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Development and Implementation of Irrigation Water Management Plans to Improve Water Use Efficiency in the Agricultural Sector

MOOI GOVERNMENT WATER SCHEME MANAGEMENT PLAN

FINAL REPORT

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water affairs

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MOOI RIVER IRRIGATION SCHEME WATER MANAGEMENT PLAN

FINAL

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EXECUTIVE SUMMARY

Background

The Department of Water Affairs (DWA) through the Directorate: Water Use Efficiency commissioned a study to develop pilot Water Management Plans (WMPs) for fourteen (14) selected irrigation schemes as part of its assistance to the agriculture sector as well as to initiate a process whereby all irrigation schemes develop their own WMPs for implementation as required by the National Water Act (36 of 1998).

The study was informed by the fact that no progress had been made by the agricultural sector with respect to the development and implementation of WMPs for that sector. Furthermore the study was initiated to address the increasing water scarcity[1] in a number of Water Management Areas (WMAs).

One of the approaches in addressing the increasing water scarcity and competition for water is to ensure that existing water users utilise their existing water entitlement efficiently.

Project Objectives and approach taken

The primary objective of the study is the development and implementation of irrigation WMPs for 14 irrigation schemes to improve water use efficiency in the agricultural sector. However the focus of the study was at the irrigation scheme level with minimal work conducted to determine on-farm irrigation water use efficiency levels.

In order to achieve this objective, the following tasks have to be undertaken:

- Compilation of a situation assessment of the current water use and irrigation water use practices in the fourteen irrigation schemes;
- Determination of the irrigation water budget and establishing water use baseline for each irrigation scheme;
- Determination of the irrigation water management issues based on the situation assessment and water budgets prepared for each irrigation scheme;

[1] Water scarcity – this is an imbalance of supply and requirement under prevailing institutional arrangements indicating an excess of water requirements over available water at the required assurance of supply, especially if the remaining supply options are difficult or costly to tap. The current utilisation as a percentage of total available resources at the required assurance of supply can illustrate the scale of the problem and the latitude for policymakers

- Identification of opportunities to improve water use efficiency in the agricultural sector;
- Benchmarking of irrigation water use efficiency and setting irrigation water use efficiency targets for each scheme;
- Preparation of an irrigation water management plan for each irrigation scheme;
- Capacity building of the Government Water Schemes (GWS's), Irrigation Boards (IBs) and Water User Associations (WUAs) to implement the identified opportunities to improve irrigation water use efficiency.

Overview of the Mooi River Irrigation Scheme

The Mooi River Irrigation Scheme was established in the early 1960's with the construction of the Klerkskraal Dam (which has a storage capacity of 7.9 million m^3) and the Boskop Dam (which has a storage capacity of 20.84 million m^3).

Schedule of rateable area

The Mooi River Irrigation Scheme has a total schedule of rateable area of 4 578.11 hectares, comprising of 865.4 ha downstream of the Klerkskraal Dam, 2 495.20 ha supplied from the Boskop Dam canal system, 278.3 ha supplied from the Gerhardminnebron canal system and 939.20 ha supplied from the Lakeside Dam canal system.

The Mooi River Irrigation Scheme has a total scheduled quota of 35.25 million m^3/a, at 7 700 m^3 per ha per annum scheduled allocation.

The main types of crops irrigated in the Mooi River Irrigation Scheme are mainly maize, wheat and vegetables.

Conveyance and delivery infrastructure

Water to the water users in the Mooi River Irrigation Scheme is delivered through a system of canal infrastructure comprising of six main canals namely the Klerkskraal left and right bank canal, the Boskop left and right bank canals, Gerhardminnebron canal as well as the Lakeside canal. There are branch canals from these main canals which deliver water to the sluice gates at the irrigators' farms.

The total length of the canal infrastructure excluding drainage canals is approximately 210 km with all the canals concrete lined. This comprises of 64 km of concrete lined canal for the Klerkskraal canal system, 92 km of concrete lined canals for the Boskop canal system including branch canals, 14.15 km of concrete lined canals for the Gerhardminnebron canal system and 41.12 km of concrete lined canals for the Lakeside Canal system.

The condition of the canals was found to be generally fair to very poor in some sections particularly in the Boskop right bank canal.

Besides the canal infrastructure there are sluice gates and Parshall Flumes to measure the volume of water taken by each water user in the canal.

Irrigation storage and regulation

There are no balancing dams in the Mooi River Irrigation Scheme. However the scheme is such that two of the major dams, Boskop and Lakeside Dam are situated in the middle of the scheme. These provide the balancing and regulation of flow to downstream water users of the Mooi River GWS. These dams have the effect of reducing the time it takes to deliver water to downstream water users while balancing any irrigation spills from upstream water users.

Findings of the situation assessments

A situation assessment of the Mooi River Government Scheme was conducted to determine the water management issues affecting the effective and efficient use of the available water to the scheme. The assessment was conducted at sub-scheme level, with the Mooi River Irrigation Scheme divided into six sub-schemes, Klerkskraal left bank and right bank sub-schemes, Boskop left bank and right bank sub-schemes, Gerhardminnebron canal sub-scheme and the Lakeside canal sub-scheme.

Best Management Practice - Expected water losses

An evaluation of the expected water losses based on the existing canal infrastructure and assuming the infrastructure is maintained was conducted for the Mooi River canal system. The analysis indicated that the unavoidable water losses due to evaporation losses and seepage due to the expected hydraulic conductivity of lined canals is 6.7 million m^3/a, which translates into 8% of the total volume of water released into the Mooi River canal system.

