific needs, and also to advice on replacement or upgrading.
- **Research:** Research is needed into more affordable irrigation systems and measures to make the technology more widely available.
- **Technical and educational support to farmers:** Establish technical and educational support services for irrigators.

Irrigation farmers do not have appropriate technical support to assist them in their operations. Any concerted effort to improve water efficiency should automatically include major funding for technical support services and farmer education. Incentives are also needed to promote greater WC and efficient application of irrigation water. Some examples are subsidies or loans to fund WUAs' water-loss control or irrigation scheduling programmes.

The concern of the South African Government (DWAF) and water users for WDM is evident from the number of initiatives already in place, or activities that will serve as forerunners to provide information for further valuable guidelines in this regard.

Initiatives already in place are mostly related to water measurement. Most of the pressurized systems (managed by WUAs or Irrigation Boards) have no other alternative than to use water meters and flow control devices to ensure the proper functioning of the system. The reason being that the sizing of the balancing dams, pumps and pipe lines was done according to a fixed annual volume, as well as a fixed flow rate that needs to be maintained at all times. In most cases, the meters are read on a monthly basis. Should a user be permitted to exceed his/her quota, the user has to pay for the additional water used (often at a penalty rate). There are many thousands of hectares being irrigated under these conditions throughout the country.

Among the initiatives already being practiced and which are covered in this report, include:

- WDM "tools" already developed, and which are promoted in the irrigation industry are the SAPWAT and WAS programs. Successful implementation of these tools are already in place, and ongoing awareness programs are conducted by DWAF and the Water Research Commission (WRC).
- A number of WDM related WRC projects have been completed in recent years. DWAF and the WRC are continuously encouraging the irrigation industry to apply the outcomes of these studies.
- WRC is presently running a number of research projects, which will impact on WDM. Two very relevant projects in this regard are:
    - Project K5/1265//4: The application of flow meters in irrigation water management.
    - Project K5/1137//4: The investigation of the range and distribution of irrigation scheduling models in South Africa in general, with specific reference to the application of selected models.

- The 3 DWAF pilot projects initiated to test the implementation of the WC/WDM strategy.
- Various feasibility studies throughout South Africa are presently being undertaken by consultants for DWAF, or are being planned, to upgrade old systems (mainly canal systems) in order to make these systems more efficient.

From observations made during the field visit to the CBA and following discussions held with leading practitioners in irrigation, it is clear that the financial benefits of WC have been the most significant incentives for implementation of WDM in irrigation. Depending on the crop type, markets and water supply costs, such benefits may include any of the following:

- improved yields;
- improved quality of produce, especially for the export markets which pay large premiums for quality;
- reduced water consumption and pumping costs; and
- easier management, especially with automated systems (although these require more skilled management - there is little margin for error, and therefore risks are higher).

6.4 Key requirements for the Successful Implementation of Water Demand Management in the Irrigation Sector

The following issues were identified for the successful implementation of WDM in the irrigation sector after a literature study on successes in Southern Africa and internationally. These requirements were selected during workshops held in Kimberley and Windhoek (Consultants only), as well as during various discussions with experts in irrigation farming and irrigation efficiency. The summary should be seen as listing the most important issues that need to be addressed to improve water use efficiency in the irrigation sector in the LORMS area.

Institutional Requirements

- Establishing WUAs for involvement of farmers in water use efficiency. (Joint WUA across borders).
- Establishing a Water User Efficiency Group.
- Training of farmers, applied research, collection, processing and dissemination of information.
- Fostering private-sector involvement for dissemination of efficient technologies, information etc.
- Tariffs: Reducing irrigation subsidies and/or introducing conservation-orientated pricing. Using tariffs as an incentive, including rebates for efficiency improvement.
- Metering of water directly or indirectly.
- Establishing a legal framework for efficient and equitable water markets.
- Lowering conveyance losses.
- Improving canal operations for timely delivery. Changing supply driven systems to demand driven systems (subject to canal design flow restrictions). Flexibility should replace rigidity.

Technical and Planning requirements

- Selecting the correct water application system.
- Leaching requirements with efficient irrigation systems, including the design and installation of proper drainage systems.

Improved Management on Farms

- Better irrigation scheduling. Propagate ‘Dipstick method’.
- Better maintenance of canals and equipment (line canals/dams).
- Improved irrigation efficiency over time (upgrading).
- Improved drainage and prevention of over watering resulting in loss of fertiliser, increased in diseases and high water tables.
- Better matching of crops to climate conditions, soil conditions and the quality of water available.
- Covering of soil to lower evaporation losses.

7. WATER DEMAND MANAGEMENT IN THE IRRIGATION SECTOR

7.1 Introduction

Irrigation is by far the largest water user in the Orange River. Irrigation water use is classified as consumptive use of water with very little or no return flow in cases of best irrigation practices. This Chapter concentrates mainly on improving of water use efficiency in the irrigation sector. Many of the key issues that have been identified are universal and applicable to the irrigation sector irrespective of the location of the activity.

Where appropriate, some examples within the LORMS area are discussed. Some of the initiatives will not necessarily reduce the water consumption, but will improve management and the water productivity index through higher crop yields.

7.2 Measurement of Improved Water Use Efficiency and Higher Crop Yields

To improve productivity in irrigation and to measure such improvement can be a daunting task due to the large number of variables like average temperatures, wind, rainfall, proper scheduling, application of fertiliser, presence of pests etc., which influence the actual water consumption. Crop water requirements can be calculated accurately through available methods, but the biggest challenge is to apply the water effectively and efficiently. The efficiency improvements are normally measured over a period of time through trends. There are methods to normalise the effect of weather changes through time series analyses. Accurate data over a period of at least 5 years is needed with exact water uses. To develop reliable figures over a period of time would be a major task.

The following indicators can be useful in such an evaluation:

Water Productivity (more crop/drop)

It is suggested that the change in water productivity be assessed on a regular basis to measure the success of WDM initiatives. Water productivity can be calculated by comparison of the percentage crop yield improvement/ha/a versus the percentage the total water consumption/ha/a.

Other Productivity Indexes

Other indexes like net disposable income (NDI) per m^3 of water applied (**Section 10.5**), job opportunities and other economic indexes are covered in **Chapter 5** of the **Water Requirements Report**, (LORMS). These factors should preferably be calculated for each crop for specific regions with similar climatic conditions.

7.3 Support Structures

Support structures are needed to create an enabling environment for farmers to increase water use efficiency and increase crop yields i.e., water productivity, as well as economic efficiency.

7.3.1 Establishing Water User Associations in the Common Border Area

For the successful implementation of WDM on irrigation schemes, a local agent or association is needed to further the cause of water use efficiency. For the successful implementation of WDM in irrigation, it is important that farmers should have regular contact, communication and direct support.

According to the South African Water Act, the WUAs were identified as the agents to implement and co-ordinate irrigation water use efficiency. WUAs are co-operative associations of individual water users who wish to undertake water-related activities at a local level to their mutual benefit. They operate in terms of a formal constitution and are expected to be financially self-supporting with income from water use charges paid by members. A WUA falls under the authority of the Catchment Management Agency (CMA) in whose area it operates.

In Namibia, the White Paper for the proposed new Water Act makes provision for the management of water supply schemes at the lowest possible level, as well as for the establishment of CMAs. The Draft Act (Version 7, Dated August 2002) makes provision for a Water Advisory Council that will advise the Minister of Water Affairs on the allocation of quotas, etc. It also states that Irrigation Boards (Act 56) will not exist after the Water Advisory Council is formed. It is assumed that the CMA will control irrigation. It is not clear how the CMA would handle the local management of irrigation schemes.

It is suggested that one or more cross border WUAs or similar organisations should be established in the CBA to facilitate the operation of schemes and water use efficiency in irrigation. Schemes, where direct pumping from the river takes place, should be included in the WUAs.

7.3.2 Establishing a Water Use Efficiency Unit.

According to the South African Water Act, the WUAs will be at the heart of agriculture's water use efficiency initiatives. It is noteworthy that WUAs are expected to present comprehensive water management plans annually that incorporate water audits of past performance and future projections. They are also expected to identify and formulate Best Management Practices (BMPs) and bench-marking procedures.

Neither the Department of Agriculture, nor the Department of Water Affairs, has the mandate, funding or trained personnel to assist the WUAs in achieving these goals. Their only recourse is to use Consultants, but these are few in number and tend to have specialised expertise.

A Water Use Efficiency Unit, established in 1999 in Dubbo (New South Wales), is unique in many respects and may be worth studying. It is a joint initiative of the New South Wales (NSW) equivalent of the Department of Agriculture and DWAF in South Africa. It is administered by the Department of Agriculture, but has personnel from both departments and is jointly funded. It plays a key role in the delivery of the agricultural components of the NSW WC strategy. The Unit is accepted as being a well-informed neutral source of unbiased information and advice. The value of a neutral professional group of this nature, to both departmental management and to the stakeholders involved in difficult negotiations, cannot be over estimated. The Unit is assisting irrigators to identify and move towards higher water use efficiency, and increase the value of irrigated agricultural production to the State, (Crosby, 2001).

The Water Use Efficiency Unit should play an important role in the collection and processing of data from irrigators on crop yields, actual water use, as well as detailed weather data. This is required to measure efficiency improvement over time. The collection of more detailed information to quantify and calculate economic indicators may be added to the list of required data.

The Water Use Efficiency Unit should also help to identify tasks in consultation with farmers for greater private sector involvement (**Section 7.3.3**) and co-ordinate the training of farmers (**Section 7.3.4**).

One of the tasks of WUAs will be to assist irrigators to identify and move towards higher water use efficiency, and to increase the value of irrigated agricultural production. To assist the WUAs in the execution of their tasks, it is suggested that a Water Use Efficiency Unit be established for the area downstream of Upington, including the CBA. The irrigation crops grown along the Orange River downstream of Upington are similar to crops grown in the CBA.

7.3.3 Fostering Private-sector Involvement

Effective management of land and water resources requires growers to be familiar with the resources on the farm, and to plan for the use of these resources. The core BMP for land and water management is to develop a plan that describes the resources of the farm, and how these are to be used sustainably. This type of plan is often called an irrigation and drainage management plan.

A good example of this can be taken from a guidelines booklet developed in Australia for the growing of cotton. Essentially, what is provided, is a comprehensive guide to cotton production, including irrigation and water management. People with scientific knowledge and a wealth of practical experience wrote the guidelines, **(Appendix A, Section A.9).**

It is recommended that the possibility of developing similar manuals for Southern Africa, covering the main commodities, should be assessed and this should include in-depth irrigation guidelines for specific types of crop.

7.3.4 Training of Farmers

In New South Wales, the transfer of knowledge and training of farmers is actively pursued. This training is part of the "Water Wise on the Farm" programme, an education and awareness programme that promotes the adoption of best irrigation management practices and technologies. Water Wise on the Farm aims to provide farmers with basic irrigation skills. The course program consists of four workshops:

- Assessing your soil and water resources;
- Evaluating your irrigation system;
- Scheduling and benchmarking; and
- Irrigation and drainage management planning.

The complete program should require about 18 hours of attendance spread over four workshop sessions and about 8 hours of the farmer's time assessing the soils and irrigation system on his own property.

The training follows the modern pattern of competency-based training and the courses are aligned to *National Competency Standards.* Those successfully completing the course can seek *Recognition of Prior Learning* (RPL) towards formal qualifications in Agriculture or Horticulture.

Each of the nine regions in New South Wales has a technical irrigation specialist and a training specialist who run the courses in the districts. The course material is outstanding and includes training manuals, detailed course notes and related practical exercises, as well as complete competency specifications and evaluation procedures. All usual irrigation methods are catered for, but only one irrigation method is dealt with in a course. The courses are aimed at farmers and the instructor has ample opportunity to pass on his own field experience.

Nothing like this exists in Southern Africa. The courses are generic in that they are as applicable to Southern Africa as they are to NSW. There would probably be no objection to using the information that obviously represents many months of preparation, but this will only be effective in conjunction with appropriate infrastructure and manpower. It is possible that this could become a private sector initiative**.** (Crosby, 2001)

If water use efficiency in the irrigation sector is pursued, training and transfer of knowledge will be an important component. This is especially applicable to new farmers that may enter the market. At least some of the expense for training will have to come from government. It is unlikely that the local communities will be able to absorb the full cost. The implementation of tax rebates for training or even a subsidy based on a 50% contribution to the cost of training from both countries in the CBA would create an enabling environment.

7.4 Institutional Policies and Control

Without clear policies with proper regulating and control structures over the execution of these policies/guidelines, it would be difficult to improve water use efficiency in the irrigation sector. Many of these policies or guidelines (mandatory metering and cost recovery tariffs) are covered in the legislation or draft legislation of both South Africa and Namibia.

7.4.1 Metering of Irrigation Water

Measurement of water is important for linking of a price to a volume of water consumed. Measurement is also an important management instrument on the farm for proper scheduling. In both South Africa and Namibia, measurement of irrigation water seems to be problematic. None of the irrigation schemes (LORMS) are charged according to actual consumption based on metered water. The quota system (area x volume) or indirect methods of measurement are used. In canal systems, volumes are determined, based on a certain flow rate over a pre-determined allocated number of hours. Implementation of WDM, including conservation orientated tariffs, without accurate measurement would be difficult as it would be impossible to measure efficiency improvements.

The following problems are experienced with irrigation water meters:

- high initial capital costs;
- high maintenance costs;
- vandalism and meter tampering;
- high cost of reading water meters regularly in remote locations; and

- meters are not robust enough.

The WDM (South Africa) strategy and implementation guidelines for irrigation are currently being tested through three pilot studies on the development of water management plans for the Gamtoos, Orange-Riet and Orange-Vaal WUAs. The Water Management Plans that will be the results of the project should reflect the current and expected future water demand, as well as proposed WC measures. At all three WUAs, water measurement is considered to be of fundamental importance for water management, but the cost of providing and installing the necessary infrastructure causes concern amongst the farmers, as well as the water management staff.

In 2001, the WRC initiated a three-year study to develop guidelines for the choice, installation and maintenance of water measurement devices by the WUAs for canal, pipeline and river distribution systems (WRC project no. K5/1265). The guidelines will be valuable for the implementation of metering within the irrigation sector.

It is the measurement of individual abstractions that poses the greatest problem for measurement and control. Extensive experimentation by WUAs has been done in the Kimberley/Douglas areas and the WRC has established monthly water use patterns for every individual crop that a farmer may want to grow in the area. Based on these figures and individual production plans, each farmer applies to the WUA for water prior to the beginning of the first growth season, of which there are two annually, through specifying the planned crop types and planted areas. In the month preceding harvesting, in both growing seasons, the WUA does crop auditing of the individual farmers by means of a Geographical Information System (GIS), remote sensing and Geographical Planning System (GPS) mapping.

Measurement at remote locations along the CBA may be problematic due to relatively small irrigation areas over long distances with access problems along some stretches. Ideally, flow should be measured, because payment per m^3 of water used enhances water use efficiency, especially when WC tariffs are applied.

In the CBA where mostly high value crops are grown, the cost of water itself is minimal compared to total operational costs, excluding labour. The cost of water represents only 1.5% of the operational costs in some cases, whilst the cost of electricity used for pumping, fertiliser, pest control, labour, marketing and transport to international markets are the biggest cost components. An informed farmer will not over irrigate and pay more for electricity, wash fertiliser from the soil, create a good micro-environment for pests and create high water tables with drainage problems. Despite the high costs, there are uninformed farmers with sophisticated irrigation systems who over irrigate in the CBA.

The indirect methods (satellite imaging, farm inspections) used in the Kimberley/Douglas area will only work if all the farmers are well informed and there are proper controls and advisory services to determine more accurate water requirements. The substitutes for direct volumetric metering can be a useful interim management aid, but could not be used to implement conservation orientated tariffs.

There is a saying ***"To measure is to know"***. The farmer, the WUA and the bulk supplier will benefit from more accurate information.

To implement metering, the following guidelines are suggested:

- Approved water meters should be installed on all new schemes as part of the development cost of the irrigation scheme. (The outcome of the WRC Study may provide useful information.)
- The WUA should pay for the installation of meters on existing irrigation schemes after the guidelines of the WRC are available.
- The replacement and maintenance cost of meters should be included in the water tariff as a fixed monthly fee payable to the WUA or the distribution authority.
- Maintenance should perhaps be privatised to a contractor.
- Farmers could read water meters themselves and phone, fax or e-mail the reading to the WUA, while the WUAs could do spot checks on a regular basis during the year.
- Farmers should be responsible for protecting water meters against vandalism and meter tampering.

7.4.2 Tariffs

The principle of cost recovery of water supply is accepted in both countries, provided that baseline water should be made available to everybody. In both countries, prices are based on historic costs. This creates the false illusion that future water resources will cost the same as resources developed in the past. This provides the wrong price signal to consumers and leads to over-consumption. In the past, water agencies have largely ignored the possibilities of influencing demand, i.e. demand can be lowered, as prices alter demand. Prices can be used intentionally to alter the water demand.

Given the theoretical goal of economic efficiency, Beecher and Chesnutt (1998) define conservation oriented water tariff structures as follows:
"Simply stated, a conservation-oriented rate structure encourages efficient water use and discourages waste by ensuring that customer bills communicate the full cost of providing water services, including the cost of new supplies. From a more technical perspective, conservation-oriented rates reflect marginal-cost pricing principles and resource efficiency goals."