There are expected to be operational inefficiencies due to the canal filling required after the dry periods, the metering errors even after calibration as well as problems in matching supplies and demands when applicants make changes to their requirements during the week. This was determined to be 10% of the total releases into the Mooi River canals respectively.

Based on the evaluation of the unavoidable water losses and the expected operational inefficiencies for the Mooi River Irrigation Scheme, the water delivery Best Management

Practice (BMP) should be based on the allowable water losses of approximately 18 % of the total inflow into the Mooi River irrigation canals.

Water balance assessment

A water balance assessment that was conducted for the Mooi River GWS irrigation sub-schemes indicated that the water losses in the all the sub- schemes exceeded the minimum expected seepage and evaporation losses. The average water loss based on the historic water use records was determined to be an average of 36% (see **Table 1** below) of the total water released into the Mooi River GWS. This ranged from 6% in the Gerhardminnebron eye canal system, to 80% in the Lakeside canal system.

Table 1: Water Losses in the Mooi River Government Water Scheme (million m^3/a)

Description	Unavoidable losses	BMP for operation & distribution	Avoidable losses	Total losses	% of total losses
Seepages	5.72			5.72	18.9%
Evaporation	1.02			1.02	3.4%
Filling losses					
Leakages					
Spills		8.31	15.14	23.45	77.7%
Operational Losses					
Over delivery to users					
Canal end returns*			53.89		
Canal end returns contributing to downstream use within the GWS			53.89		

Description	Unavoidable losses	BMP for operation & distribution	Avoidable losses	Total losses	% of total losses
Total (excl the canal tail-ends which contribute to downstream users within the GWS)	6.72	8.31	15.14	30.19	
% of total losses	22%	28%	50%	100%	
% of total volume released into system	8%	10%	18%	36%	

The equivalent depth of water released per actual unit area irrigated was determined. In the Mooi River Government Scheme, the trend line indicates that it has been fairly constant at 3 500mm per ha of water diverted from 2001 to 2008 water years for the scheme. However there was a decline after 2006 in the release per unit of irrigated areas (see **Figure 1** below).

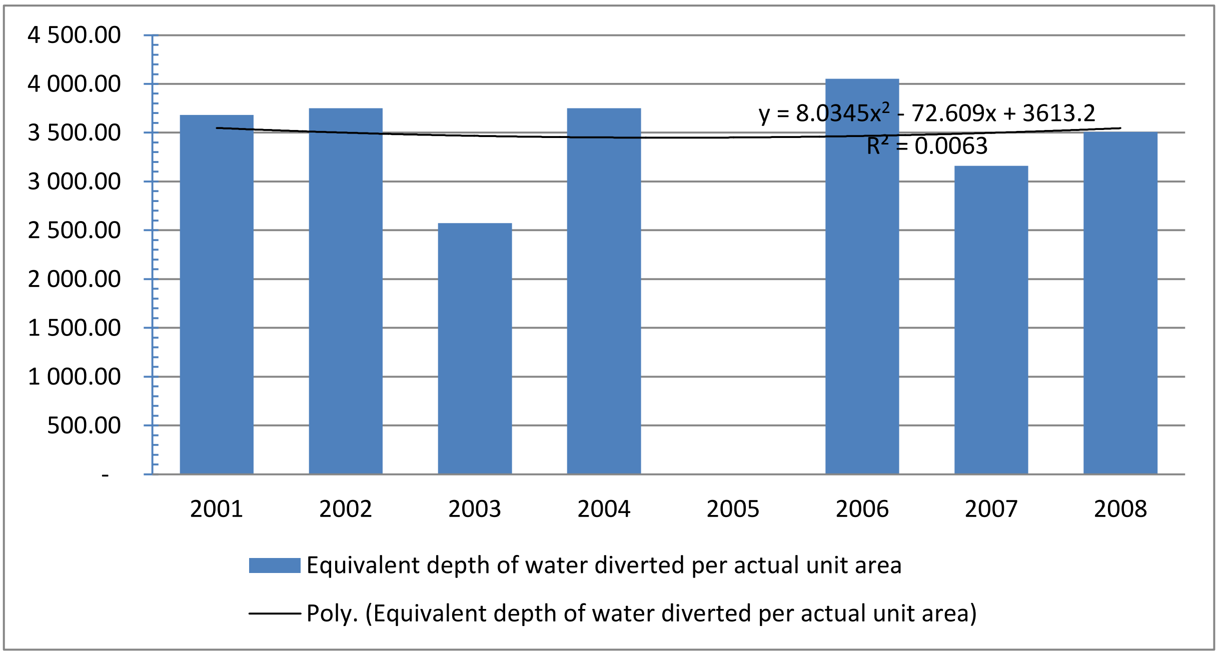

Figure 1: Irrigation water released expressed as an equivalent depth of water released per actual unit area irrigated for the Mooi River GWS canals

The slight decline in the irrigation diversions per unit of irrigated land is to an extent an indication that there are some improvements in irrigation water use efficiency during the period when the records were available.

However when sub-scheme is analysed the Lakeside canal system the trend line indicates that the irrigation conveyance efficiency has been declining over the same period (see **Figure 2** below). This may be attributed to the fact that more water is being released into the canals than is necessary because of the high volumes of spills at canal tail ends.

Any improvements for example in on-farm water use efficiency maybe likely to be offset with the increase in water losses. This conclusion has however only been reached with very limited data as no other historical data was available and will need to be verified in time.

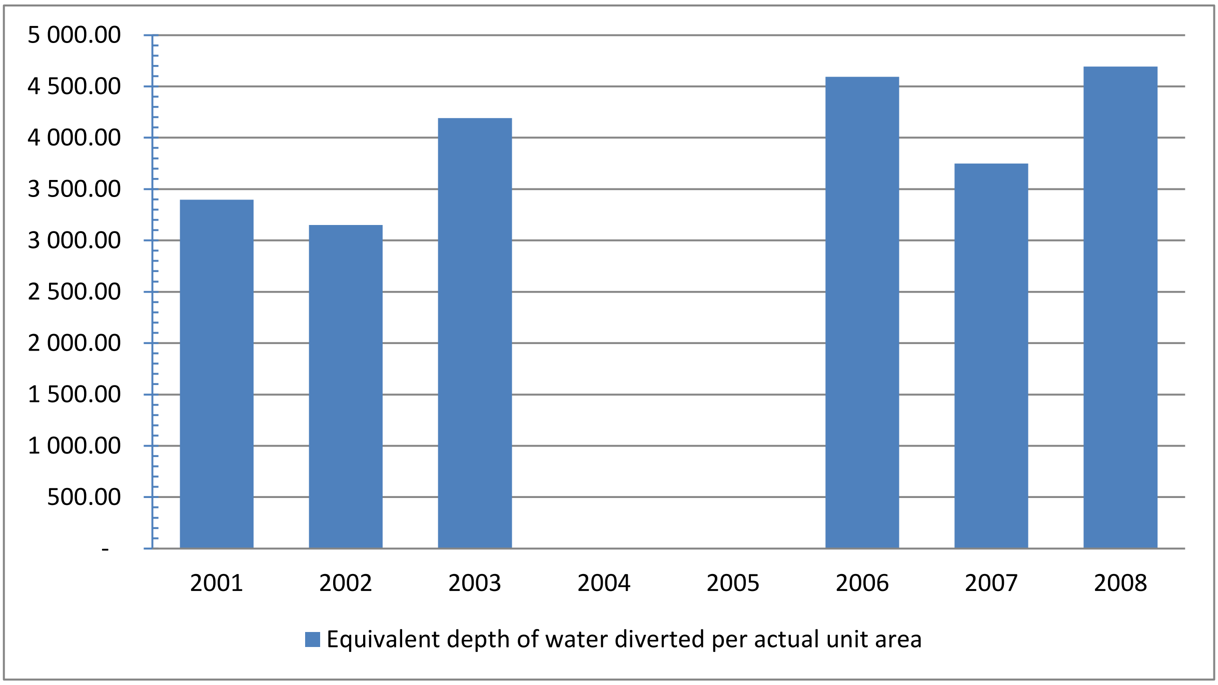

Figure 2: Irrigation water released expressed as an equivalent depth of water released per actual unit area irrigated for the Lakeside canals

Water Management Issues

A number of water management issues affecting the effective and efficient use of water in the Mooi River Irrigation Scheme were identified based on the water balance assessment, discussions with scheme managers and some field work that was conducted. The main water management issues identified include the following:

(i) There is a lack of measurement at some of the critical points in the scheme for a comprehensive water balance assessment to be conducted. These include the canal tail ends as well as flows into the downstream dams. The spills at the last two canal tail ends of the Boskop right bank and Lakeside canals are considered losses and can be avoided if regular flow measurements were taken. Therefore the current water balances are not accurate as they are based on estimates.

(ii) Although there is sufficient flow measurements, the accuracy of some of the measuring system such as Parshall Flumes and lack of continuous flow monitoring to enable quick responses to operational problems have resulted in the low water use efficiency levels in the Mooi River Irrigation Scheme.

(iii) The water administration system to manage water use is not being fully utilised for sub-scheme water budgets.

(iv) The conditions of the canal infrastructure particularly in the Boskop right bank canal system were found to be poor. There are sections of the canal which will require complete renewal as some of the concrete panel sections have moved. This is attributed to soil conditions of the area. The DWA has already commenced with the refurbishment of these canal sections.

(v) The capacity of the Mooi River GWS to conduct full maintenance of the canal infrastructure including refurbishment is limited while the current water charge by the DWA for the Return on Assets (ROA) does not appear to cover for the full cost of depreciation of the assets.

(vi) The current water rate structure does not have elements of incentive based pricing aspects. The fact that water users are charged a flat rate based on their scheduled quota does not provide an incentive to improve water use efficiency through managing demand.

Water Management Plan for the Mooi River Irrigation Scheme

Establishment of water saving targets at sub-scheme level

The implementation of a Water Management Plan for the Mooi River Irrigation Scheme to reduce water losses will imply reducing the water released per unit of the land area irrigated in the scheme. As is expected this will not affect the yields of the maize, wheat, vegetable crops being irrigated in the scheme area.

Therefore reducing the water released per unit of land area would mean an increase in productivity per unit of water which would be a clear indication of progress towards greater efficiency for the Mooi River Irrigation Scheme assuming the scheduled quota of 7 700 m^3/ha/a remains constant.

A number of water management intervention measures were identified and a management plan developed to improve irrigation conveyance water use efficiency by reducing the avoidable water losses. The long term water savings targets for improving water use conveyance efficiency in the Mooi River Government Water Scheme is to save approximately 15.13 million m^3/a over a 10 year period (see **Table 2** below).