If this definition of conservation tariffs is accepted, then it is clear that the supply of water without measurement (i.e. irrigation water) and rising block tariffs not linked to marginal cost (or the financial cost of future schemes) do not qualify as conservation tariffs.

Introduction of two-step tariffs in irrigation water, can lead to major savings in overall water demand and improved water use efficiency. Despite the fact that the price of irrigation water is very low, major savings can be realised if irrigators are sensitised about their water use as they will not want to pay a punitive tariff that could be as much as 2.5 times higher than the normal tariff, (Hanemann, 1999).

Water should be priced and managed as a volume. The present system does amount to a volume estimate (area x quota), but expressing water allocation in terms of volume and managing it as such could "fix" the idea of a volume of water. This implies the measuring of water, which is a problem at present due to the high cost of measuring devices and problems of reliability and lack of ruggedness of some meters.

Selling water at a higher price will result in the farmer feeling/seeing the effect of inefficiency in his bank balance, but one must be careful how it is applied. The cost of water for farmers who pump water is higher than for those that receive "gravity" water from a canal. For each and every farmer, the total cost of water must still be affordable. This approach could impact negatively on newly settled farmers or farmers that invest to improve irrigation efficiency, unless some special arrangement be made for them through a rebate system.

If the development of high value perennial crops along the CBA at high costs (R 300 000 to 350 000 per ha) is actively promoted, the issue of linking a tariff to the level of security of supply needs to be resolved. There are two ways to recover this cost, i.e.:

- A higher tariff linked to the higher security of supply; or
- A higher tariff that will be payable during periods of water shortages.

The latter method, where the prices are higher during scarcity, is more linked to market forces where the price is higher in times of a shortage. It may also help to stabilise the income of the supply authority during periods of shortage. Security of supply is covered in the Water Requirements Report of the LORMS.

7.4.3 Establishing a Legal Framework for Efficient and Equitable Water Markets

Water markets are based on the principle that rights to use water can be sold to third parties. This is an important allocation instrument for economic efficiency when properly controlled. The requirements for successful water markets are summarised in **Appendix A.10.**

In the Los Angeles (LA) Metropolitan Area, the cheapest option to augment the water supply was to improve the irrigation systems and water distribution canals of private farmers. The higher water use efficiency on the irrigation schemes made surplus water available to the LA Metropolitan Area, Haneman (1999).

A case study was recently conducted along the LOR in South Africa on the development of a market for the trading of water rights. Water rights in areas with high cost related to irrigation (“outer land” water rights) were sold to areas in the LOR. The market started because of a scarcity of water rights in the LOR, as well as a large number of willing sellers and the increasing demand for water rights for the growing of table grapes. The transactions were regulated by DWAF and led to the use of water for high value crops, (Armitage *et al* 1999).

In Israel, water is re-allocated from agriculture to industrial use during periods of water shortage and drought. Farmers are then reimbursed for losses as a result of such a re-allocation of water.

The requirements for a successful implementation of water markets, if properly controlled, are all met in the LORMS area. The following issues need to be finalised on an international level between Namibia and South Africa for the CBA:

- The transfer of water rights between the countries on a permanent basis, if allowed.
- The transfer of water rights on a seasonal basis to protect perennial high value crops.
- The control of such transfers if allowed.

The view of the Consultant is that permanent transfers should not be allowed unless there is an agreement between the countries to use the water on a short-term basis (say 5 years), if one of the neighbouring countries cannot utilise its allocation. Seasonal transfer of water rights is supported, provided that it is properly controlled and that such allocations are accepted and administrated by the controlling authority.

7.5 Operation Efficiency of Bulk Supply Schemes

7.5.1 Conveyance Losses in Canals

Conveyance losses are the normal transmission losses expressed as a percentage of the upstream inflow to a specific system node and are generally used for canal losses and transfer losses. The information in **Table 7.1** was summarised from the Water Requirements Report (LORMS). The estimated canal losses (gross) above 5 Mm^3 are summarised in **Table 7.1** for the Upper Orange River, while for the CBA, all the estimated losses are indicated.

Table 7.1: Estimated Canal Losses in the Orange River System

River Reach		Estimated Canal Losses (Mm^3/a)	Estimated Return Flow (Mm^3/a)	Estimated Net Canal Loss (Mm^3/a)	Net losses as % of the Canal Input
No	Description				
7a	Ramah and Vanderkloof Canal.	11.03	6.62	4.41	6.00
7b,c,d	Orange Riet Canal	22.67	1.13	21.54	14.25
8b	Lower Riet	6.35	0.32	6.03	14.25
9a,b.c	Modder River Scheme	12.11	4.42	7.69	24.00
12	Kalkfontein Scheme	5.91	3.55	2.36	6.00
14a,b	Douglas Weir and river	11.75	3.53	8.22	10.50
16a	Boegoeberg Canal	20.01	12.00	8.01	6.00
17a,b	Upington Canal	17.45	10.47	6.98	6.00
17c	Keimoes Canal	13.47	8.08	5.39	6.00
18a,b	Kakamas Canal	10.05	6.03	4.02	4.00
Common Border Area					
21a	Vioolsdrif South	1.59	0.95	0.64	6.00
21b	Vioolsdrif North	1.01	0.60	0.41	6.00
21c	Aussenkehr	1.45	0.87	0.58	6.00

All the figures are best estimates that were determined in consultation with DWAF personnel for the modelling exercise and may be subjective as all the canals after 16a are estimated at 6%. The Boegoeberg Canal is very old, but the net losses are only estimated at 6%. Losses of 6% on unlined earth canals seem to be unrealistic for Keimoes.

As far as can be ascertained, no detailed investigation was done to determine seepage, evaporation losses and leakages on canals. This information is very important to determine possible efficiency improvements through canal rehabilitation. No cost figures could be obtained for remedial work on canals linked to a specific figure of leakage reduction. At Vioolsdrif/Noordoewer, there are areas where irrigation fields adjacent to the canal show signs of saturation. The hidden costs of areas with lower crop yields as a result of water saturation were not mentioned in any of the reports on canal rehabilitation.

7.5.2 Improving Canal Operations

Delivery of the required volume of water at the time when it is required by crops has a major effect on the actual crop yields. If crop yields could be increased without an increased total water requirement, the water productivity index improves. If canal systems are operated on water demand requests, the system is more organised and more conservation orientated than the rotational delivery system. Irrigators cannot abstract water at will, as the irrigator must submit a written request on a regular basis, normally weekly. The capacity of the canals is not sufficient to transport water for all the irrigators simultaneously. Furthermore, it takes several hours for water being released at the source to reach the users and therefore the management of the scheme has to evaluate all requests, calculate the quantity of the release and determine the dates, times and volumes of the release to each irrigator.

A good example is in the Kimberley/Douglas area where the main aim of the WUA is to improve the service to their Clients and to reduce the tail water losses from the canal back to the river. The WUA has to pay for the water that is diverted into the canal, which is a good incentive to reduce losses on the canal and reduce tail water spills. To optimise systems further, will require more automation and even enlarged systems to cater for higher peaks or more on-site storage to match the peak demand with irrigation requirements. The lowering of tail water losses (in most cases the tail water returns to the river) through better canal operation will not make more water available in the Orange River System. The biggest benefit of flexible regulation in a canal will be higher yields to farmers, because water will be available when required within the volume/time constraints of a specific canal system. In most canals, the system was designed for constant flow that requires storage by farmers to enable irrigation in peak demand periods.

7.6 Technical and Planning Requirements

7.6.1 Selection of the Correct Irrigation System

The selection of the correct irrigation system is influenced by various factors that include capital costs, operation costs, crop type, soil type, topography, climatic conditions, water quality and availability of labour. During the site visit to the CBA, various irrigation systems were observed on new schemes. It was obvious that some of the newly installed systems may not be the optimum solution for the prevailing circumstances along the CBA. It was also mentioned by some farmers that they had to change from one system to another at very high costs. Variations in design efficiency also contribute significantly to the ranges experienced in irrigation efficiency.

In the ORRS Report, it was suggested that new irrigation schemes, and old schemes being up-graded or renovated, be designed and developed professionally by trained and experienced personnel. Designers should be South African Irrigation Institute (SAII) approved members or registered by the Engineering Council of South Africa (ECSA). This will not guarantee that the system will be of the best design, but it may help to set standards.

Institutions in both countries could help to set a certain standard. The above suggestion could be enforced in the permit conditions. Collection of information and distribution of such information on the performance and problems experienced with different systems could form part of the guidelines as recommended in **Section 7.2.3** for different crop types along the CBA.

7.6.2 Leaching Requirements and Proper Drainage Systems

Soil quality, irrigation systems, water quality, as well as the salt tolerance of the plants influence leaching requirements. All irrigation water contains salts, which accumulate in the soil over a period of time. Their removal, before harmful effects set in, is important. The extra water required in such a way becomes drainage water and is not considered wasteful as it is performing a vital function and re-enters the system as return flow, with the likelihood of further downstream utilisation. Over-irrigation is much in evidence with flood irrigation - in most cases sufficient to obviate additional leaching.

There are various places in the LORMS area, especially in the floodplain areas where high water tables are present, mainly as a result of over irrigation or inadequate drainage systems. With more advanced irrigation systems like drip irrigation or micro irrigation systems, and with proper scheduling, an allowance should be made to flush the salts from the soil once or twice a year, depending on local circumstances. It is estimated that 10 to 15% additional water requirements will be needed for leaching in the CBA. With saline soils in new developments in the CBA, it can be anticipated that the initial water requirement will be higher in order to condition the soil by leaching out excessive salts.

It was clear at several sites visited along the CBA, that even new developments do not have proper drainage systems. It was also clear that irrigation fields irrigated at higher elevations cause drainage problems to lower lying farmers. This was evident at Aussenkehr.

Leaching requirements and proper drainage systems need to be taken into account with quota allocations and approval of new developments along the CBA. These irrigation areas should be identified and if the problems are not rectified within a stipulated period, abstraction permits should be withdrawn.

7.7 Improved Management on Farms

7.7.1 Better Irrigation Scheduling

Irrigation scheduling should ensure that crops are supplied with just sufficient water to obtain optimum yield and, where applicable, the desired quality. In Southern Africa, the number of farmers that actually use "scheduling", is confined to the limited group producing high value crops and applying intensive irrigation methods. Generally speaking, however, the indications are that scheduling is the exception rather than the rule in the Orange River System. Evidence of this is the widespread high water-table problem in many of the areas within the Orange River System. Atmospheric evaporative demand fluctuates violently from day to day, quite impossible to map or follow, but over a week or a month this smoothes out and, unless there are exceptional weather systems, seasonal variations are not so great.

It has been found in South Africa that it is possible to irrigate according to a pre-season programme that can even go as far as justifying equal applications weekly, right throughout the growing season. The empirical computer model BEWAB enables pre-season programmes to be drawn up and has produced exceptional results in the extensive area where it was developed. All that is required of the farmer is to keep a record of the depth of irrigation water applied on a weekly basis and to correct if the depth applied is not in line with the programme. In the case of sprinkler and center pivot systems, a rain gauge is placed in the field and read weekly. In addition, the soil profile water content should be checked periodically for major deviations, using an appropriate method.

The 'Dipstick Method' that was developed and implemented in the Kimberley/Douglas area is ideal for duplication in other areas. It was established that cost savings on water, fertiliser and pesticides is much higher than the cost of implementing and maintaining the system. Unfortunately, no detailed studies have been done to date to quantify actual water savings.

Haarhoff (2001) summarised the benefits of scheduling as follows:

- Better absorption of fertiliser by plants;
- Prevent saturation of soil and high water tables;
- Save water costs and pumping costs;
- Prevent soil becoming more dense;
- Improved product quality;
- Improved yield; and
- Prevent certain crop diseases.

The SAPWAT program was used extensively to develop crop coefficients that are well suited to specific cropping circumstances. The so-called "Dipstick Method" used in the area can serve as a good example for duplication in other major irrigation areas and in areas where high value crops are cultivated.

Scheduling through the "Dipstick Method"

Rain can present a problem but in the more arid areas the pre-season programme is set-up in terms of "water in the rain gauge", irrigation or rainwater. A methodology, nick-named "dipstick", has been developed to a fine art in the semi-arid area along the Orange River by the Griekwaland West Co-operative and this year is mandatory over an area of some 30 000 hectare of centre pivot wheat cultivation. The Cooperative develops the crop factors for a range of crop varieties and planting dates, a task simplified by the application of the FAO (Food and Agriculture Organisation) four-stage crop factor curve as built into SAPWAT. The pre-season programmes can also be set up in accordance with various irrigation methods and application strategies by running these scenarios on SAPWAT or if warranted on SWB. Each week during the season the Cooperative calculates the water use for each cultivar, variety and planting date utilising the Penman Monteith reference evaporation calculated from an automatic weather station and the matching crop factor. This is sent to farmers by e-mail, fax or telephone. The farmer can see immediately if the demand during the past week was as targeted or above or below, and can make minor adjustments to irrigation application depths during the coming week to compensate. Nobody tells the farmer to add so many mm of water. That decision is left to him.

It is important that the water content of the profile be checked periodically, just as one needs to check the oil level of an engine, and hence the name of the neutron probe service provided by the Cooperative viz. "dipstick". Before commencing this service, the technicians of the Cooperative determine the water release curve of the soil and the farmer is regularly provided with a table and graph indicating the progressive "oil level" throughout the season.

The costs for the service provided to farmers is summarised in **Table 7.2**.

Table 7.2: Cost of Griekwaland West Co-operative Scheduling Service to Farmers

Amount of Blocks @ 15 Measurements	Total Cost (VAT excl) (R)	Cost per Block (R)	Cost/ha with 40 ha Block (R)	Cost per Ton @ 6 Ton/ha (R)
5	5 371.35	1 074.27	26.87	4.48
10	6 804.15	680.42	17.01	2.84
15	8 237.10	549.14	13.73	2.29
20	9 670.05	483.50	12.09	2.02

The costs in **Table 7.2** give an indication of the cost of the service for specific crop types and are mainly for centre pivot irrigation systems. The approach can be adapted for other irrigation schemes. It should be kept in mind that there is also a benefit of scale (30 000 ha was scheduled in 2002) in the Kimberley/Douglas area where large irrigation areas are found at one location.

Costs per mm Water as given by the Rietrivier Scheme (quota 11 000m^3/a):

Water costs:	R 0.86 per mm/ha/year
Electricity:	R 0.68 per mm/ha/year
Total costs as given per mm water:	R 1.54 per mm/ha/year

It is clear that the cost to provide the service is very low relative to possible gains such as water savings and increased crop yield. The required savings in water to pay the total cost of the services are 2 to 4% of the total water requirement. The other benefits that accrue to the farmer such as higher yields, lower fertiliser cost, lower pesticides were unfortunately not quantified.

It is estimated that even informed farmers without the aid of weather information, updated soil moisture content and continuous plant water requirements, irrigate approximately 15% more than necessary. Various practitioners in the irrigation sector in South Africa and Namibia agreed that savings of approximately 15% could be achieved through improved management and proper scheduling. (Personal communication Bennie 1999, De Wet 2003.) It was not possible to get any confirmed figures determined through actual measurement for Southern Africa. During a meeting of the consultants and personnel of DWAF (South Africa) and DWA (Namibia) in Kimberley, it was agreed that a figure of 10% is achievable.

In a study done by the University of California (1996), it was determined that, through scientific scheduling, net savings of 13% were realised in California. The average crop yield increase was 8%. Due to a lack of more accurate information for Southern Africa, it is recommended that for the LORMS, a conservative figure of 10% (less 30% return flow) be accepted for water savings with an estimated crop yield increase of 8%.

7.7.2 Improved Irrigation Efficiency

There is much scope within the LORMS area to improve the efficiency of the prevailing irrigation application systems, with a considerable associated water saving. Inefficiency stems largely from irrigation systems not being appropriate for the local conditions, or not managed to accommodate specific local constraints.

Table 7.3 shows different types of irrigation systems for the SAII's suggested efficiencies, as well as the typical cost of the systems per hectare. These costs are based on 35 hectare units. These costs are average costs and without detailed investigations on individual farms, more accurate figures cannot be determined. The installation or upgrading will depend entirely on cost benefit analyses. It will not pay at all to upgrade irrigation systems to the best technology without training of farmers, proper scheduling, proper maintenance and increasing the value of crops grown.

Table 7.3: Efficiencies and Costs of Various Types of Irrigation Systems

Irrigation System	Design Efficiency	Capital Costs (R/ha)
Flood: Furrow	65	5 600
Flood: Border	60	7 600
Flood: Basin	75	8 100
Sprinkler: Dragline	75	10 700
Sprinkler: Quick-coupling	75	9 700
Sprinkler: Permanent	85	14 900
Sprinkler: Hop-along	75	11 700
Sprinkler: Big gun	70	8 700
Sprinkler: side-roll	75	11 500
Sprinkler: Boom	75	8 700
Sprinkler: Travelling gun	75	9 400
Sprinkler: Travelling boom	80	10 000
Sprinkler: Centre pivot	85	18 700
Sprinkler: Linear	85	30 000
Sprinkler: Micro sprinkler	85	15 700
Micro: Spray	90	23 000
Micro: Drip	95	20 000

Note: Prices are based on 35 ha units and provide for 1 000 m supply line, pumps, filtration, automated control and installation.

It should be kept in mind that the irrigation efficiencies are further influenced by the following factors:

- A Distribution Uniformity Factor is applied (normally 0.85) to minimise the adverse effects of poor irrigation distribution when aiming for high production/yield targets.
- Conveyance losses will also influence the final efficiency of application.

Surface irrigation systems are notoriously inefficient, mostly due to the lack of management opportunity to fine-tune them. The application problems associated with surface irrigation are inadequate flow-rates, excessively long beds, uneven beds, soils with low water-holding capacity and layered soils associated with riverine deposits. Management of surface irrigation schemes must be of high quality. The ranges of efficiency values within which certain current systems actually operate are at less than 40% efficiency. However, where conditions are correct (soil type, bed shape, slope, flow rate) and levelling has been undertaken accurately (using laser-controlled equipment), surface irrigation systems have been measured to be more than 90% efficient with proper management.

Usually, one or two factors would be dominant. For example, soils may be too light or the terrain too broken for surface systems or insufficient labour may have been available for conventional sprinkler irrigation. In some circumstances, potential crop returns may have been sufficiently high to warrant drip irrigation, where water could be saved and plant diseases and weed problems minimised. In other circumstances, economic pressures may have made the most suitable irrigation system unaffordable. There are many situations in the LORMS area where change from one system to another is desirable, but for various reasons, often linked to the prevailing growing of low-value crops, very low water tariffs, such change cannot be economically justified.

Vineyards planted within the flood plain of the Orange River remain on basin irrigation systems, whereas plantings out of the flood-plain are predominantly irrigated by drip and micro-jet, as the expensive micro-systems are vulnerable to flood damage. Planting vineyards under micro-irrigation on slopes away from the river can only be justified by the high value of the table-grape crop. Other crops have not been grown there in the past because of the high pumping costs.

It is foreseen that drip or micro-systems will be used predominantly with new developments in the CBA for the cultivation of high value crops because of the high cost of pumping water to higher elevations.

According to studies done in the USA, Israel, Spain, India and other countries, a change from flood irrigation to drip irrigation reduced the water requirement by 30 to 70% with crop yield increases of 20 to 90% for different types of crop. Unfortunately, for the higher figures quoted for water savings (India), the reduction in seepage and tail water was not quantified. In Israel, irrigation efficiency improvement (drip systems) over a period of 15 years resulted in a reduction of 37% in water use (8 200 to 5 200 m^3/ha/a), while the yield increase was threefold and the crop values increased tenfold. (Postel, 1999).

Most of these figures are based on average figures and may differ significantly on different farms depending on soil and climatic conditions. The improvement in crop yield is mostly realised by applying the required water needs of a plant at a specific time to get the best absorption by the plant. Most of the advanced systems like drip or micro irrigation can apply water and fertiliser daily or even a few times a day (sandy soils) if required. With flood irrigation and other less advanced irrigation systems, this is practically impossible.

It was not possible to get figures on crop yield increases based on research in Southern Africa, though the general feeling among practitioners are that significant yield increases are experienced when converting to a more sophisticated irrigation system. For the purpose of LORMS, the SAPWAT program was used to calculate yield losses due to increased irrigation application intervals. For maize on a light soil, e.g. compared to a 2-day irrigation cycle (center pivot), it estimates a reduction in yield of 11% if a 7-day is used, or 18% if a 10-day cycle is used. These calculations were done for a number of crops and locations, and it is suggested that estimated yield increases be limited to a maximum of 7.5%.

7.7.3 Better Maintenance of Equipment

The summary below was made from the ORRS Report.

In-field systems for water distribution can contribute significantly to losses, with unlined furrows/canals and storage dams being the worst culprits. Unlined furrows are mostly associated with flood irrigation. Such furrows may lead directly from the bulk distribution turnout, or may only occur as tertiary canals or header lines. The length of the on-farm earthen furrows is important with regard to seepage losses, as this is directly related to overall water/soil contact area. Many systems comprise a short canal leading to an on-farm 'night storage' dam. From the night storage dam, water is gravitated out to the irrigation lands through furrows, or piped under pressure - where a sprinkler system is installed. Evaporation from on-farm canals and dams is considered to be small compared to the water losses from the more extensive bulk water distribution systems along the Orange River.

Replacement of un-lined tertiary and header canals and night storage dams must be seen as an important strategy for water saving in the Orange River System. Cost will be an important factor – as lining is expensive. There are, however, a number of less costly seepage reduction methods available. These include replacing header furrows with gated pipes or lay-flat tube and partial sealing of earthen furrows with cement stabilised soil mixes or bentonite. Special low-pressure pipelines, designed for sewage/drainage, may be used as the principal tertiary distribution system. Whilst more expensive than 'partial lining' techniques, such pipes have the added advantage of better control of water, and they obviate tail-end losses.

In the CBA, it is expected that most of the water used for high value crops will be through pumping systems and pressure irrigation. In this case, pump efficiency and wear and tear on the moving parts need to be closely monitored to ensure efficiency over time. Maintenance of micro and drip irrigation systems will also require special attention, because it will influence the potential of the crop yields. There is a tendency to develop new schemes without proper preventative maintenance. Farmers need to be sensitised to the importance of proper maintenance. This may be another opportunity for private sector involvement.

7.7.4 Better Matching of Crops

There is a concern in the CBA that everybody wants to get his/her fair share of the lucrative export market. Farmers need to be aware of changing water quality over time that may damage crops. Crops should be selected to get the best benefit from climatic conditions, soil conditions and the quality of water available. The awareness of new cultivars with higher production rates, higher water use efficiency (more crop/drop) and higher value per m^3 water used should be propagated in all irrigation areas.

7.7.5 Covering of Soil to Stop Evaporation

The average rainfall varies from approximately 100mm/a at 20^0 East longitude to less than 50 mm/a west of Aussenkehr. The evaporation decreases from 3 400 mm/a in the east (20^0 East longitude) to approximately 2 500 mm/a along the coast. At Aussenkehr, the evaporation losses is approximately 2 900mm/a. The CBA falls in a region where evaporation losses are more than 30 times the average annual rainfall.

Mulch is normally a layer of inert material covering the soil surface around plants to reduce evaporation losses. Mulches can be organic materials such as pine bark, compost and woodchips; or inorganic materials, such as lava rock, limestone or permeable plastic, not sheet plastic. Good mulch conserves water by reducing moisture evaporation from the soil. Mulch also reduces weed populations, prevents soil compaction and keeps soil temperatures more moderate.

The use of mulch is a widely applied practice in Southern Africa. In countries with low rainfall and high evaporation, mulch is used intensively to protect the surface areas of soil from evaporation. In Israel, where crops are grown in similar desert conditions, soil is covered with plastic strips manufactured to reduce evaporation losses from the surface area. The use of underground drip irrigation also reduces evaporation losses.

7.8 Summary of Identified Water Demand Management Initiatives

Table 7.4 and **Table 7.5** provide a summary and a time framework for the different initiatives identified in the report. The time indicates when the initiative should start. Most of the actions should be continuous and should not be stopped after the expected time indication. The proposed short-term measures can be implemented simultaneous with the Pilot Study, as discussed in **Section 10.5.6.**

Table 7.4: Proposed Institutional actions to Improve Irrigation Water Use Efficiency

Water Authority (supplier)		
Timing	**WDM Measure**	**Expected Results**
Short-term Immediate to five years	**Support structures** • Establish WUA's in the common border area • Establish water use efficiency advisory group • Foster private sector involvement • Train farmers **Policies and control** • Volumetric allocation of water • Control abstraction through the metering of irrigation water • Develop and implement conservation orientated tariffs/rebates etc. **Technical & Planning** • Allocate quotas based on certified proper irrigation system planning on new schemes • Allocate quotas based on proper drainage systems on all schemes	Improved farm management and water productivity Estimated savings of 7% in net water consumption. Higher water use efficiency and higher yields through water application and proper drainage
Medium term Five to ten years	**Policies and Control** • Introduce water markets through legislative process • Introduce assurance-based supply mechanisms incorporated in the tariffs **Operational** • Lower conveyance losses	Would add more value to water consumed (R output/m^3) Higher scheme water use efficiency
Long term Ten to fifteen years	**Operational** • Introduce demand-driven supply to canal based irrigation schemes	Higher crop yields

Table 7.5: Proposed Farming Management actions to Improve Irrigation Water Use Efficiency

Management of Farms		
Timing	**WDM Measure**	**Expected Results**
Short-term Immediate to five years	• Acquire scheduling system • Improve maintenance of application systems, canals and storage facilities • Initiate proper drainage	7% net water saving. Higher value crops and higher crop yields /m^3 water used.
Medium term Five to ten years	• Re-engineer existing irrigation systems • Install more efficient irrigation systems • Better matching of crops to climate, soil and water quality • Consider selling of water quotas	Net water savings up to 10.3% and increased crop yields. Uneconomic water uses would be lower.
Long term Ten to fifteen years	• Install more efficient irrigation systems • Cover soil to lower evaporation	Improve water use efficiency.

Note: Net water savings are based on a 30% return flow

7.9 Implementation Strategy for Water Demand Management

The following steps were identified by the Environmental Protection Agency in the USA (2000) for the implementation of a WDM strategy, mostly in urban areas. This process can be adapted for irrigation as well. The implementation of WDM will be the same for the various water use sectors along the Orange River.

1. Specify WC/WDM planning goals.
2. Develop a water system profile (demand history, tariffs, plans, customer profile, accounting system).
3. Prepare a demand forecast.
4. Describe planned improvements for supply augmentation and cost them.
5. Identify conservation measures and cost them.
6. Select competitive conservation measures.
7. Integrate resource options (Combine capital, human, technical and financial resources. Modify demand forecast to reflect anticipated effects of conservation).
8. Evaluate effect on purchases, improvements, additions and the effect on revenue of the utility, as well as water users.
9. Present an implementation and evaluation strategy to measure the improved efficiency.

8. POTENTIAL FOR WATER CONSERVATION AND DEMAND MANAGEMENT IN THE VAAL RIVER AND EASTERN CAPE

The status and success of WDM in the upstream area has an effect on the availability of water for future development along the Common Border. The information on WDM was summarised from existing reports, information supplied by Rand Water and discussions with WUAs . It is realised that the water sector in South Africa is in a period of transition to implement the requirements of the new Water Act.

8.1 Vaal River System[1]

The graph in **Figure 8.1** shows the water requirements in the Vaal River System. It is clear from the graph that most of the water is used in the urban, industrial and mining sector. The irrigation sector uses also a substantial volume of water (796 Mm^3/a). The biggest potential for efficiency improvement in Vaal River System is within the urban and the irrigation sectors.

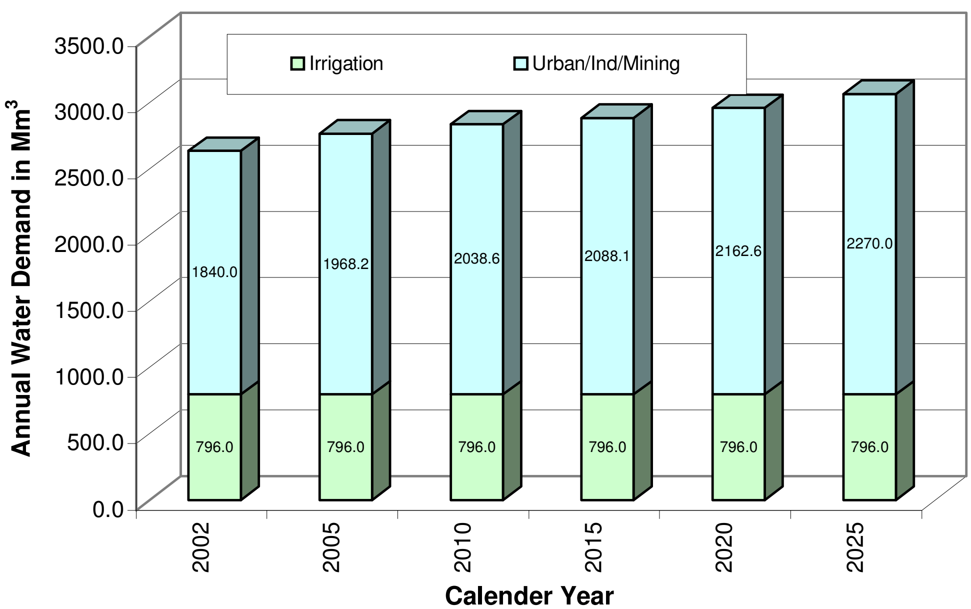

Figure 8.1: Water Requirements in the Vaal River System

[1] Concise summary, Vaal River System Analysis Update – Summary Report, Project Team (Compiled by HGM) Project No:P603315, DWAF Report No: PC000/00/19496, July 2001.

The available information on WDM is not spelled out in detail in the Vaal River System Analysis Update (VRSAU) and it is impossible to do a detailed assessment of the level of water use efficiency within the Vaal River Catchment. The following information was compiled from information received from Rand Water and from the VRSAU.

8.1.1 Urban/Industrial and Large Industries

The graph in **Figure 8.1** shows that urban and industry consumed more than 62% of the water consumption in the Vaal River System (2002). Very little is said in the VRSAU on WDM within these sectors. It is commendable that Rand Water shows a lower growth scenario, mainly as a result of water cycle management initiatives. There is indeed scope for major improvements in urban areas supplied by Rand Water. The information in **Table 8.1** gives an indication of the status of non-revenue water in centres provided by Rand Water.

Table 8.1: Non-revenue Water in the Rand Water Supply Area

Area	% Non-revenue Water
Ekurhuleni	25
Johannesburg	42
Tshwane	24
Mogale City	15
Emfuleni	34
MWC Municipalities	14

Non-revenue water does not give a clear indication of physical system losses, but it gives a good indication of the efficiency of the distribution authorities and the financial losses that occur as a result of such inefficiencies. It is accepted that the projected lower growth scenario is based on the reduction of system losses, as well as end use consumption.

8.1.2 Irrigation

The following points raised in the VRSAU (2001) with respect to irrigation, need further attention: "*Small dams are situated throughout the study area with the highest concentrations in the Vaal Catchment. The total capacity of the small dams (normally very shallow) in the Vaal Catchment is estimated to be 587.09 million m^3. This is almost equivalent to half of the storage of Bloemhof Dam (1 269.2), one of the large dams in the system. The total maximum evaporation area from the small dams is estimated to be in the order of 267.81 km^2 and is 15% more than the full supply area of Bloemhof Dam (234.27 km^2), which in itself has a small average depth. This emphasises the fact that evaporation losses from the small dams are* *significant".* The above statement was adjusted to exclude catchments that augment supply to the Vaal River Catchment.

Irrigation is still one of the major consumers of water in the Vaal River System. The bulk of the irrigation is located in the Middle and Lower Vaal, which together represent 85% of the total irrigated area of the Vaal River System (excluding Usutu, Tugela, Komati catchments, etc.) The irrigation areas given in the report were summarised and add up to 144 535 ha, including the Government Water Control Area, Irrigation Boards and Private Irrigators in the Vaal River Catchment only. This clearly illustrates the importance of irrigation as a water user group. It is stated in the VRSAU that: "*A significant quantity of water is lost through inefficient irrigation (± 20 % to 50 %) and could contribute to significant savings, if reduced".* Although this statement may be a general statement, and may only be applicable to some farmers/irrigation areas, it is clear that potential savings could be realised in the irrigation sector.

The Vaal River is operated as a closed system with no or very little inflow into the Orange River. Inefficient irrigation, high return flows and seepage contribute to the quality deterioration in the Vaal River. With the agreed transfer quota of water from the Senqu River through the LHWP, surplus water may be available in the Vaal River. The water quality in the Lower Vaal River is of concern, because of the high TDS values. This may in turn influence the water quality downstream of the confluence with the Orange River during periods of temporary surpluses.

Since the irrigation sector is one of the largest water users in most catchments, while at the same time providing little reliable information regarding water use and return flows, the VRSAU made the following recommendations relating to irrigation:

1. that projects should be initiated to obtain better information regarding irrigation areas, the monthly irrigation water use, as well as irrigation return flows.
2. irrigation should play an important role in the demand management plan to obtain a significant reduction in the overall water use.

There is no reason why a net saving of 7% (as determined for irrigation in the Orange River System) in water consumption cannot be realised in the irrigation sector in the Vaal River catchment through better management and scheduling. Appropriate pricing, metering and improved irrigation systems could also realise substantial further savings that cannot be quantified due to a lack of more detailed information. If the trend along the Vaal River System is similar to the LORMS area and the Eastern Cape, expected further savings could be in excess of 20% of the unrestricted irrigation demand.

For the purposes of the LORMS, it is assumed that any savings on irrigation use in the Vaal River System will be used for development in the upper catchment area. The Vaal River System is a good example where improved irrigation efficiency through upgrading of systems could provide water for expected urban growth. The experience in California where urban areas (Los Angeles) help to upgrade irrigation systems of farmers, provided that they get access to the realised water savings, warrants further detailed assessment in the Vaal River System.

The following issues need to be taken into account regarding the efficient use of water in the Vaal River System:

1. The transfer volume for the implemented Lesotho Highlands Water Scheme is a fixed volume annually according to the Treaty. Water use inefficiency in the Vaal catchment would impinge on the future availability of water in the LORMS if further phases of the Lesotho Highlands Water Scheme need to be implemented as a result of higher water demand in the Vaal River System.

2. Deterioration of the water quality in the Vaal River and transfer of good quality water from the Senqu River may have a negative impact on the water quality below the Vaal/Orange confluence at Douglas. Although the operating rule on the Vaal River System strives to prevent spills from the Vaal River into the Orange River, the fixed transfer volumes in the upper catchments may create temporary spills.