Table 2: Estimated water saving targets for the Mooi River Government Water Scheme (million m^3/a)

<table>
<tr><th rowspan="2">Description</th><th rowspan="2">System Inflow</th><th colspan="5">Present Situation - Losses</th><th colspan="2">Acceptable Water Losses</th><th colspan="3">Target Water Savings</th></tr>
<tr><th>Unavoidable losses</th><th>BMP for distribution losses</th><th>Avoidable losses</th><th>Total losses</th><th>% of Total Volume Released</th><th>Annual Volume</th><th>% of Total Volume Released</th><th>Annual Volume</th><th>% of Total Volume Released</th><th>Intervention measure</th></tr>
<tr><td>Seepages</td><td></td><td>5.72</td><td></td><td></td><td>5.72</td><td>6.9%</td><td></td><td></td><td>0</td><td>0%</td><td>None</td></tr>
<tr><td>Evaporation</td><td></td><td>1.02</td><td></td><td></td><td>1.02</td><td>1.2%</td><td></td><td></td><td>0</td><td>0%</td><td>None</td></tr>
<tr><td>Filling losses</td><td></td><td></td><td rowspan="6">8.31</td><td rowspan="6">15.14</td><td rowspan="6">23.45</td><td rowspan="6">28.2%</td><td rowspan="5">15.1</td><td rowspan="5">18%</td><td></td><td>0%</td><td></td></tr>
<tr><td>Over delivery to users</td><td></td><td></td><td></td><td>0%</td><td></td></tr>
<tr><td>Leakages</td><td></td><td></td><td rowspan="2">7.71</td><td rowspan="2">9%</td><td rowspan="2">Refurbishment & resealing</td></tr>
<tr><td>Infrastructure condition</td><td></td><td></td></tr>
<tr><td rowspan="2">Operational Losses</td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2">3.28</td><td rowspan="2">4%</td><td>Flow measurement & monitoring</td></tr>
<tr><td></td><td></td><td>Recalibration of Parshall flumes</td></tr>
</table>

Description	System Inflow	Present Situation - Losses					Acceptable Water Losses		Target Water Savings		
		Unavoidable losses	BMP for distribution losses	Avoidable losses	Total losses	% of Total Volume Released	Annual Volume	% of Total Volume Released	Annual Volume	% of Total Volume Released	Intervention measure
Canal end returns									4.10	5%	Management of Canal tail ends
											Management of Operational spills, eg removal of aquatic weeds
Other					0.00	0.0%				0%	
Total		6.74	8.31	15.14	30.19	36.3%	15.1	18%	15.09	18%	
Loss as a % of total losses		22%	28%	50%	100%						
Loss as a % of total volume released into system		8%	10%	18%	36%						
Total releases into Scheme	83.14										

Identified water management measures to improve water use efficiency in the Mooi River Irrigation Scheme

The priority water management measures to improve irrigation water use efficiency on the Mooi River Government Water Scheme include the following:

(1) Water measurements of the flow rates, duration and volume of flows at all the critical points which include the inflow and outflow at the balancing dams, the branch canals, as well as the canal tail ends, etc.

(2) Preparation of more detailed water balance assessments for the Mooi River Government Water scheme, as well as the sub-schemes to enable prioritisation of intervention on the sub-schemes where the conveyance efficiency levels are found to be very low.

(3) Implementation of all modules of the WAS programme to enable irrigation monitoring and control of water use to reduce operational losses such as canal tail ends spills to be carried out as well as undertake water balance assessment at scheme as well as sub-scheme level.

(4) Reducing the algae and water grass problems which are affecting the hydraulic capacity of the canal infrastructure resulting in flow measurement inaccuracy.

(5) Installation of telemetry infrastructure to enable real time monitoring of irrigation water in the long term.

(6) Maintenance and refurbishment of the existing delivery canals as well as the siphons, in order to reduce leakage losses, improve flow rates and increase head at diversion points.

(7) Developing an incentive based water pricing structure to improve irrigation water use efficiency and reduce significant fluctuations in demand.

Conclusions and Recommendations

A water management plan for the Mooi River Irrigation Scheme was developed to address the water losses taking place in the scheme and to improve irrigation water management of the scheme. The identified measures for implementation to reduce the water losses from the current 36% to 18% of the total inflow into the irrigation scheme include the following:

(i) *Installation of water measurement* - This measure has the second most benefit with estimated water savings 3.28 million m^3/a, at an average incremental cost of R0.09 per m^3. It is however easy to implement and should be considered a priority as all other measures are dependent on availability of sufficient water measurements in the Mooi River Irrigation Scheme.

(ii) *Operational spills and Chemical management of aquatic weeds and algae growth in canals* - This measure has the most benefit with estimated water savings of 4.1 million m^3/a, at an average incremental cost of R0.08 per m^3. It should be carried out at the same time as the first intervention measure.

(iii) *Water Accounting System* - This measure is aligned to the first measure and will provide the system necessary to identify areas where irrigation water management can be improved. The changes in operation of the canals and canal tail ends can result in water savings for the scheme if no water is allowed at the canal tail ends.

(iv) *Refurbishment of the canal infrastructure* - This measure is likely to be very expensive but will benefit the scheme in the long term with the estimated water savings of 7.71 million m^3/a. Because of the high capital investment requirements, the average incremental cost to implement this water management measure is likely to be very high

(v) *Incentive based water pricing structure*- This measure has the least benefit with estimated water savings of 1.09 million m^3/a. The average incremental cost to implement this water management measure is likely to be very low as this will be done at national level.