8.2 Eastern Cape

The graph in **Figure 8.2** shows the water requirements in the Eastern Cape of the water transferred from the Orange River System. It is clear from the graph that most of the water is used for irrigation purposes. The biggest potential for efficiency improvement in Eastern Cape is within the irrigation sector.

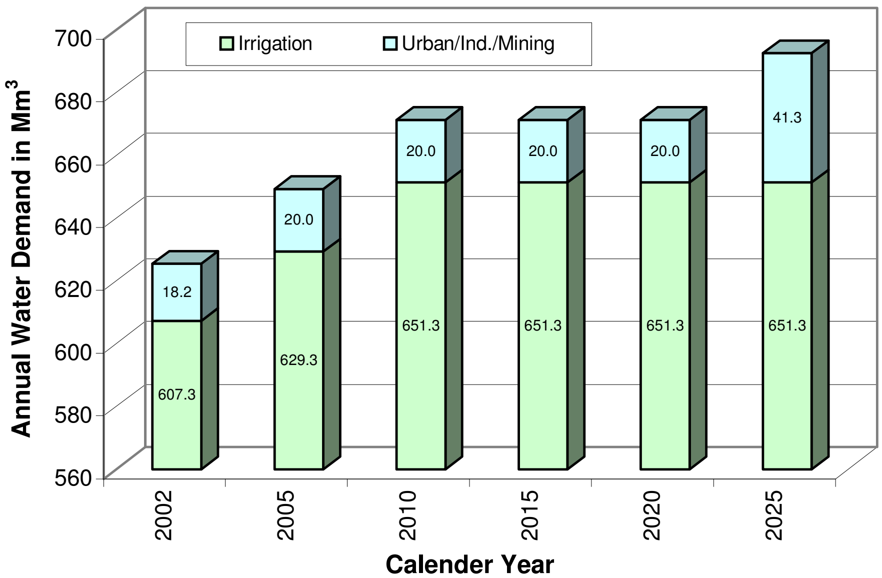

Figure 8.2: Water Requirements in the Eastern Cape

8.2.1 Urban and Industrial Consumption

This is a very low percentage of the use. Approximately 20 Mm^3/a of the water transferred from the Orange River is transferred to the Nelson Mandela Metropolitan Area. Non-revenue water in the Metropolitan Area is approximately 20%, which is an indication that the system is managed more efficiently than most of the urban areas in the Vaal River System. The re-use of water in the Port Elizabeth area is a positive factor pertaining to integrated use of all water resources as any return flow would be lost to sea.

8.2.2 Irrigation

Approximately 97% of all the water consumed in the Eastern Cape (Orange River transfer volume) was used of irrigation.

Cropping patterns change due to market forces. In the Eastern Cape, for example, the cropping pattern has changed as summarised in **Table 8.2**.

Table 8.2: Breakdown of Crop Types by Areas in Eastern Cape

	Lucerne	Fodder & Pasture	Maize	Wheat	Cotton	Legu-mes	Veg + Potato	Grape	Fruit & Citrus
ORRS Report	49.1%	11.0%	11.0%	14.1%	4.3%	-	-	4.5%	17.0%
2002	49.0%	15.0%	8.0%	3.0%	0	0	8.0%	0	17.0%

It is doubtful whether this change would have a significant influence on total water requirement. It should be kept in mind that cropping change as a result of market forces should be treated as a variable.

As in the Orange River upstream of Upington, a large percentage of the crops grown in the Eastern Cape can be regarded as cash crops. As stated in the ORRS[2], a large percentage of lucerne and fodder are utilised by farmers to produce their own fodder for livestock.

Very little information is available on the water use efficiency in the Eastern Cape. An estimated net saving of approximately 42.5 Mm^3/a (7%) on irrigation water could easily be achieved through improved management and scheduling. Appropriate pricing and metering will also contribute to further savings on the reduced consumption of approximately 7%, representing 37.5 Mm^3/a on the reduced consumption after scheduling.

A similar evaluation to the one carried out for the Orange River, was done for the Eastern Cape on the efficiency of irrigation systems. It was found that approximately 31.5 Mm^3/a (16%) could be saved on the reduced demand at a total estimated investment cost of R 761 million. The Eastern Cape, with the Nelson Mandela Metropolitan Area, is a good example where urban water users (high value) can subsidise/support the cost of farmers to improve irrigation efficiency. In this way, water can be freed up for urban/industrial development.

8.3 Orange River Upstream of Vanderkloof Dam

The area upstream of Vanderkloof Dam does not form part of the LORMS area. The water abstracted from this part of the river is approximately 6% of total abstraction and is handled as part of the LORMS area for the purpose of the WDM Report.

[2] Orange River Development Project Replanning Study, Agriculture Economic Analysis for Irrigation Water in the Orange and Fish River Basins FINAL 6847h.wpd 3 - 3 April 1998

9. WATER DEMAND MANAGEMENT IN THE LORMS AREA

9.1 Introduction

As stated in **Section 8.5**, the area upstream of Vanderkloof Dam is included in the discussion of the LORMS area upstream of the Common Border.

9.2 Reducing Losses

9.2.1 River Requirements and Operation Losses

Reducing of river requirements and river operation losses may also be regarded as a WDM initiative, because it is based on efficiency improvement of the conveyance system. Reducing the river operation losses (270 Mm^3/a) is part of a separate component of the hydraulic modelling to determine the system yield. Reduction in operation losses is discussed in more detail in the Water Requirements Report, as well as the discussion system yield and is not covered in this report.

9.2.2 Conveyance Losses in Canals

Seepage and evaporation losses, as well as leakage influence the canal losses. It should be noted that the figure of 88 Mm^3/a is the volume of water that is not returned to the Orange River System. The losses in the Eastern Cape are estimated at approximately 80 Mm^3/a. For the CBA, the net losses are only 5.1 Mm^3/a if the same assumptions are used together with the updated demands. All these figures are based on best estimates.

Conveyance losses are the normal transmission losses expressed as a percentage of the upstream inflow to a specific system node and are generally used for canal losses and transfer losses. The estimated net percentages of conveyance losses in canals are summarised in **Table 7.1**.

No detailed information could be obtained from WUAs or DWAF personnel, where total canal losses (seepage, evaporation and leakage) were quantified and measured separately. There is not enough information available to estimate possible savings and costs through reduction of seepage or leakage. The best way to solve this will be through detailed studies with proper measurement, water balances, calculation of acceptable seepage and evaporation to quantify leakage in the WUA's participating in the WDM/WC pilot project. In many cases (Noordoewer/Vioolsdrift), leakages are obvious from saturated soil and high water tables that can be detrimental to the best utilisation of adjacent irrigation fields. The losses to crop production are normally not taken into account in the evaluation on canal upgrading.

The net losses of 21.54 Mm^3 on the Orange/Riet Canal System warrants a more detailed investigation during the full Feasibility Study to determine if it is competitive with other schemes of efficiency improvement and/or supply augmentation.

9.3 Orange River System Upstream of the Common Border Area

The graph in **Figure 9.1** shows the water requirements in the Orange River upstream of the CBA (excluding Lesotho). It is clear the graph that most of the water is used for irrigation purposes. The biggest potential for efficiency improvement in Orange River upstream of the Common Border is within the irrigation sector.

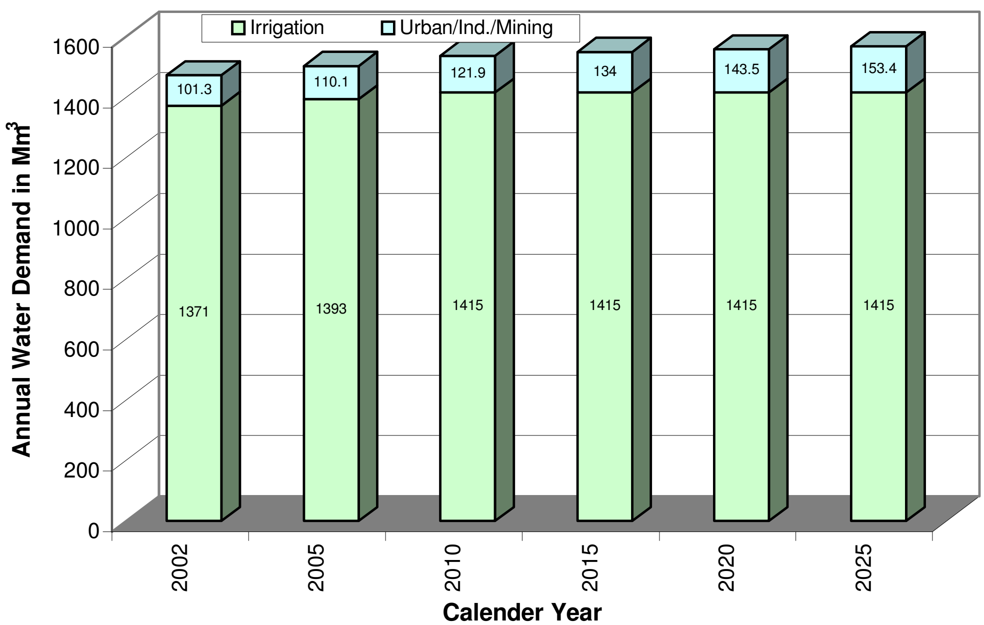

Figure 9.1: Water Requirements in the Orange River Upstream of the Common Border Area

In the ORRS, WDM was identified as an important aspect that needs to be addressed within the next ten years. It is accepted that WDM was not such a high priority during the investigation and no clear targets were set for savings that can be realised as a result of the implementation of WDM.

Table 9.1 can be regarded as the main summary of the recommendations on WDM in the ORRS.

Table 9.1: Proposed Goals to Improve Water Use Efficiency (ORRS)

Possible short, medium and long-term goals		
Timing	**Water Authority (supplier)**	**User/Irrigator**
Short-term Immediate to one year	• Begin water re-pricing exercise (work toward a market related price) • Improve measuring and control systems • Re-evaluate quotas and revise quota allocation system • Promote water conservation awareness • Regulate current quota sales system	**Irrigation** • Acquire scheduling system • Look to increasing financial returns/m³ • Re-engineer existing irrigation systems • Initiate salinity amelioration strategies • Initiate drainage control strategies **Urban** • Regular plumbing checks • Introduce nightflow measurements • Pressure management of system
Medium term One to five years	• Complete water re-pricing exercise • Line canals and balancing dams where appropriate • Introduce water market through legislative process	• Initiate planting of higher value crops • Implement deficit irrigation strategies • Line furrows and lei dams • Finalise salinity amelioration and drainage strategies • Consider selling of water quotas
Long term Five to ten years	• Introduce demand-driven supply to canal based irrigation schemes • Introduce assurance-based supply mechanisms (which will also affect the price of water)	• Continue replacement of existing with higher value crops • Install more efficient irrigation systems

It was further stated that higher water tariffs to cover costs might result in the discontinuation of irrigation farming along certain river stretches due to the lack of high value crops. The importance of co-operation, a proper data base, water allocation and valuation, control of salinity/drainage, technical support and a proper implementation strategy formulation must, therefore, be emphasised.

A number of the above goals defined for the irrigator should be reached as the result of the implementation of a reviewed water pricing strategy combined with a review of existing quotas. These goals should be indicated as such, e.g. a higher price for water and a stricter application of a water quota could motivate farmers to be more efficient in their water use and to produce more profitable (high-value) crops. Development and implementation of revised tariffs will have to be done after a proper investigation and should be phased in with great care over time in order to allow users to adapt and to prevent any negative consequences.

Table 9.2 gives a summary of the breakdown of different crop types from ORRS.

Table 9.2: Breakdown of Crop Types along the Orange River

River System	Lucerne	Fodder & Pasture	Maize	Wheat	Cotton	Legu-mes	Veg + Potato	Grape	Fruit & Citrus
Orange River (ORRS)	11.2%	4.4 %	18.1%	33.9%	6.4%	5.2%	2.7%	17.5%	0.6%

Most of the crops grown in the Orange River System are cash crops that were normally regarded as low value crops. Since 1996, there have been changes to more perennial crops (mainly grapes) in the area around Upington up to the Common Border. This could change the information in **Table 9.2** to large extent as indicated in **Figure 9.2** and **Figure 9.3**. Recent detail information was not available to update the information in **Table 9.2** for the LORMS area.

The graphs in **Figure 9.2** and **Figure 9.3** show the change in land-use over the period 1996 to 2002 for the area between Boegoeberg Dam and Blouputs, (Water Requirements, LORMS, 2003)

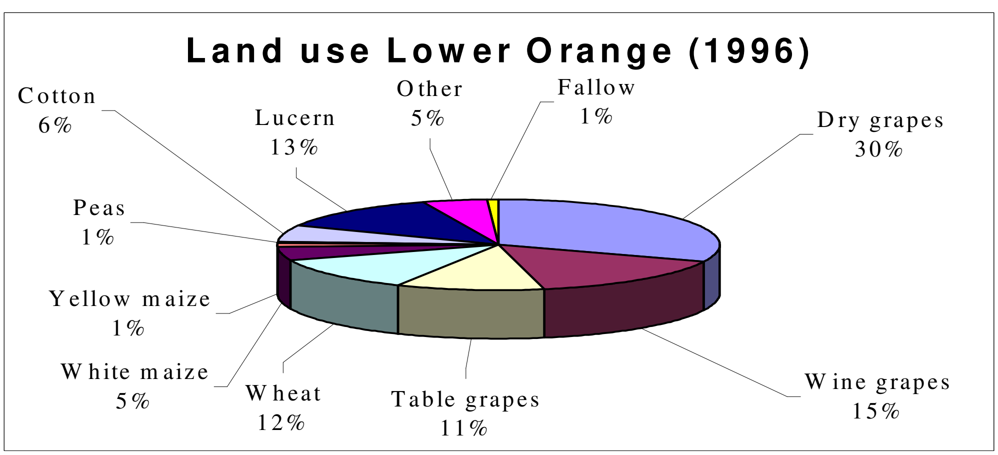

Figure 9.2: Land Use during 1996

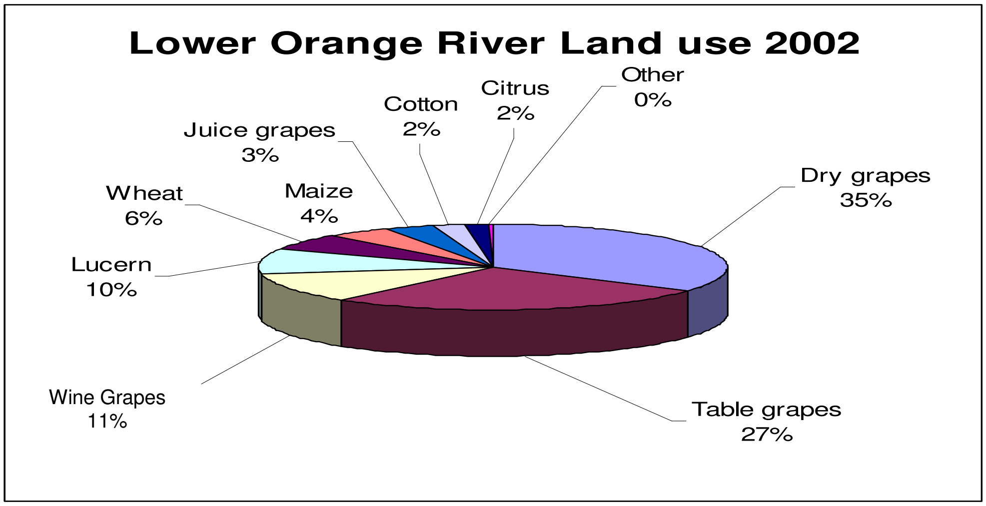

Figure 9.3: Land Use in 2002

It is clear that there is a movement from cash crops to higher value perennial crops along the Orange River, mainly from Upington to the Common Border.

Canal losses are not quantified through accurate measurement in most of the canal systems in the Orange River. A few exceptions may be in areas where WUAs make an effort to reduce system losses as far as possible. It should be kept in mind that, depending on the position of the canal, most of the seepage may go back to the river. There are some canals (Boegoeberg, Kanon Eiland and others) that are in a poor condition. Canal losses contribute significantly to higher water tables and salination. Local losses in canal systems need to be replaced by a higher input at the canal inlet.

The effort to improve water use efficiency in the Kimberley/Douglas area is commendable although the improvement cannot be quantified, because water to end-users is not directly measured. The positive result is a combined effort of DWAF, WUA, the Griekwaland West Co-operative and the local farmers. It shows what can be achieved through a partnership amongst all the role players. The WUA uses satellite images twice a year to control irrigation areas to ensure that farmers do not irrigate a larger area than their allocation through double cropping or rotation of irrigation areas. All the farms are also inspected twice a year to confirm which crops are grown.

It is known that the WUAs in the Kimberley area are part of the pilot sites to implement WC and WDM and may not be representative of the whole catchment area. However, it shows what can be achieved over a relatively short period through proper co-operation (Public Private Partnerships) and the use of appropriate technology with innovative approaches.

9.4 Common Border Area

The water requirements along the CBA in Namibia and South Africa are depicted in **Figure 9.4** and **Figure 9.5**, respectively. It is clear from the graph that most of the water is used for irrigation purposes along the CBA. In Namibia, it is expected that mining will also require substantial volumes on water in the future. The current water demand for irrigation and mining is relatively low in comparison with the rest of the Orange River System. This creates an opportunity to ensure that all planned new developments along the CBA should be planned in such a way to ensure water use efficiency.