In order to enable the implementation of the Water Management Plan (WMP) for the Mooi River Irrigation Scheme it is imperative that Scheme Manager, Chief Water Control Officer and Water Control Officers are appointed by the DWA Regional Office for the optimal running of the Scheme.

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ABBREVIATIONS

AIC	Average Incremental Cost
BMP	Best Management Practice
DWA	Department: Water Affairs
ET	Evapo-Transpiration
EWR	Environmental Water Requirements
GIS	Geographic Information System
WUA	Water User Association
IB	Irrigation Board
MAE	Mean Annual Evaporation
MAP	Mean Annual Precipitation
MISD	Matching Irrigation Supply and Demand
O&M	Operation and Maintenance
RAT	Remote Assessment Tool
RTU	Remote Telemetry Unit
SLA	Service Level Agreement
WARMS	Water Allocation Registration Management System
WAS	Water Administration System
WCA	Water Control Aid
WCD	Water Control Department
WC/WDM	Water Conservation and Water Demand Management

WCO	Water Control Officer
WMA	Water Management Area
WMP	Water Management Plans
WUA	Water Use Association
WUEAR	Water Use Efficiency Accounting Report

GLOSSARY OF TERMS

Application efficiency	The ratio of the average depth of irrigation water infiltrated and stored in the root zone to the average depth of irrigation water applied, expressed as a percent.
Applied water	Water delivered to a user. Also called delivered water. Applied water may be used for either inside uses or outside watering. It does not include precipitation or distribution losses. It may apply to metered or unmetered deliveries
Conduit:	Any open or closed channel intended for the conveyance of water.
Conservation	Increasing the efficiency of energy use, water use, production, or distribution.
Consumptive use (evapo-transpiration)	Combined amounts of water needed for transpiration by vegetation and for evaporation from adjacent soil, snow, or intercepted precipitation. Also called: Crop requirement, crop irrigation requirement, and consumptive use requirement.
Conveyance loss	Loss of water from a channel or pipe during conveyance, including losses due to seepage, leakage, evaporation and transpiration by plants growing in or near the channel.
Conveyance system efficiency	The ratio of the volume of water delivered to irrigators in proportion to the volume of water introduced into the conveyance system.
Cropping pattern:	The acreage distribution of different crops in any one year in a given farm area such as a county, water agency, or farm. Thus, a change in a cropping pattern from one year to the next can occur by changing the relative acreage of existing crops, and/or by introducing new crops, and/or by cropping existing crops.
Crop water requirement:	Crop consumptive use plus the water required to provide the leaching requirements.
Crop irrigation	Quantity of water, exclusive of effective precipitation, that is needed

requirement:	for crop production.
Crop root zone:	The soil depth from which a mature crop extracts most of the water needed for evapo-transpiration. The crop root zone is equal to effective rooting depth and is expressed as a depth in mm or m. This soil depth may be considered as the rooting depth of a subsequent crop, when accounting for soil moisture storage in efficiency calculations.
Deep percolation:	The movement of water by gravity downward through the soil profile beyond the root zone; this water is not used by plants.
Demand scheduling:	Method of irrigation scheduling whereby water is delivered to users as needed and which may vary in flow rate, frequency, and duration. Considered a flexible form of scheduling.
Distribution efficiency:	Measure of the uniformity of irrigation water distribution over a field.
Distribution loss:	See conveyance loss.
Distribution system:	System of ditches, or conduits and their appurtenances, which conveys irrigation water from the main canal to the farm units.
Diversion (water):	Removal of water from its natural channels for human use.
Diversion (structure):	Channel constructed across the slope for the purpose of intercepting surface runoff; changing the accustomed course of all or part of a stream.
Drainage:	Process of removing surface or subsurface water from a soil or area.
Drainage system:	Collection of surface and/or subsurface drains, together with structures and pumps, used to remove surface or groundwater.
Drip (trickle) irrigation:	An irrigation method in which water is delivered to, or near, each plant in small-diameter plastic tubing. The water is then discharged at a rate less than the soil infiltration capacity through pores, perforations, or small emitters on the tubing. The tubing may be laid on the soil

	surface, be shallowly buried, or be supported above the surface (as on grape trellises).
Drought:	Climatic condition in which there is insufficient soil moisture available for normal vegetative growth.
Dry Period:	A period during which there will be no water flowing in the canal system.
Evaporation:	Water vapour losses from water surfaces, sprinkler irrigation, and other related factors.
Evapo-transpiration:	The quantity of water transpired by plants or evaporated from adjacent soil surfaces in a specific time period. Usually expressed in depth of water per unit area.
Farm consumptive use:	Water consumptively used by an entire farm, excluding domestic use. See irrigation requirement, consumptive use, evapo-transpiration.
Farm distribution system:	Ditches, pipelines and appurtenant structures which constitute the means of conveying irrigation water from a farm turnout to the fields to be irrigated.
Farm loss (water):	Water delivered to a farm which is not made available to the crop to be irrigated.
Geographic Information System (GIS)	Spatial Information systems involving extensive satellite-guided mapping associated with computer database overlays
Incentive pricing	This involves setting water rates that provide motivation to use water efficiently
Irrigation schedule	This is the list prepared by the Board showing the sequence the Irrigators will lead and dependent on the scheduled area the time period that the Irrigator is entitled to receive water
Maintenance	This is the process of keeping the irrigation and drainage infrastructure assets in good repair and working order to fulfil the

functions for which they were created.