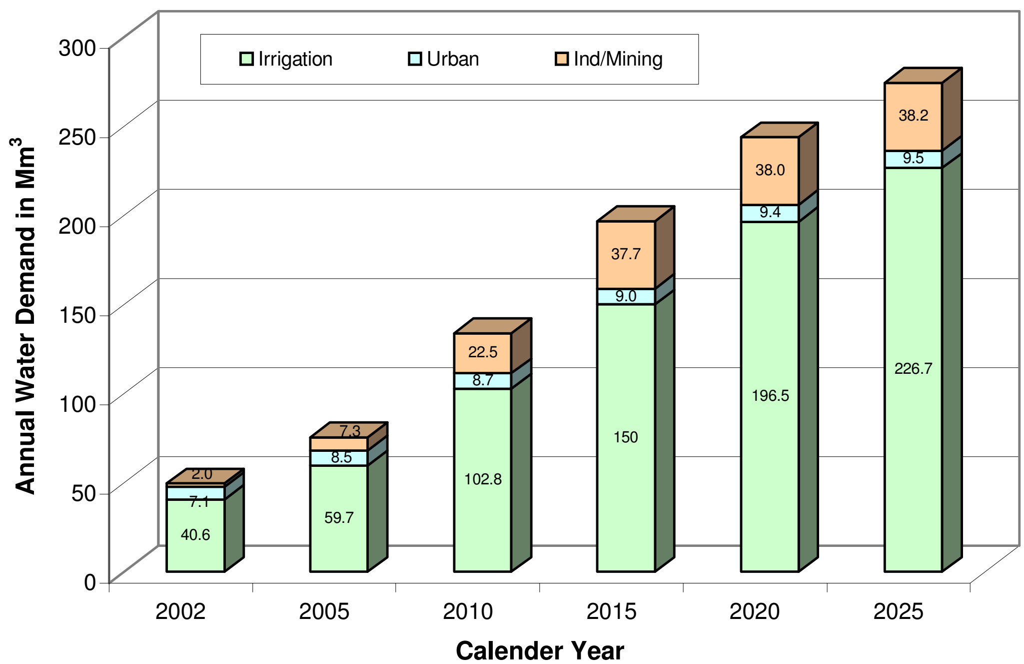

Figure 9.4: Water Requirements in Namibia along the CBA

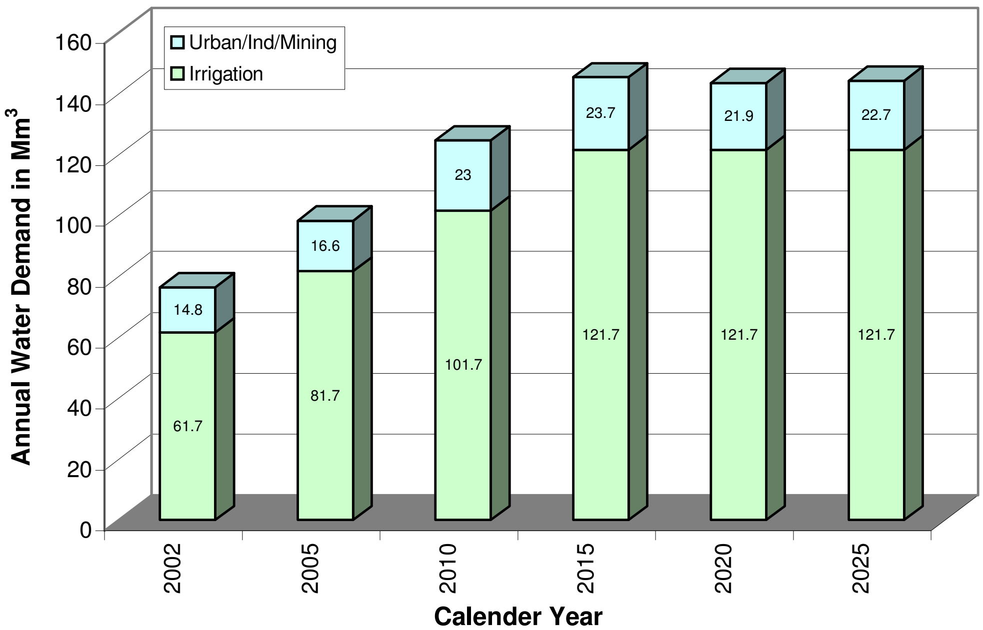

Figure 9.5: Water Requirement in South Africa along the CBA

9.4.1 Urban and Domestic Users

Urban water demand is only 13% of the total water demand in the CBA, excluding environmental requirements. Most of the towns along the CBA are relatively small.

The urban water consumption of Namibian towns and villages along the Orange River is summarised in **Table 9.3**. Most of the towns rely on groundwater and may be linked to the river for supply in future.

Table 9.3: Urban Water Consumption for Namibia in 2001/02 (CBA)

Consumer	Consumption (m^3/a)	Population	Unit Consumption (l/p/d)
Ariamsvlei (gw)	43 035	428	275
Aussenkehr	0		
Grunau (gw)	9 501	379	68
Karasburg (gw)	237 992	14 693	44
Noordoewer	70 300	1 211	159
Oranjemund	6 445 762	5 451	3 239
Rosh Pinah Town	601 145	1 537	1 071
Warmbad (gw)	37 126	162	628

Note: gw: groundwater

The per capita consumption in Oranjemund and Rosh Pinah is exorbitant and it is suggested that permit allocations be done on a figure of 350 litre per person per day, taking local climatic conditions into account. Both at the Oranjemund and Rosh Pinah Mines, certain WDM practices are undertaken in the mining processes to enhance water use efficiency, but the practices undertaken in the towns associated with the mine are inefficient. The main reason for misuse of water is the fact that water is not metered and is supplied free of charge by the mine to the residents. In Oranjemund, purified effluent is used to irrigate the golf course. The mine outsources the management of municipal services in Oranjemund to a private company. This may contribute to better maintenance of water systems. Warmbad needs further verification that the high consumption may be linked to stock watering.

The water demand of towns in the RSA has a similar pattern in cases where water is supplied free of charge by the mine. The information supplied by the different Water Boards is summarised in **Table 9.4**.

Table 9.4: Urban Water Consumption for South Africa (CBA)

Town	Annual Water Use (Mm^3/a)	Population	Unit Consumption (l/p/d)
Main urban demand centres supplied by Namakwa Water Board			
Springbok	0.78	10 950	195
Nababeep & Okiep	0.70	10 336	185
Concordia	0.11	3 933	77
Steinkopf	0.24	6 907	95
Alexander Bay supply area			
Port Nolloth	0.44	4 689	257
Alexander Bay Mine	0.18	n.a.	
Alexander Bay Town	2.60	3 164	2 250
Alexander Bay total	3.22		

The urban water consumption in Alexander Bay is also very high and needs verification, because the split between the water used by the mine and town is based on estimation. The estimated consumption includes irrigation of four soccer fields, rugby field, golf course, school fields, parks and gardens. Private water consumption is not measured and residents are not paying for their water use as the mine provides water free of charge.

It was only possible to do benchmarking of towns such as Upington and Prieska. It was not possible to do benchmarking for the mining towns Rosh Pinah and Oranjemund, because there are no water meters or water sales. The benchmarking forms for Upington and Prieska are attached as **Appendix B.**

Upington:

Although the non-revenue water appears to be low at 14%, the infrastructure leakage index of 8.6 indicates that there is considerable scope for improvement as far as reducing leakage is concerned. For systems with an average consumption of ± 2 700 litres/connection/day, it is possible to reach leakage levels of 5% and below, particularly if the system pressures are as low as the 25 m suggested in the benchmarking form.

It seems, however, that the cost of the raw water is extremely low and it is clearly not economically viable to lower leakage, unless the price of water provides an incentive for change.

Prieska:

The system appears to be well managed and leakage is very low with little scope for improvement, as shown by the infrastructure leakage index of just below 2.4. No recommendations regarding leakage reduction can be given.

9.4.2 Mining and Industrial Users

This section of the report will focus on Mining, because industrial activities in the CBA use negligible volumes of water. The cost of water to mines is not a major cost factor in comparison with other operational costs, but due to the economy of scale they may get a high return on investments to enhance water use efficiency. Examples include Rössing Uranium Mine (Namibia) that is very large and sophisticated and can exploit economies of scale in water saving techniques such as large scale recycling.

Since 1977, the amount of freshwater used by Rössing Uranium Mine has decreased from 26 000m^3/day (9.5Mm^3/a) to 7 500m^3/day (2.7Mm^3/a). However, the total amount of water used by Rössing has remained at 1977 levels, the freshwater being largely substituted by the use of recycled water. The comparison is made below.

SOURCE	1977 (Mm^3/a)	1977 (%)	1997 (Mm^3/a)	1997 (%)
NamWater	9.5	100	2.6	27.66%
Recycled	0.0	0.0	6.5	69.15%
Brackish	0.0	0.0	0.3	3.19%
TOTAL	9.5		9.4	

It is evident that Rössing Mine finds the new water management strategy less costly than obtaining all its water from NamWater. A brief financial cost benefit analysis by Rössing themselves shows that the benefits outweigh the costs by approximately N$ 67 million (1994) and as such, there are obvious incentives for them to undertake these measures.

In Oranjemund, the mine makes use of seawater for its process, while the town is provided from boreholes drilled in an alluvial terrace adjacent to the Orange River. The boreholes are re-charged by sub-surface inflow from the river.

The Auchas Mine in Namibia is located adjacent to the Orange River and abstracts water directly from the river. There are two mining processes, one in the old riverbed and a mobile plant that is used for processing of the gravel at different locations. The mobile plant has a recycling facility and uses a relatively small amount of water per metric ton of material processed. The water use is approximately 0.45m^3/ton in comparison with approximately 1m^3/ton in the riverbed operation.

The planned Haib Mine near Noordoewer in Namibia has very high water requirements (60 Mm^3/annum). It is a typical example where the regulating authority can stipulate good water use practices. The application of a two-tier water charge with a higher charge for consumption above a certain volume/ton of ore processed may force the mine to strive for better water use efficiency.

At Baken Mine (RSA) tests are being considering where paste is produced from thickeners. This paste contains significantly less water than existing slimes and less water will be put onto slimes dams. This means less water loss due to evaporation and seepage and hence, even more re-use of water. The process involves thickening slime to densities where the thickener underflow looks and behaves similarly to toothpaste.

The mine also intends depositing slime into mined-out mine areas, which reduces the surface area relative to the volume and thus reduces evaporation. Re-use of water over the last three years has increased significantly compared to the past. All water is recycled from slimes dams and evaporation is actually to their disadvantage. Future closure of plants not designed and built for optimum water usage is also envisaged, although for reasons other than water consumption.

The consultant is not aware of specific water intake (SWI) figures, i.e. water intake/ton of processed ore, for the different kinds of mining activities. It may be useful to collect these figures and distribute the information to mining enterprises.

To prevent misuse of water in the mining industry in the CBA, it is suggested that the following stipulations be made in permit applications and approvals pertaining to water use efficiency:

- 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, no free water to residents in mining towns.

- Strict application of water pollution criteria to prevent water pollution in the CBA.
- Strict adherence to closing down of mining activities to prevent negative effects pertaining to water pollution and use of land for irrigation purposes after termination of mining activities.

Different ministries like Mines and Energy, Nature Conservation and others normally regulate some of these activities. Close co-operation will be needed to minimise long-term negative consequences.

9.4.3 Irrigation

The irrigation sector in the CBA uses approximately 81% (102.2 Mm³) of the total water consumption. Approximately 69% of the irrigation systems are more advanced systems like centre pivot (5%), micro or drip irrigation. Approximately 50% of the irrigation areas apply scheduling techniques.

9.5 Water Demand Management in the Fish River Catchment in Namibia

9.5.1 Urban & Mining

There are no mining enterprises supplied with water from the Fish River Catchment. The urban water consumption of towns and villages along the Orange River is summarised in **Table 9.5**.

Table 9.5: Current Urban Water Consumption in the Fish River Basin (Namibia)

Consumer	Population	Consumption (Mm³/a)	Unit Consumption l/c/d
Keetmanshoop	14 945	1.79	328
Mariental	11 977	0.93	212
TOTAL		**2.27**	

Both towns implement rising block tariffs and the opportunity for major water savings is limited. The non-revenue water of both towns is less than 17% and efficiency improvement is limited. It was not possible to do benchmarking, because the relevant information was not available from either of the Municipalities.

9.5.2 Irrigation

All the irrigation off takes at Hardap were provided in the past with water meters. Most of the water meters are not operational anymore. The malfunctioning of meters is related to algae problems, damage to meters, maintenance problems, as well as possible meter tampering. The authorities are investigating the replacement of the meters provided that suitable irrigation meters can be acquired. The intention is to make the farmer responsible for the safeguarding of the water meter and to prevent meter tampering or damaging of meters. The tariffs levied per hectare amounts to N$ 322.00 ha/a.

There are four private firms that do laser levelling at the Hardap irrigation scheme and in 2002, approximately 80% of all the irrigation fields were levelled, using this method. Some of the farmers are changing from cash crops to perennial crops, like table grapes and dates. It is assumed that savings of 19% can be achieved through proper scheduling, metering and conservation tariffs. Potential savings from irrigation system improvements may be very low due to the higher efficiencies already obtained through laser levelling. Increasing crop yields through more sophisticated systems, like drip and micro irrigation, requires a more detailed investigation.

10. EXPECTED WATER SAVINGS AND COST OF WATER DEMAND MANAGEMENT

10.1 Introduction

It was assumed that any potential savings in the Vaal River System and in the Eastern Cape would be utilised in the specific catchments where savings could be realised. These two areas fall outside the main focus area for LORMS and are not discussed further in this Chapter.

This Chapter concentrates on the Orange River and the potential savings, as well as costs and practical considerations that need to be taken into account should the identified WDM initiatives be actively pursued as a potential source along the Orange River. The irrigation sector is the largest user of water and has the greatest potential to improve water use efficiency.

The greatest potential for WDM is upstream of the Common Border. There is a practical complication for water use along the Common Border, as it would be impossible to link the availability of irrigation water for Namibia to the successful implementation of WDM in South Africa. Most demand management options require an integrated approach and most of the savings can only be realised over time. It is doubtful whether Namibia will contribute to the cost of implementing WDM in South Africa that would mostly benefit South African farmers through improved yield. South African farmers may be very reluctant to invest in irrigation efficiency knowing that it would reduce their allocated quota and that savings would be utilised in a neighbouring country.

Experience elsewhere in the world has demonstrated that WDM in the irrigation sector was only successful if the farmers benefited through improved yields or savings in operation and labour costs. A good example is the “Water for Profit” scheme in Queensland (Australia) where farmers are supported by the Government to improve irrigation systems and farm management to save water and to increase crop production. With an investment of A$ 41 million by the Queensland Government, 180 Mm^3/annum of water was saved and the value of crop yield improvement was A$ 280 million/annum, (Robertson, 2003). In the Los Angeles area, the Metropolitan Area supplied advanced irrigation systems (capital investment costs) and benefit of lower irrigation water use was transferred from the irrigation sector to the urban users who met the costs of the improvements. There are no similar examples documented in Southern Africa and the benefit to the farmers needs to be demonstrated before they will participate actively in WDM initiatives.

It is suggested that the principle should be accepted that WDM options in a specific country should only be used to satisfy water requirements for the river system. This implies that savings in the Orange River System may be used elsewhere in the system like in the Eastern Cape, Vaal River System or in the CBA. If this principle is accepted, an equitable share of water for Namibia cannot be dependent on the successful implementation of WDM upstream of the Common Border in South Africa.

The measuring of such improvements could also be difficult to quantify without detailed modelling, because of variation in the climate and on-farm factors like soil conditions, maintenance and management that influence efficiency. 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 at present and in the future. There is a need for developing forecasting methods to support evaluation of long-term and short-term WDM alternatives.

Along the CBA, both countries should strive for comparable levels of water use efficiency. If the desk study of the area upstream of the Common Border shows that the implementation of a specific WDM option is competitive, more detailed investigations will need to be done into the specific areas identified for improvement during the full Feasibility Study.

10.2 Reducing Operation and River Losses

The potential for the reducing of operation losses in the Orange River downstream of Vanderkloof Dam can be substantial. The possible savings are determined as part of an additional task “Hydraulic Modelling of the Orange River” approved for this study. According to the modelling exercise, the system yield would increase by approximately 80 Mm^3/a with improved flow monitoring and the utilisation of inflows (spills) from the Vaal River.

Possible minor reductions in evaporation losses (river losses), if any, that cannot be quantified with the current accuracy limitations, may be realised. This may be achieved through optimised water releases from Vanderkloof Dam, provided that control and or storage is created downstream of Vanderkloof Dam to cater for shorter but higher releases, in order to lower the average evaporation losses in the river.

10.3 Urban and Industrial Water Demand Management

The industrial component of the water requirements is relatively small and is included in the urban component. The cost of implementing of WDM in urban areas is normally less than 1% of the annual operation costs of the water system. It is suggested that basic information on WDM be made available to all the towns in the LORMS area.

The largest known water wastage occurs at Oranjemund and Rosh Pinah with 3 240 litre/capita/day (ℓ/c/d) and 1 071 ℓ/c/d, respectively. If it is accepted that 350 lℓc/d is a reasonable allocation, the target for reduction in residential consumption can be set at 5.7 Mm^3 and 0.4 Mm^3 for Oranjemund and Rosh Pinah, respectively. The best way to achieve the targets will be through the reduction of the allocated quotas, installation of water meters to end consumers and charging for actual water use. (The abstraction of the water for Oranjemund is from boreholes and would require control over groundwater abstraction.)

Except for the two mining towns of Oranjemund and Rosh Pinah, the water consumption in all the towns is reasonable. The budget price for the installation of water meters in the two mining towns is estimated at N$ 2.1 million for Oranjemund and N$ 0.6 million for Rosh Pinah, respectively. If pre-payment water meters are installed the cost could be 2.5 times higher. This cost will be for the account of the mining companies, if implemented. The annual capital redemption cost, if meters are repaid over 7 years at 15% interest, is N$ 0.11/m^3. The operational cost for meter reading and billing amounts to approximately N$0.26/$m^3$/month.

The estimated water consumption in Alexander Bay is also very high, but needs to be verified through proper metering. It is suggested that a similar approach be taken by reducing the quota to force the mine to meter end consumers and to charge for water.

10.4 Improved Mining Water Use Efficiency

The cost of WDM in the mining sector is normally included in their operations cost. In most cases, major cost savings can be realised by mines by recycling water. Further water saving options by the current mines is limited, except for mining towns. As discussed in **Section 8.3.2**, both countries should insist that water from tailings dams should be recycled as part of the permit conditions for existing and new mines.

10.5 Irrigation

10.5.1 Economic Parameters to Evaluate the Benefits of Water Demand Management Initiatives

In **Chapter 5** of the Water Requirements Report, the economic parameters as summarized in **Table 10.1** below, are discussed in more detail. These figures were established for a Pilot Study on a number of farms in different irrigation areas to determine the viability of irrigation along the Orange River. Except for the 14% area covered in Upington-Keimoes irrigation areas, the other areas are represented by 24% to 90% sample coverage of the irrigation farms along the Orange River. This higher coverage can be regarded as a representative sample of farming activities along the river. With no better figures available, is assumed that the Upington-Keimoes region is also representative for purpose of this discussion.

Table 10.1: Economic Parameters for Irrigation along the Orange River

Item	VDKL-HT	P-D	Boegoe	Up-Keim	Kakamas	Aug-Blou
Long-term crops (ha)	546	430	1324	994	2003	1046
Short-term crops (ha)	10252	15907	669	20	49	0
Total irrigated area (ha)	**10798**	**16337**	**1993**	**1014**	**2051**	**1046**
Capital investment per ha irrigated in R	47782	48475	55395	143772	161549	205605
Gross income (R/ha)	12255	11978	17002	38168	41657	91034
DAC per ha	7279	6389	9905	24044	24553	44199
Total gross margin/ha	4976	5589	7097	14124	17104	46834
Overheads per ha	2946	3330	3787	6633	7400	24793
NDI per ha	2030	2259	3310	7491	9703	22042
Water use per ha	11000	10000	15000	15000	15000	15000
NDI per m^3	0.18	0.23	0.22	0.50	0.65	1.47
Employment						
Number of permanent labourers	337	302	339	444	896	904
Seasonal - permanent equivalent labourers (240 days)	437	180	666	1025	1565	1292
Total number of labourers	**774**	**482**	**1005**	**1469**	**2461**	**2196**
Labourers per ha irrigated	0.07	0.03	0.50	1.45	1.20	2.10

Notes:		
	VDKL-HT:	Vanderkloof-Hopetown
	P-D:	Prieska- Douglas:
	Boegoe:	Boegoeberg:
	Up-Keim:	Upington-Keimoes:
	Aug-Blou:	Augrabies-Blouputs
	DAC:	Direct Allocatable Costs
	NDI:	Net Disposable Income

It is clear that the labourer requirement per ha increases substantially from Vanderkloof Dam to the Augrabies-Blouputs area. Both seasonal and permanent labour requirements increase. The results of the analysis in this section clearly indicate that the financial rewards are substantially higher in a region where higher value crops are produced. From a development point of view, it is therefore important to only consider high yield potential, high value, medium to low risk crops. Also, new developments in the CBA can be expected to generate approximately R20 000 NDI/ha and create employment for 1.5 labourers/ha/a (permanent equivalent), since it is likely that long-term high value crops will be produced.

10.5.2 Water Efficiency Unit

For the implementation of WDM initiatives in the irrigation sector, it is accepted that WUAs or similar institutions will be formed to support farmers to realise water savings within the irrigation sector. To strengthen the WDM function of the WUA, it is suggested that a Water Efficiency Unit be established for the Upington area, including the river stretch along the Common Border. This area concentrates more on high value crops while the climatic conditions are also more comparable. The cost of establishing such a unit with branch offices, internet links and professional help is estimated to be in the order of R 2.5 to 3.0 Million/annum, depending on the size, type of operation and location of the unit.

It is difficult to put a price tag on training irrigation farmers. The importance of training will also depend on policy decisions in both countries. It seems that the training of irrigation farmers is not a high priority at this stage. The respective Governments can perhaps facilitate linkages with foreign institutions (New South Wales Training Modules) where excellent training modules have been developed. If training is left to the private sector, the best way to facilitate such training may be through tax incentives and tax deductions to farmers.

The main areas identified to improve water productivity are:

- Scheduling;
- Metering and Tariffs;
- Improved irrigation efficiency;
- Production of higher value crops; and
- Lowering of conveyance losses on the farms.

It is not possible, to quantify specific improvements related to the water productivity of the user efficiency unit and the training of farmers. For the informed farmers with efficient management skills, advanced knowledge of scheduling, marketing etc., the benefits may be small. The benefits over time should be substantial for the majority of farmers through increased water productivity.

10.5.3 Scheduling

The improvement in better farm management and proper scheduling services may realise savings of approximately 13%, as discussed in **Section 7.7.1**. For the purpose of this report, it is suggested that savings 10% on average be accepted (an allowance was made for 30% return flow) with a crop yield improvement of approximately 8%. This figure is in line with figures determined through international research. The cost of basic scheduling services could be recovered from participating farmers.

Table 10.2 summarises the irrigation requirements, expected water savings, costs and increased income, as a result of higher crop yields for specific river reaches along the Orange River, should scheduling be implemented successfully.

Table 10.2: Estimated Costs and Water Savings through Scheduling

River Reach			Requirement		Water Savings		Cost of Scheduling Service			Cost of Water Saved (c/m³)
No	River	Reach	Existing Systems (Mm³/a)	Scheduling Scenario (Mm³/a)	Volume 70% Saving (Mm³/a)	Percent (%)	Area (Ha)	Tariff (R/ha/a)	Cost (R mil/a)	
1 to 6*	Caledon/ Orange	Gariep to Vanderkloof	102.3	95.1	7.2	10.0	12 340	40.30	0.50	6.95
7 to 18	Orange/Mod. Riet/Vaal	ds Vanderkloof to the border	1 268.7	1 204.8	63.9	7.2	76 076	26.87	2.04	3.20
19 to 22	Orange	CBA	102.3	98.7	3.6	5.0	6 817	53.74	0.37	10.24
Total			1 473.3	1 398.6	74.7		95 233			

* Excluding Lesotho

Estimated Improved Yield and Change in Water Productivity

River Reach			NDI for Region (R/m³)	Value of Water Saved based on NDI (R mil/a)	Average Improved Yield		Change in Water Productivity (%)
No	River	Reach			Percentage	Value based on NDI (R mil/a)	
1 to 6	Caledon/Orange	Gariep to Vanderkloof	0.18	1.29	8%	2.00	16.1%
7 to 18	Orange/Mod. Riet/Vaal	ds Vanderkloof to the border	0.23 0.65	14.50 40.99	8%	13.47 44.66	13.7%
19 to 22	Orange	CBA	1.47	5.26	8%	12.02	11.9%

Notes:

- A total of 30 000 ha are scheduled in the Kimberley Douglas area, while approximately 50% of the water use is better controlled in the Common Border Area (CBA).
- Only 70% of the water is regarded s real saving, 30% is regarded as return flow.

10.5.4 Metering and Tariffs

No references to expected savings as a result of metering of irrigation schemes were found in the literature. According to various studies in urban areas, savings of 25% to 30% were achieved when users were metered and charges were changed from a fixed monthly payment irrespective of water consumption, to a conservation tariff based on actual volumetric water consumption, (Louw & Kassier, 2002).

The mere metering of irrigation water will not result in a saving of water. The present system of a fixed charge per/ha per annum for a specific quota (that is not measured) is no incentive for efficient water use. The charging for water according to actual consumption would be an incentive to farmers if it would be linked to a conservation tariff structure. Metering can also provide useful information regarding possible leakages and/or maintenance requirements on the farmers distribution and infield irrigation systems.

According to research done by the University of California, in the Broadway District of California, savings of 9 to 31% (depending of the type of crop) were achieved through rising block tariffs depending of the type of crop. Higher tariffs were applied for water use based on an allocation of 10% lower than the average crop water usage by farmers. There was also a reduction of 66% in drainage water. The reduction of the measured drainage water indicates that over-irrigation had been practiced. It is not clear from the article if the realised savings were net savings.

The DWAF water tariff (water from the river) for agriculture is at present 1.3 cents per cubic meter. Farmers pumping directly from the river, pay this tariff, based on their quota. The tariffs charged by WUAs, where canal systems are used, vary typically between R 900 and R 1 300/ha/year.

In the CBA, the water price is higher for fields at higher elevations as a result of high pumping costs. The cost for irrigation water from the Noordoewer/Vioolsdrift canal amounts to R 315/ha/annum (approximately 2.1c/m^3 calculated at 15 000 m^3/ha/a), while the cost payable for river abstraction is R 167/ha/annum (approximately 1.1c/m^3). The pumping cost at Aussenkehr varies from N$ 4 000/ha (27.0c/m^3) up to N$ 7 000/ha (46.0 c/m^3), depending on the pumping head. The schemes are approximately 30 km apart. The cost of maintenance of pump infrastructure, pipelines and storage reservoirs needs to be added to the above price. In the CBA, with higher pumping heads, operational cost can be higher than R 1. 00/m^3. It is clear from the above examples that the cost of water on established schemes (canal systems) is much lower in the CBA than for new schemes pumping water directly from the river.

The development of tariffs is not within the scope of the present investigation. The information in **Table 10.3** illustrates of the effect of punitive tariffs, based on a rising block 2.5 times higher than existing tariffs and conservation tariffs, based on future supply schemes. It was accepted that average water use by farmers over a period of one year is the same as the allocated quota. It is suggested that the marginal cost be accepted as R0.30/m^3 to illustrate the effect of a conservation tariff, based on the actual costs of the next supply augmentation scheme.

Both the punitive and the conservation annual charges/ha are based on the premise that there was no saving in water consumption. The reduction shows the water consumption when the higher block water tariff is applicable. It should be kept in mind that any punitive tariff or conservation tariff can only be applied if water is billed on a measured volumetric basis.

Table 10.3: Conservation Orientated Irrigation Tariffs

Area	Water Use (m^3/ha/a)	Present Price (R/ha/a)	Reduced Water Use (m^3/ha/a)	Punitive Tariff (R/ha/a)	Conservation Tariff (R/ha/a)
Kimberley/Douglas	11 000	860.00	9 900	989.00	1 104.00
Vioolsdrif/Noordoewer Canal	15 000	316.00	13 500	363.40	734.40
River abstraction	15 000	195.00	13 500	224.25	625.50
Hardap (Namibia)	15 000	322.00	13 500	370.30	739.80

From the literature study, it is reasonable to accept that a net saving of 10 % can be realised with proper metering and tariff structures.

The cost of installing water meters is relatively high. Not only are reliable water meters expensive, but the correct installation is also costly. For the average installation (pump station to supply 75 ha), the cost will be in the order of R100 per hectare. Smaller installations will be more expensive per hectare. A figure of R200 per hectare can be used for a 10 hectare installation.

Table 10.4: Estimated Costs and Water Savings through Conservation Tariffs and Metering

River Reach			Requirement		Water Savings		Cost of Metering					Cost of Water Saved
No	River	Reach	After Scheduling (Mm³/a)	10% Scenario (Mm³/a)	Volume 70% Saving (Mm³/a)	Percent (%)	Area (Ha)	Costs: Meters (R/ha)	Maint. (R/ha/a)	Reading (R/ha/a)	Total Cost (R mil/a)	(c/m³)
1 to 6	Caledon/ Orange	Gariep to Vanderkloof	95.1	88.5	6.7	10	11 363	150	7.5	0.52	0.34	5.10
7 to 18	Orange/Modder Riet/Vaal	ds Vanderkloof to the border	1 204.8	1 104.9	84.3	10	87 666	150	7.5	0.52	2.63	3.12
19 to 22	Orange	CBA	98.68	91.8	6.9	10	6 632	150	7.5	0.52	0.20	2.88
Total			1 390.0	1 292.7	97.3		105 434					

Estimated Improved Water Productivity

River Reach			NDI for Region	Value of Water Saved Based on NDI	Average Improved Yield		Change in Water Productivity
No	River	Reach	(R/m³)	(R mil/a)	Percentage	Value Based on NDI (R mil/a)	(%)
1 to 6	Caledon/ Orange	Gariep to Vanderkloof	0.18	1.20	No change	0.00	7.5%
7 to 18	Orange/Modder Riet/Vaal	ds Vanderkloof to the border	0.23 0.65	19.40 54.82	No change	0.00	7.5%
19 to 22	Orange	CBA	1.47	10.15	No change	0.00	7.5%

Notes:

- 70% of the water saving is a real saving, balance of the saving regarded as a reduction in return-flow.
- Savings as a result of scheduling were taken into account with the system requirement.
- Maintenance cost of meters accepted as 5% per annum and reading fee accepted as 30% of a man month, plus expenses.
- Meters are written off over 15 years at 12 % interest/annum
- The total area has been reduced to allow for double cropping. River reaches 1-6: 8.6%; River reaches 7-18: 21%; River reaches 19-22: 2.8%.

10.5.5 Improved irrigation efficiency

Water savings are possible if existing infield irrigation systems are replaced with more efficient systems. The saving will of course depend on the opportunity for these conversions to take place. Generally speaking there is a price to pay for this saving in the sense that more efficient irrigation systems cost more than those with a lower efficiency. It is also important to recognise that with flood irrigation improvement (laser levelling) a few hectares could be added every year at a rate affordable to the farmer.

Table 10.5 shows a summary of the distribution of irrigation systems along the Common Border Area. Updated information on crops and irrigation systems was not obtained during the registration process in South Africa nor was it possible to verify the types of irrigation systems with the Department of Agriculture at Upington.

Table 10.5: Summary of Irrigation Systems along the Common Border Area

System type	South Africa		Namibia		Total	
	Area (ha)	Annual Irrigation (Mm³)	Area (ha)	Annual Irrigation (Mm³)	Area (ha)	Annual Irrigation (Mm³)
Flood: Border	1 050	18.79	606	9.09	1 656	24.84
Sprinkler: Dragline, Side-roll etc.	78	1.36	250	3.75	328	4.92
Sprinkler: Centre pivot	710	7.45	150	2.25	860	12.9
Sprinkler: Micro/drip	773	10.09	1 697	25.46	2 470	37.05
Total	2 610	39.15	2 703	40.55	5 313	79.70

(ORRS information for South Africa, updated information for Namibia)

An attempt was made to calculate realistic values for possible savings and the accompanying cost of irrigation conversions in the area upstream of the Vanderkloof Dam and in the LORMS area. The procedure followed was to make use of the crop distribution as summarised for the ORRS for the different river reaches. For each of these crop/location subdivisions the area was again subdivided according to irrigation systems in use. These were estimates based on the project team's own experience, as well as consultations with knowledgeable people in the various regions.

The figures quoted in **Table 10.6** give an indication of improvements in water use that can the realised along the Orange River.

Table 10.6: Estimated Costs and Water Savings through Improved Irrigation Systems

River Reach			Requirement		Water Savings		Cost of Upgrading Irrigation System						Cost of Water Saved (c /m³)
No	River	Reach	Existing Systems (Mm³/a)	Best Scenario (Mm³/a)	Volume 70% Saving (Mm³/a)	Percent (%)	Area (Ha)	Costs (R x 10^6) Irr System Total	Labour Saving (R mil/a)	Add Maint. (R mil/a)	Add Energy (R mil/a)	Total Cost (R mil/a)	
1 to 6	Caledon/ Orange	Gariep to Vanderkloof	88.5	80.0	8.4	13.6	11 363	177.76	3.84	7.61	1.14	31.01	367.1
7 to 18	Orange/Mod. Riet/Vaal	ds Vanderkloof to the border	1 120.4	1 004.9	115.5	14.7	88 666	738.89	19.63	32.16	20.11	141.12	122.2
19 to 22	Orange	CBA	91.8	85.6	6.2	9.6	6 632	21.42	0.45	0.59	0.63	3.92	63.4
Total			1 300.7	1 170.5	130.2		105 660						

Estimated Improved Yield and change in Water Productivity

River Reach			NDI for Region (R/m³)	Value of Water Saved Based on NDI (R mil/a)	Average Improved Yield			Change in Water Productivity (%)
No	River	Reach			Area Upgraded (ha)	Percentage	Value Based on NDI (R mil/a)	
1 to 6	Caledon/Orange	Gariep to Vanderkloof	0.18	1.52	9 306	7.5%	1.42	18.8%
7 to 18	Orange/Modder Riet/Vaal	ds Vanderkloof to the border	0.23 0.65	26.57 74.09	36 172	7.5%	6.13 20.32	19.9%
19 to 22	Orange	CBA	1.47	9.08	1 104	7.5%	1.83	15.3%

Notes

- 70% of the water saving is a real saving, balance of the saving is regarded as return-flow.
- Savings as a result of scheduling, metering and tariffs were taken into account with the system requirement.
- Irrigation systems were written off over 15 years at 12 % interest/annum
- Improved yields are based on runs with SAPWAT program (first order estimates)
- These figures can only be used as an indication of cost with an accuracy of plus or minus 30%. If these need to be compared with other options, on-farm detailed inspections need to be done in the main feasibility study. Cost of bulk infrastructure for electricity is not included and may not be feasible in remote areas.
- The total area has been reduced to allow for double cropping. River reaches 1-6: 8.6%; River reaches 7-18: 21%; River reaches 19-22: 2.8%.