Modernisation This is the process of upgrading (replacing) an existing asset in order to meet enhanced technical capacity and level of service objectives.

On-farm: Activities (especially growing crops and applying irrigation water) that occur within the legal boundaries of private property.

On-farm irrigation efficiency: The ratio of the volume of water used for consumptive use and leaching requirements in cropped areas to the volume of water delivered to a farm (applied water).

Operational losses: Losses at the tail ends, sluices not opened or closed on time or opened to big and spills

Operational waste: Water that is lost or otherwise discarded from an irrigation system after having been diverted into it as part of normal operations.

Pan evaporation: Evaporative water losses from a standardized pan. Pan evaporation is sometimes used to estimate crop evapo-transpiration and assist in irrigation scheduling.

Parshall flume: A calibrated channel-like device, based on the principle of critical flow, used to measure the flow of water in open conduits. Formerly termed the Improved Venturi Flume.

Percolation: Downward movement of water through the soil profile or other porous media.

Rehabilitation: This is the process of renovating an existing asset whose performance is failing to meet its original objective to its original design specifications. This may also be referred to as asset reproduction.

Reservoir: Body of water, such as a natural or constructed lake, in which water is collected and stored for use.

Return flow: That portion of the water diverted from a stream which finds its way back to the stream channel, either as surface or underground flow.

Return-flow system:	A system of pipelines or ditches to collect and convey surface or subsurface runoff from an irrigated field for reuse. Sometimes called a "reuse system or a “recovery system”.
Risk cost:	This is usually expressed as the product of the cost of damage caused by the actual hazard occurrence and the probability of occurrence.
Run-off	This is the water produced when irrigation water is applied to fields at rates and in amounts greater than can be infiltrated into the soil profile Tail end water i
Request Form :	A form on which an Irrigator requests the quantity of water he requires.
Tail end water	This is water at the endpoint of a canal
Telemetry	Involving a wireless means of data transfer
Water Note	A form issued by the Control Officer informing the Irrigator of the quantity of water he will be receiving.

1 INTRODUCTION

1.1 Background

Irrigation agriculture is the biggest water user in the South Africa, using approximately 62% of the current water use nationally. With the increasing competition between existing user sectors, the available water cannot meet the demand under current water use practices and operating conditions in all water use sectors. It is therefore imperative to ensure that available water supplies are used efficiently and effectively to avoid supply shortages and intermittent water supplies, which would have a major impact on the socio-economic growth and development of the country.

The savings that can potentially be made from implementing WC/WDM measures will delay in the need for the development of additional new water supplies, while ensuring that the natural environment is maintained or is not degraded further. The Department of Water Affairs (DWA) identified that, based on preliminary assessment of water losses in the agricultural sector, there was potential to implement measures to improve water use efficiency in the sector. The overall aim in reducing water losses and improving irrigation water use efficiency levels in the Water User Associations (WUAs)/Irrigation Boards (IBs) is that the limited available water can be optimally utilised to ensure a high economic return for the scheme area.

The study was commissioned because of the increasing water scarcity[2] in a number of Water Management Areas (WMAs). One of the approaches in addressing the increasing water scarcity and competition for water is to ensure that existing water users utilise their existing water entitlement efficiently. The Department of Water Affairs (DWA) Directorate: Water Use Efficiency, which has the mandate to ensure the efficient use of the water resources in the country by all water use sectors, identified that since the development of the pilot Water Management Plans (WMPs) for improving water use efficiency in irrigation agriculture, no

[2] Water scarcity – this is an imbalance of supply and requirement under prevailing institutional arrangements indicating an excess of water requirements over available water at the required assurance of supply, especially if the remaining supply options are difficult or costly to tap. The current utilisation as a percentage of total available resources at the required assurance of supply can illustrate the scale of the problem and the latitude for policymakers

progress had been made by the irrigation sector with respect to the development and implementation of WMPs for that sector.

In order to ensure the irrigation sector review their current water use efficiency levels and develop strategies to improve their water use efficiency, the DWA has identified a need to assist a number of irrigation schemes in developing their irrigation water management plans in order to primarily reduce their water losses. A secondary outcome can be seen as the enablement of irrigators to increase their on-farm irrigation efficiency.

Following the meetings with DWA Directorate: Water Use Efficiency, Mooi GWS and the DWA Regional Offices, this report provides the following:

- Overview of the water allocation and irrigation water use situation of the Mooi River GWS and related institutional arrangement for irrigation water management
- Identification and assessment of the water management issues and management goals expected to address the irrigation water management issues identified.

1.2 Study Objectives

The primary objective of the study is the development and implementation of irrigation WMPs for 14 irrigation schemes (see **Figure 1.1** below) to improve water use efficiency in the agricultural sector. In order to achieve this objective, the following tasks have to be undertaken:

- Compilation of a situation assessment of the current water use and irrigation water use practices in the fourteen irrigation schemes;
- Determination of the irrigation water budget and establishing water use baseline for each irrigation scheme;
- Determination of the irrigation water management issues based on the situation assessment and water budgets prepared for each irrigation scheme;
- Identification of opportunities to improve water use efficiency in the agricultural sector;
- Benchmarking of irrigation water use efficiency and setting irrigation water use efficiency targets for each scheme;
- Preparation of an irrigation water management plan for each irrigation scheme;
- Capacity building of the GWS, IBs and WUAs to implement the identified opportunities to improve irrigation water use efficiency.