The information in **Table 10.6** is only a rough estimate and should be regarded as an indication only of what can be achieved through improved irrigation efficiency under ideal conditions. The figures are based on known crop patterns. To obtain more accurate information, detailed farm surveys will be needed. The availability of electricity, as well as lands below flood levels will also play a major role in the final selection of the irrigation system. The availability of capital to upgrade, as well as the value of crops grown may hamper the upgrading of systems. Depending on the future water pricing policies (two tier tariff, rebates, etc), cost of labour, etc., there may be an annual improvement in application methods. With the low prices of irrigation water, it is doubtful whether major changes will occur over a short period.

Estimated savings of only 6.2 Mm^3/annum along the Common Border are relatively low, because a large percentage of the irrigation by means of micro and drip systems on both sides of the border.

In the economic evaluation of supply options these figures can be used as an alternative source of water supply for comparison of options at the pre- feasibility level only. If the initial figures compare well with other supply options a more detailed investigation will be needed. This falls outside the scope of the present investigation. A principle decision needs to be taken on the sharing of cost between farmers and the Government (rebate or capital) for the installation of improved irrigation systems in the upper catchment. In the CBA, it is suggested that efficient irrigation systems be required in the permit conditions for all new applications.

The Gifkloof/Neusberg area has the highest potential for savings at the lowest cost. The potential savings in are estimated at 53.4 Mm^3/annum at capital investment cost of R 240.9 million while the estimated cost amounts to R 0.90/m^3 water saved. Improvement in water productivity is 24.1%. According to the investigation of the development potential (Water Requirements Report, LORMS), the Gifkloof/Neusberg area may have the highest potential, because most of the area is utilised for high value crops like grapes.

Table 10.7 shows the information on irrigation systems for the river reach between Gifkloof and Neusberg, (ORRS). It was not possible to get updated information on irrigation systems in the Gifkloof/Neusberg area from the Department of Agriculture in Upington.

Table 10.7: Summary of Irrigation Systems between Gifkloof and Neusberg

System type	Area (ha)	Annual Irrigation (Mm^3)
Flood: Border	12 883	241.18
Micro spray	1 663	24.56
Total	**14 546**	**265.74**

If the Gifkloof/Neusberg Area is accepted as a target area the upgrading can be done over a period of 15 years provided that the enabling environment is created within three years through the provision of scheduling services, farmer training, metering, tariffs as well as incentives for irrigation system upgrading.

10.5.6 Pilot Study in the Gifkloof Neusberg Area

Irrigation water use accounts for approximately 95% of the water consumed from the Orange River (excluding the water used in the Vaal River System). In the Water Conservation and Demand Management (WC/DM) documents produced by DWAF (DWAF, 1999a, 1999b, 2000), it is acknowledged that there is scope to improve the efficiency of water use, especially in the irrigation sector. The measurement of improvements brought about by WDM options is difficult to quantify without detailed measurement. Due to the lack of verified information in Southern Africa, it was agreed, in consultation with the Client, to do a Pilot Study, preferably in the Gifkloof/Neusberg Area, covering a group of twenty farmers (10 progressive farmers and 10 average farmers using flood irrigation) to get updated water consumption figures, improved crop yields and even higher value crop yields to compare actual figures with the estimated figures used in the report. Various role players should carefully select the specific area of the pilot project in order that conclusions, based on the project outcome, may be applied as widely as possible.

The aim of the project will be to determine the actual water and cost savings, and the improvement in crop yield that are achieved when certain irrigation WDM initiatives are applied on farms along the Orange River. The initiatives to be applied are the following:

- Provision of information on water use efficiency to farmers;
- Improved scheduling;
- Metering of water; and
- Improvement of the efficiency of infield irrigation systems.

The project staff could consist of five people: Two engineers, two technicians and an economist. This team will be complemented by various other role players, e.g. soil experts, crop water specialists, etc. A Steering Committee would be selected to evaluate the work done by the project team, as well as to assist and give guidance throughout the project term.

The estimated cost for the Pilot Study, including the upgrading of 20 farms, amounts to R 11.33 million. This includes an amount of N$ 9.13 for capital cost on participating farms and R 2.20 million (2004) for professional fees and disbursements. The cost summary is included in **Appendix C.** If the pilot project were to start in January 2005, the expected completion date would be December 2009.

10.5.7 Reducing Conveyance Losses in Canals

According to the estimated net losses, the Orange/Riet Canal (**Section 9.2.3**) is a good candidate for a more detailed investigation by the WUA. It is not possible to quantify potential savings as part of this study due to a lack of accurate information.

10.6 Summary of Potential Savings with Costs

The figures in **Table 10.8** give a summary of what can be achieved through WDM initiatives, if implemented. The success of the measures will depend on final conclusions after the yield modelling has been carried out, as well as the creation of clear policy guidelines pertaining to tariff policies/rebates and advice on scheduling and training of farmers.

Table 10.8: Summary of Expected Savings through WDM Initiatives

Activity and Location	Volume Mm^3	Costs/ m^{3}saved (c)	Remarks
Water Efficiency Unit (Upington)	Unknown	Unknown	Improves water productivity.
Scheduling			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
Metering & Pricing			Improves water productivity.
Upstream Vanderkloof	6.7	5.13	7.0 % net savings on the reduced consumption
Downstream Vanderkloof	84.3	3.12	after the implementation of scheduling.
Common border	6.9	2.88	
Irrigation Systems			Improves water productivity with 24.1%.
Gifkloof/Neusberg	53.4	89.7	
Conveyance losses			
Orange Riet Canal	Unknown	Unknown	Requires a detail investigation.
Urban			
Oranjemund & Rosh Pinah	6.1	0.37	Lower water use.
Alexander Bay	Unknown	Unknown	Water use to be verified.
Mining	Unknown	Unknown	Reuse to be controlled with permit conditions.

11. CONCLUSIONS

11.1 Water Demand in the Orange River System

The water demand in the Orange River System is summarised in **Table 11.1**.

Table 11.1: Present Water Demand on the Orange River System (2002)

Demand Area	Irrigation (Mm^3)	Urban/Ind/ Mining (Mm^3)	Total (Mm^3)
Vaal River System	796.0	1 840.0	2 636.0
Eastern Cape	607.0	18.9	626.2
Upper & Middle Orange	1371.0	101.3	1 472.3
Diffuse irrigation	397.3	0.0	397.3
Common Border Area	102.3	23.9	126.2
TOTAL			**5 258.0**

Note: The figure excludes irrigation demand in Lesotho

11.2 Water Demand Management in the Vaal River System and Eastern Cape

The major water use from the Orange River is concentrated in the area upstream of the CBA. It is assumed that any potential savings in the Vaal River System and the Eastern Cape would be used for expected future water requirements in these areas. The identified savings in the two areas are approximately 22% (net saving) in the irrigation sector if conditions are similar to those in the LORMS area.

The following issues regarding the efficient use of water in the Vaal River System needs to be taken into account:

1. The transfer volume for the implemented Lesotho Highlands Water Scheme is a fixed volume annually. Water use inefficiency in the Vaal catchment would impinge on the future availability of water in the LORMS if further phases of Lesotho Highlands Water Scheme need to be implemented as a result of higher water demand in the Vaal River System.

2. Deterioration of the water quality in the Vaal River and transfer of good quality water from the Senqu River may have a negative impact on the water quality below the Vaal/Orange confluence at Douglas. Although the operating rules on the Vaal River System strive to prevent spills from the Vaal River into the Orange River, the fixed transfer volumes in the upper catchments may create temporary spills.

11.3 Water Demand Management in LORMS

11.3.1 Reducing Operation Losses

Reducing the river operating losses (270 Mm^3/a) may also be regarded as a WDM initiative, since these losses are related to the efficiency improvement of the conveyance system. River requirements and operating losses are discussed in more detail in the Water Requirements Report.

11.3.2 Reducing Conveyance Losses in Canals

According to the estimated net losses in the system the Orange/Riet Canal is a good candidate for a more detailed investigation by the WUA. It is not possible to quantify potential savings as part of this study due to a lack of more accurate information.

11.3.3 Water Demand Management in Urban Areas in the Common Border Area

The greatest potential to improve water use efficiency in towns is in Oranjemund, Rosh Pinah and Alexander Bay. Residents in these towns get unmetered water free of charge from the Mines. This practice leads to wastage. The per capita water consumption is summarised in **Table 11.2.** It is suggested that a limit of 350ℓ/p/d be accepted.

Table 11.2: Urban Water Consumption of Mining Towns

Consumer	Consumption (Mm^3/a)	Population	Consumption (l/p/d)
Oranjemund Town	6.45	5 451	3 239
Rosh Pinah Town	0.06	1 537	1 071
Alexander Bay Town	2.60	3 164	2 250

The following basic WDM instruments were identified as minimum requirements for implementation of WDM in Urban areas in the LORMS area:

- Appropriate tariffs that enhance water conservation.
- Metering of water to all end users.
- Information and education of water users.
- Regular water balances to establish non-revenue water with benchmarking.
- Good maintenance of reticulation and plumbing systems.
- Monitoring of night-flow measurement.
- Pressure management.

11.3.4 Water Demand Management in the Mining Sector

Most of the mines use water efficiently. To prevent misuse of water in the mining industry in the CBA, it is suggested that the following stipulations be made in permit applications and approvals pertaining to water use efficiency:

- 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, no free water to residents in mining towns.
- Strict application of water pollution criteria to prevent water pollution in the common border area.
- Strict conditions for closing down of mining activities to prevent negative effects pertaining to water pollution and use of land for irrigation purposes after termination of mining activities.

If specific water intakes for the different types of mines are determined, conservation tariffs could also be applied to the mines.

11.3.5 Water Demand Management in the Irrigation Sector

Irrigation water use is the highest consumer of water in the LORMS area. The identified WDM initiatives concentrate on this sector, because the biggest potential for savings exists in this sector. Except for scheduling in the Kimberley-Douglas area, it seems that very little progress has been made in the Orange River System to implement WDM. The WUA in the Kimberley-Douglas area uses satellite images to determine the extent of cash crop cultivation. This can serve as an example to other areas. The success achieved is the result of the combined effort of DWAF, the WUA, the Griekwaland West Cooperative and the local farmers. It illustrates what can be achieved through a partnership amongst all the role players.

Table 11.3 summarises the identified issues and the expected time frame that need to be addressed to realise WDM savings in the irrigation sector in the LORMS area. The proposed timeframe for implementation are linked to the successful completion of a Pilot Study that may take up to 5 years to implement.

The potential net water savings (after and allowance for 30% return flow) are estimated in order of priority as follows:

1. Proper scheduling (7% net savings on the present demand).
2. Metering and Pricing (7% net saving on the reduced demand after scheduling).
3. Improvement of irrigation systems. (up to 10.2% net saving on the reduced demand).

The following issues are important for the creation of an enabling environment for farmers to realise water savings and higher crop yields:

- Establish water use efficiency advisory group;
- Foster private sector involvement; and
- Train farmers.

Table 11.3: Proposed actions to Improve Irrigation Water Use Efficiency

Water Authority (supplier)		
Timing	**WDM Measure**	**Expected Results**
Short-term Immediate to five years	**Support structures** • Establish WUAs in the common border area • Establish water use efficiency advisory group • Foster private sector involvement • Train farmers **Policies and control** • Volumetric allocation of water • Control abstraction through the metering of irrigation water • Develop and implement conservation orientated tariffs/rebates etc. **Technical & Planning** • Allocate quotas based on certified proper irrigation system planning on new schemes • Allocate quotas based on proper drainage systems on all schemes	Improved farm management and water productivity Estimated net savings of 7% in water consumption. Higher water use efficiency and higher yields through water application and proper drainage
Medium term Five to ten years	**Policies and Control** • Introduce water markets through legislative process • Introduce assurance-based supply mechanisms incorporated in the tariffs **Operational** • Lower conveyance losses	Would add more value to water consumed (R output/m^3) Higher scheme water use efficiency
Long term Ten to fifteen years	**Operational** • Introduce demand-driven supply to canal based irrigation schemes	Higher crop yields

Management of Farms		
Timing	**WDM Measure**	**Expected Results**
Short-term Immediate to five years	• Acquire scheduling system • Improve maintenance of application systems, canals and storage facilities • Initiate proper drainage	7% net water saving Higher value crops and higher crop yields /m³ water used. Increasing financial returns/m³
Medium term Five to ten years	• Re-engineer existing irrigation systems • Install more efficient irrigation systems • Better matching of crops with climate, soil and water quality • Consider selling of water quotas	Water savings up to 10.3% and increased crop yields. Uneconomic water uses would be lower.
Long term Ten to fifteen years	• Install more efficient irrigation systems • Cover soil to lower evaporation	Improve water use efficiency.

Experience elsewhere in the world demonstrated that WDM in the irrigation sector was only successful if the farmers benefited through improved yields or savings in operation and labour costs. A good example is the “Water for Profit” scheme in Queensland (Australia) where farmers are supported by the Government to improve irrigation systems and farm management to save water and to increase crop production output. With an investment of A$ 41 million by the Queensland Government, 180 Mm^3/annum water were saved and the value of crop yield improvement was A$ 280 million/annum. There are no similar examples documented in Southern Africa and the benefit to the farmers needs to be demonstrated before they will participate actively in WDM initiatives.

It is suggested that the principle should be accepted that WDM options in a specific country could only be used to satisfy demand requirements for the river system. This implies that the equitable share of water for Namibia cannot be dependent on the successful implementation of WDM upstream of the Common Border.

Along the CBA, both countries should strive for comparable levels of water use efficiency. If the desk study in the area upstream of the Common Border shows that the implementation of a specific WDM option is competitive, more detailed investigations should to be done into the specific areas identified for improvement during the full Feasibility Study.

The figures in **Table 10.8** give a summary of what can be achieved through WDM initiatives, if implemented. The success of the measures will depend on the final results of the yield model (reducing of operation losses) as well as defining clear policy guidelines pertaining to tariff policies/rebates and advice on scheduling and training of farmers.

It was agreed, in consultation with the Client, to do a Pilot Study in the Gifkloooof/Neusberg area, covering a group of twenty farmers (10 progressive farmers and 10 average farmers using flood irrigation) to get updated figures on water consumption figures, improved crop yields and even higher value crop yields to compare actual figures with the estimated figures used in the report. The estimated cost for the Pilot Study, including the upgrading of 20 farms, amounts to R 11.33 million including capital cost, professional fees and disbursements.

The measuring of such improvements will be difficult to quantify without detailed modelling due to variations in climate, on-farm factors like soil conditions, use of fertiliser, management and other factors influencing water use efficiency. 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 currently and in the future. There is a need to develop forecasting methods to support evaluation of long-term and short-term demand management alternatives.

A budget price for establishment of a Water Efficiency Unit from Upington downstream, including the CBA, is estimated to be R 2.5 Million of which 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. The cost sharing could be done based on the respective irrigation areas in the two countries.

12. RECOMMENDATIONS

The following recommendations and time frames are proposed to improve Demand Management in the LORMS area:

It is recommended that:

1. That a Pilot Study be done (January 2005 to December 2009), covering approximately 20 farms in the Neusberg/Gifkloof area to verify expected water savings, cost of such savings and improved crop yields for farmers before any major WDM initiative are implemented in the two targeted areas identified in this study. The benefits and costs of specialised advice to farmers (Water Use Efficiency Group), scheduling, metering and tariffs (rebates) and improved irrigation systems needs to be established for the two farmer groups.