Figure 1:1: Location of the 14 irrigation schemes where WMPs have been developed

The development of the WMPs for the selected Irrigation Schemes will not only provide a plan for reducing water losses and improve system efficiencies, but if the management plan is implemented and water losses and water demand is reduced, the benefits to the agricultural sector, customers and the catchments in general will include:

- Improved system efficiencies;
- Reduction in irrigation water return flows;
- Reduction in system operation and maintenance expenses;
- Potential cost savings due to deferral or downsizing of capital works;
- Benefits which are important but difficult to quantify such as reduced environmental impact resulting from delays in or deferment of construction of water sources and the maintenance of higher water levels in rivers and reservoirs.

1.3 Structure of the report

This report has been structured to first provide a perspective of the Mooi River Irrigation Scheme as well as the potential for irrigated agriculture in the Mooi River GWS catchments.

Chapter 1 provides the overall objective of assessing water conservation and demand management measures in the context of increasing competition between existing water users and the need for water for the environment.

Chapter 2 describes the catchment characteristics of the Mooi River catchment in which the Mooi River Government Water Scheme is situated.

Chapter 3 describes the history of the Mooi River Irrigation Scheme and the scheduled quota. It also describes the catchment and the current land-use practices in the catchment. The chapter also describes the background to the scheme, the institutional arrangements.

Chapter 4 gives an overview of the inventory of the existing irrigation water management infrastructure which includes the size and capacity of the canals, the dams supplying the scheme; any balancing dams in the Mooi River Irrigation Scheme as well as the flow measurements available in the scheme.

Chapter 5 describes the condition of the conveyance infrastructure. A framework for determining the condition assessment of the infrastructure is described while the condition of the various sections of the main canals and the branch canals are discussed based on discussions with scheme operators; surveys conducted during the various site visits, and available information.

Chapter 6 of this report describes how the scheme is currently being operated to provide irrigation water to the irrigators. The scheme operating procedures including how the irrigators are supplied during drought periods is presented in this chapter.

Chapter 7 uses the information from the previous chapters to determine the irrigation water Best Management Practices for the irrigation schemes. This determines how much water losses would be expected if the scheme infrastructure is well maintained. Therefore the approach used to determine the expected seepage losses as well as the evaporation losses are described in the chapter of the management plan. It then describes the standards that can be adopted as appropriate for benchmarking of irrigation water use and management practices.

Chapter 8 describes the water balance assessment, as conducted, based on the water use and compared with expected irrigation efficiency levels for the different irrigation systems. This chapter also provides the performance benchmarking of the irrigation sector when compared with the expected standards.

Chapter 9 of this report describes the existing irrigation water management measures that the irrigation scheme is currently undertaking to improve irrigation water management efficient and reduce the water losses taking place in the irrigation scheme. is currently undertaking. These include flow measurement, availability of balancing dams, flow monitoring to reduce operational losses if any, canal maintenance during the dry periods; etc.

Chapter 10 then discusses the water management issues identified from the previous chapters. It then sets the management goals required to ensure any identified water management issues can be addressed.

Chapter 11 of the report provides an assessment of the identified water management measures that can be implemented to achieved the goals and objectives set in chapter 9. This is the strategic WC/WDM business plan for irrigation agriculture. The chapter also provides an estimate of the capital investment required to implement the strategy. It also provides the performance indicators for monitoring and controlling the implementation of the measures.

Chapter 12 presents the water management plan. This summarises all the water management issues, the irrigation water saving targets recommended to be achieved and the water management tasks to achieve the targets set to reduce water losses and improve irrigation water management efficiency of the scheme.

Chapter 13 provides a conclusion and recommendation for the irrigation sector.

2 CATCHMENT CHARACTERISTICS OF THE MOOI RIVER CATCHMENT

2.1 Overview

The Mooi River Government Water Scheme is in the North West Province. It traverses two Local municipalities namely the Ventersdorp and Tlokwe Local Municipalities which are situated in the Dr Kenneth Kaunda District Municipality which is located in the North West Province. The nearest main town is Potchefstroom located within the government water supply scheme area. **Figure 2.1** presents the locality map of the Mooi River Government Water Scheme area.

The Mooi River has its headwaters in dolomitic aquifers which discharge at the Bovenste eye upstream of Klerksraal Dam. The Mooi River has the Wonderfonteinspruit as its main tributary. It has its headwaters in the Wonderfonteinspruit eye where there are dolomitic aquifers. The main source of the Mooi River is therefore from the dolomitic aquifers.

There are two main storage dams in the Mooi River catchment, namely Klerkskraal and Boskop Dam. The Klerkskraal Dam is located at the headwaters of the Mooi River. The dam has a storage capacity of 7.9 million m^3. The dam was constructed in 1965 to meet the irrigation water requirements of the lands downstream of the Mooi River.

The Boskop Dam is located further downstream in the Mooi River after the confluence with the Wonderfonteinspruit. The dam was built in 1959 to improve the security of supply to the irrigation sector. It has storage capacity of 20.84 million m^3.

2.1.1 Climate and rainfall distribution

2.1.1.1 Precipitation

The climate and temperature variations of the Mooi River catchment are closely related to elevation. The study area experiences extreme conditions during the summer months (DWAF: 1999) with rainfall categorised into two climatic zones.