2 The proposed measures and time table to improve water use efficiency for the irrigation sector as summarised below be accepted:

Water Authority (supplier)		
Timing	**WDM Measure**	**Expected results**
Short-term Immediate to five years	**Support structures** • Establish WUAs in the common border area • Establish water use efficiency advisory group • Foster private sector involvement • Train farmers	Improved farm management and water productivity
	Policies and control • Volumetric allocation of water • Control abstraction through the metering of irrigation water • Develop and implement conservation orientated tariffs/rebates etc.	Estimated savings of 7% (net) in water consumption. Higher water use efficiency and higher yields through water application and proper drainage
	Technical & Planning • Allocate quotas based on certified proper irrigation system planning on new schemes • Allocate quotas based on proper drainage systems on all schemes	
Medium term Five to ten years	**Policies and Control** • Introduce water markets through legislative process • Introduce assurance-based supply mechanisms incorporated in the tariffs	Would add more value to water consumed (R output/m^3)
	Operational Lower conveyance losses	Higher scheme water use efficiency

Water Authority (supplier)		
Timing	**WDM Measure**	**Expected results**
Long term Ten to fifteen years	**Operational** • Introduce demand-driven supply to canal based irrigation schemes	Higher crop yields
Management of Farms		
Timing	**WDM Measure**	**Expected results**
Short-term Immediate to five years	• Acquire scheduling system • Improve maintenance of application systems, canals and storage facilities • Initiate proper drainage	7% net water saving Higher value crops and higher crop yields /m³ water used. Increasing financial returns/m³
Medium term Five to ten years	• Re-engineer existing irrigation systems • Install more efficient irrigation systems • Better matching of crops with climate, soil and water quality • Consider selling of water quotas	Net water savings up to 10.3% and increased crop yields. Uneconomic water uses would be lower.
Long term Ten to fifteen years	• Install more efficient irrigation systems • Cover soil to lower evaporation	Improve water use efficiency.

3 The principle that WDM options in a specific country can only be used to satisfy requirements (instream flow requirements, increased demand, etc.) for the whole river and that allocation of an equitable share for Namibia cannot be linked to the successful implementation of WDM in South Africa be accepted.

4 The principle that both countries should strive for comparable levels of water use efficiency within the irrigation sector along the CSBA be accepted.

5 A Water Use Efficiency Group for the area downstream of Upington (similar crop types), including the CBA, be established at an estimated initial cost of R 2.5 million (R1.5 million recurrent costs) and that the cost be shared annually in accordance with the irrigation areas between the two countries.

6 The high estimated net losses of the Orange/Riet Canal be investigated in more detail during the full Feasibility Study in order to determine the viability of lowering conveyance losses.

7 A more detailed investigation be carried for the Gifkloof/Neusberg area to determine the viability of improved irrigation systems as part of the main Feasibility Study.

8 The principles and guidelines as discussed in the report relating to metering and conservation tariffs be developed further for finalisation between the two countries.

9 Permit allocations for the mining towns of Oranjemund, Rosh Pinah and Alexander Bay (after verification) be reduced to lower the excessive water consumption to approximately 350 ℓ/p/d with the condition that end-consumers are metered and that they pay for water consumed within the next three years.

10 The following basic WDM instruments be approved as minimum requirements for implementation of WDM in urban areas in the LORMS area:

- Appropriate tariffs that enhance water conservation.
- Metering of water to all end users.
- Information and education of the water users.
- Regular water balances to establish non-revenue water with benchmarking.
- Good maintenance of reticulation and plumbing systems.
- Monitoring of night-flow measurement.
- Pressure management.

11. The following stipulations be added to permit applications and approvals pertaining to water use efficiency in the 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, no free water to residents in mining towns except for baseline water (6kl/household/month).

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APPENDIX A:

WATER DEMAND MANAGEMENT IN THE IRRIGATION SECTOR

A.1 Policies in India

The main strategic adjustments to India's irrigation management policy are:

- Participatory management of irrigation schemes by farmers.
- A programme of training and action research.
- Revision of water rates.
- Technological improvements such as drip and sprinkler irrigation, data storage systems and canal automation.
- NGOs, social research institutions, water and land management institutes etc. would be involved in motivating farmers.
- Increased human resources development through water and land management institutes and action research programmes.
- Rationalisation of water rates to reflect the scarcity and value of water.
- Subsidies to encourage the adoption of drip and sprinkler systems.

(Suryanarayanan, 1996).

A.2 Feedback and Irrigation Efficiency: Rocky Mountain Institute

Case studies have shown the following types of information have been found to be the most effective:

- Information about the real cost of water use – this includes the cost of the water plus energy, materials, maintenance, labour, and the cost of drainage water.
- Information about how much water is actually being used – including diversions, evaporation, leakage and seepage before reaching the crop.
- Information about how much irrigation water a given crop actually needs and when does the crop need additional moisture from irrigation (Scheduling).

Programmes to improve flow of information and the provision of incentives for an appropriate response to feedback signals have been successfully implemented using the following techniques.

- Water and energy pricing – pricing schemes that provide a comparison of actual water use to real crop needs, show farmers the real cost of water use.
- Technical assistance for monitoring water use and needs.
- Financial assistance for improvements in monitoring - water and energy providers benefit from offering rebates, grants, give always, or low-cost loans to irrigators for the improvement of monitoring capabilities.
- Rebates for saving water and energy – water and energy providers can give rebates to irrigators who install water and energy saving equipment.
- Educational programmes – workshops, videos and printed materials can provide general information to farmers.

A.3 Irrigation Efficiency techniques of feedback: Rocky Mountain Institute

The following techniques of providing feedback to the water use decision maker have been found to be effective.

- Simplify - large and complex programmes discourage farmer participation and co-operation. Once initiated, a programme can be expanded as the capacity of farmers to use new information and techniques increases.
- Specify – farmers find programmes that take their specific needs into account more useful.
- Demonstrate – field-testing, presentation and demonstration are crucial in order to convince farmers to adopt new technologies.
- Use economic arguments – the effectiveness an efficient technology, must also be shown on the farmer’s bottom line to ensure involvement and implementation.
- Contact leading farmers – getting the leading farmers in a community to adopt a new technology or practice may help to persuade other local farmers to follow.
- Build trust in the field – farmers are more likely to implement changes when they trust the field representative. Training a trusted local community member may lead to increased adoption of new practices.
- Create a positive attitude – the success of a programme may rely on how it is presented to the farmers. Rather than telling farmers that they are wrong, it may be more effective to propose the programme as a way to improve productivity and provide the reasons why it may work.

(Laird and Dyer,1992).

A.4 Efficient Water Management Practices for Agricultural Water Suppliers in California

List A- Generally applicable Efficient Water Management Practices (EWMPs)

- Prepare and adopt a water management plan.
- Designate a water conservation co-ordinator.
- Support the availability of water management services to water users.
- Improve communication and cooperation among water suppliers, water users, and other agencies.

List B-Conditionally Applicable EWMPs

- Facilitate alternative land use.
- Facilitate financing capital improvements for on-farm irrigation systems.
- Facilitate voluntary water transfers that do not unreasonably affect the water user, water supplier, the environment, or third parties.
- Line ditches and canals or insert pipes.
- Increase flexibility in water ordering by, and delivery to, water users within operational limits.

- Automate canal structures.

List C-Other EWMPs

- Water measurement and water use reporting
- Pricing and other incentives (Hanemann, 1999)

A.5 Blyde River Scheme in South Africa

The scheme to install a pipeline (cost R 105 million) was implemented to upgrade a very poorly maintained channel distribution system. The same allocation from the river was allowed for the new scheme. One of the objectives was also to make irrigation land available for the subsistence farmers in the region.

- the effective transmission of water from the present level of less than 40% increased to more than 95%;
- water under sufficient pressure was supplied to operate micro-irrigation schemes;
- water was supplied according to seasonal crop demand to 7 025 ha.
- 800 ha was made available to new upcoming farmers from deprived communities.
- electricity cost for farmers was reduced by between R 200 to R 2000 as a result of the pressure line connection. The fixed irrigation charge is R 1 450/ha/year to pay for the scheme.
- quotas of 9 990 m^3/ha/year were allocated and all water is metered.
- Not only did the pipe network reduce the risk to crop production of the loss or unavailability of water (except in extreme conditions of drought), it also enabled optimal and equitable water distribution amongst users. Water savings effected through improved efficiency of use were applied to increase the area served by present water quotas. The number of job opportunities will increase from 1 800 fulltime and 2 100 seasonal workers to 9 300 workers after the change to high value perennial crops like mangoes and oranges is complete.

(Van der Merwe *et al,* 1999)

A.6 High Plains Underground Water Conservation District Irrigation Efficiency

The High Plains Underground Water Conservation District in West Texas achieved a 25-40% cut back in regional irrigation water use. The self-financed effort employed techniques such as replacing unlined ditches with pipelines, shortening furrows and watering with short surges, recirculating tail water at a faster rate to reduce evaporation, using soil moisture monitoring devices, switching from high to low pressure drop-line sprinkler systems. The programme was voluntary and respect of farmers for the irrigation district employees contributed significantly to the success of the programme. (Postel, 1999).

A.7 Benefits of Irrigation Water Measurement.

Except for the legislative reasons for measuring irrigation water, many other benefits related to practical water management, are derived from upgrading water measurement programs and systems, some of which are the following:

- Accurate accounting and good records help allocate equitable shares of water between competitive uses both on and off the farm
- Good water measurement practices facilitate accurate and equitable distribution of water within district or farm, resulting in fewer problems and easier operation.
- Accurate water measurement provides the decision-maker on the farm with the necessary information to achieve the best use of the irrigation water available while minimising negative environmental impacts.
- Installing canal flow measurement structures reduces the need for time consuming current metering, which is frequently needed after making changes of delivery and to make seasonal corrections for changes of boundary resistance caused by weed growth, sectional bank slumping or sediment deposits.
- Instituting accurate and convenient water measurement methods improves the evaluation of seepage losses in unlined channels. Thus, better determinations of the cost benefits of proposed canal and ditch improvements are possible.
- Permanent water measurement devices can also form the basis for future improvements, such as remote flow measurement and canal operation automation.
- Good water measurement and management practice prevents excess run-off and deep percolation, which can damage crops, pollute ground water with chemicals and pesticides, and result in drainage flows containing contaminants.
- Accounting for individual water use combined with pricing policies that penalise excessive use, can be implemented.

(Water Measurement Manual, 1997)

A.8 Broadview Water District in California: Water Pricing

In an effort to slow infiltration of salts and selenium into ground water, the Broadview Water District in California developed incentives to encourage efficient irrigation. Crop-specific tiers of water use were set at 10% below the required amount. The price difference between the tiers was more than 150%. The successes of the programme were.

- Involvement of the District Board in designing and updating the pricing programme.
- Establishment of prices and tiering levels that represent realistic goals and are relevant to local conditions.
- Collection of field-specific data describing water deliveries, irrigation events, and other cultural practices.
- The timely exchange of information among district farmers.

(Hanemann, 1999)

A.9 Australian Guidelines for Specific Crops

The guidelines are not confined to irrigation and water management but deal with all aspects of cotton production. It is an authoritative “how to do it” regional guide for the irrigation farmer. There was a time when similar publications were developed in South Africa, although few focused on irrigation. The secret is probably that the first priority then for experienced senior staff was the production of manuals of this nature for the farming community. Times and priorities have changed and few now have the necessary scientific knowledge combined with practical on-the-ground experience that is required**.**

The introduction to this draft best management practice manual is worth quoting in detail because it indicates the direction in which technology transfer is moving in Australia. Successful cotton production relies on the sustainable use of land and water resources. Soils, water, and crops need to be managed so that the farm is profitable well into the future, and so that the risk of any adverse environmental impacts is minimised.

Effective management of land and water resources requires growers to be familiar with the resources on the farm, and to plan for the use of these resources. For example, the types of soil found on the farm, and their condition will affect how those soils are managed. Similarly, the quality of water available for irrigation can affect how that water is best used. The core best management practice for land and water management is to develop a plan that describes the resources of the farm, and how these are to be used sustainably. This type of plan is often called a land and water management plan or an irrigation and drainage management plan. Both the New South Wales and Queensland governments have developed guidelines for the

development of these plans. Plans consist of a farm map and overlays, and written information on land, water and crop management.
The planning guidelines and practices outlined in this module are consistent with these government guidelines. Growers who have addressed the issues outlined in this book will have gone a long way to meeting any legal requirements for land and water management established under state government legislation.

Many growers will have already adopted the practice as recommended in this booklet. Recording these practices and a plan provides evidence of good practice, and can be used to make changes and improvements in the future.
(Crosby, 2001).

A.10 Establishment of Water Markets

Water markets is an important instrument to improve water use efficiency.

Prerequisites for successful markets are:

- physical transportability of water
- enough market participants so that no one can unilaterally influence price
- security of allocation and of use/transfer of rights
- access to complete information on the water commodity as well as its alternatives
- knowledge of all benefits and costs of using water
- no costs or negative impacts imposed on third parties as a result of a transfer
- minimal transaction costs. (Haddad, 1996).

The Orange River System including the Vaal River System complies with most of the above requirements. Theoretically it will be possible to transfer water rights from low value users to high value users along the system. It will also be possible to buy efficiency improvement in irrigation and transfer the ‘water savings’ to a user along the system. There are practical limitations that need to be addressed because transfer of rights may necessitate additional infrastructure.

The practice of trading water allocations, between and among sectors, should be encouraged. This may be a self-regulating mechanism, similar to increased tariffs, for a spontaneous movement to higher-value crops or trading with other users such as local industries or municipalities. If irrigation water is sold at an attractive price during periods of scarcity, there may be an incentive for a farmer that grows low value crops (maize, cotton etc.) to sell his water rights to another farmer growing perennial crops with a higher value.

In the agricultural sector, the issue of water markets needs to be investigated more thoroughly. Many water managers and sociologists warn against the misuse of transferable water rights, establishing monopolies, and not contributing to equity in the distribution of water rights. A closely allied danger is that water markets could exacerbate inequality. This has been reported in Chile, a commonly cited example of the negative effects of the uncontrolled use of water markets. The Chilean example should be examined to analyse the effects and construct controls to reduce this risk. In addition, indiscriminate transfer of water rights is not always possible due to geographic constraints or lack of infrastructure.

(Van der Merwe *et al,* 1999)

A.11 Komati River Scheme in South Africa

In Mpumalanga on the Komati River, the WUAs have appointed a consultant to develop and install a sophisticated monitoring and control system at the river pumps owned and operated by the farmers. Called WAMS (Water Allocation Management System), the system comprises the water abstraction control for the Komati River Irrigation Board on 96 river pump stations along some 60km of river length from Swaziland up to Komatipoort. The first system was commissioned in 1996. This system is now being replaced with a new upgraded system after the flood damage of Feb 2000.

The system consists of the following units:

- physical transportability of water
- Magflow / Safmag electronic water meters on each delivery pipe from the river (110 meters in total sizes, 100 to 800mm dia).
- WAMS control unit: This unit picks up a signal from the water meter, totalises and adds the results to other abstraction meter readings under the same water allocation and compares it to the allocated water total that is sent by radio signal to all pump stations from the control station computer. The WAMS unit receives the allocated volume by radio signal on a weekly basis and down counts according to the actual rate of abstraction from the river. When zero is reached a signal is sent to contactors in the switchgear of the electrical supply to the motor. The owner cannot switch the pump on again until the unit receives a new water allocation. The unit is designed to be tamper-proof and the data is encoded until final report printing. The unit is electronically designed to detect any tampering.
- Base computer: This unit is programmed to manage all the members' data information and allocations with real-time updating of the water used.
- Administration and diagrams for each pumpstation: A documentation system was developed to ensure the pipe work, pumps, meters and any other equipment installed is not tampered with, without the approval of the Irrigation Board management.

The water levels at weirs are also monitored real time by 12 depth sensors mounted at the weirs all along the river length. This data is also sent to the base station for management purposes and water restrictions evaluation.

APPENDIX B: LEAKAGE BENCHMARKING FORMS

APPENDIX C:

ESTIMATED COST FOR THE PILOT STUDY

Appendix C 1: Estimated Cost for the Pilot Study

Project team hours per year	Tariff (R/h)	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Engineer 1 (h)	R 600	200	150	200	150	250	950
Engineer 2 (h)	R 600	200	150	200	150	250	950
Technical assistant 1 (h)	R 200	150	100	200	100	150	700
Technical assistant 2 (h)	R 200	150	100	200	100	150	700
Other specialists (h)	R 500	50	50	100	50	75	325
Recoverable costs		R 122,400	R 122,400	R 122,400	R 122 400	R 122,400	

Cost estimate for pilot project													
Cost component	**Capital**	**Additional annual cost per ha**				**Total costs**		**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Total**
	per ha	**Services**	**Maint.**	**Energy**	**Labour**	**Capital**	**Annual**	**(R)**	**(R)**	**(R)**	**(R)**	**(R)**	**(R)**
Cost of WDM initiatives													
Scheduling services		R 80.61					R 60,458	60,458	60,458	60,458	60,458	60,458	302,288
Water metering	R 150	R 1.56	R 7.50			R 112,500	R 5,625	118,125	5,625	118,125	5,625	118,125	365,625
Improving infield systems	R 10,000		R 372	R 233	-R 227	R 7,500,000	R 283,396	0	0	7,961,978	283,396	283,396	8,350,187
Remote monitoring equipment	R 80					R 120,000		120,000	0	0	0	0	120,000
Sub total	R 10,230	R 82	R 380	R 233	-R 227	R 7,732,500	R 349,478	298,583	66,083	7,961,978	349,478	461,978	9,138,099
Cost of project team													
Time cost								325000	245000	370000	245000	397500	1,582,500
Recoverable cost								122,400	122,400	122,400	122,400	122,400	612,000
Sub total								447,400	367,400	492,400	367,400	519,900	2,194,500
Total cost	R 10,230	R 82	R 380	R 233	-R 227	R 7,732,500	R 349,478	745,983	433,483		716,878	981,878	11,332,599

Recoverable costs per month	Total	Rate
Travel per month (km)	4000	R 2
Accommodation and meals (d)	4	R 300
Communication (R)	R 1,000	

Note: Cost estimates are based on two areas of 750 ha with good and bad WDM practices respectively (20 farms)