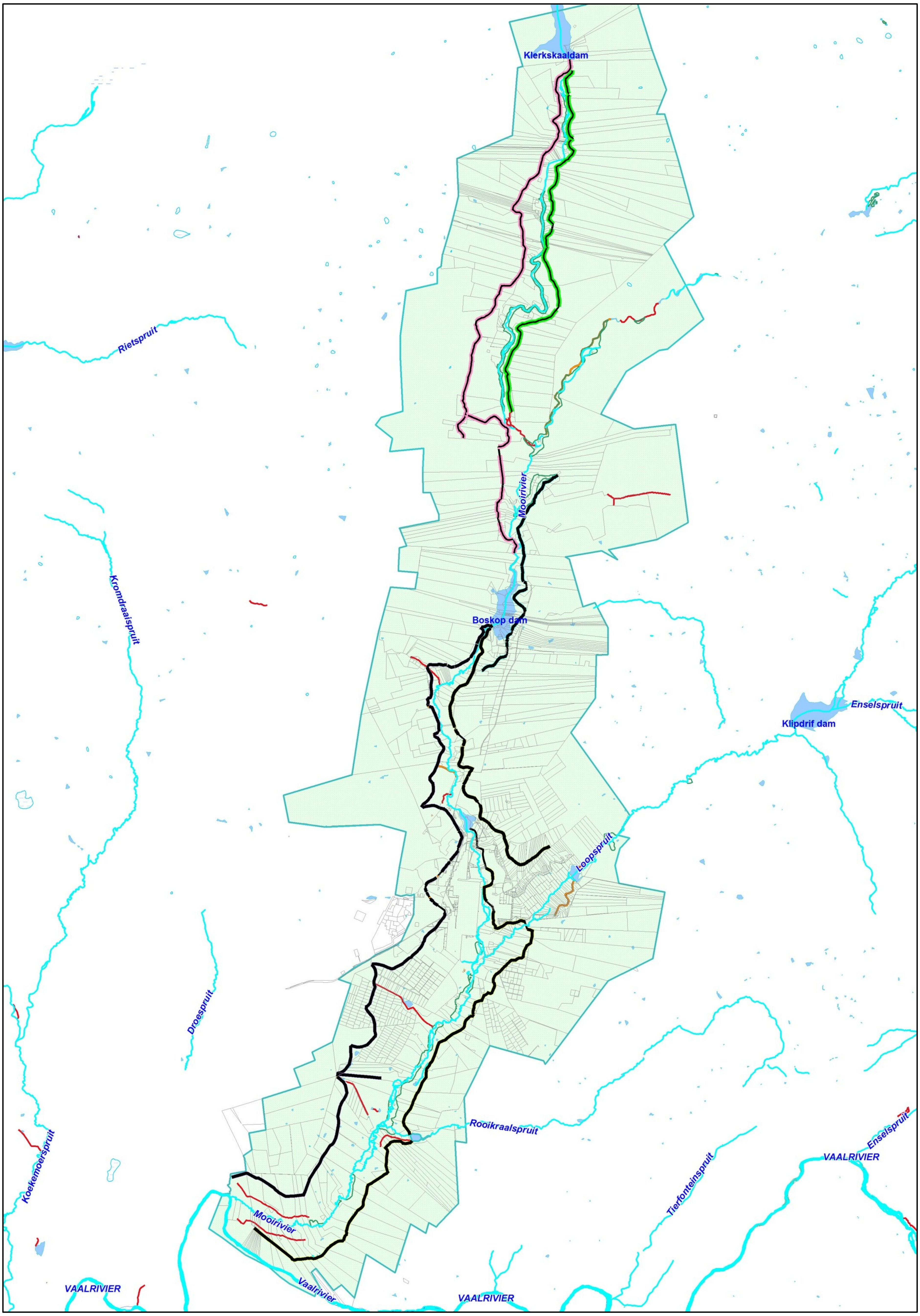

Figure 2:1: Map of Mooi River Government Water Scheme

The upper Mooi River catchment is characterised by the mean annual precipitation (MAP) ranging from 500mm to 599 mm in some areas while in other parts of the upper catchment the mean annual precipitation can be as high as 600 mm to 699 mm (see **Figure 2.2** below). The low rainfall requires the need to irrigate the lands in the Mooi River Government Water Scheme area.

The lower Mooi River catchment is characterised by slightly higher mean annual precipitation ranging between 600mm and 699 mm of rainfall.

2.1.1.2 Evaporation

The Mooi River Irrigation Scheme is located in one evaporation zone. The evaporation ranges between 1600mm to 1700mm in the whole of the irrigation scheme. The high evaporation rate has a direct correlation with the irrigation water use requirements.

2.1.2 Geology and soils of the catchment

The geology of the area supplied by the Mooi River Government Water Scheme (GWS) has an assemblage of dolomitic aquifers in the upper and middle catchments. This is the main source of the water supply into the Mooi River.

As a result of the predominant geological strata as well as the climate, the soils of the Mooi River Government Water Scheme can be categorised as moderate to deep sandy loam soils on undulating plains (see **Figure 2.3** below). The average soil depth in the scheme area is 650 mm. It is important to note that the sandy loam soils are ideal for irrigation because they possess a good balance between ability to drain water and water holding capacity. The water holding capacity is high, estimated to range between 104 mm per m and 117 mm per m (J.L. Schoeman and M. van der Walt).

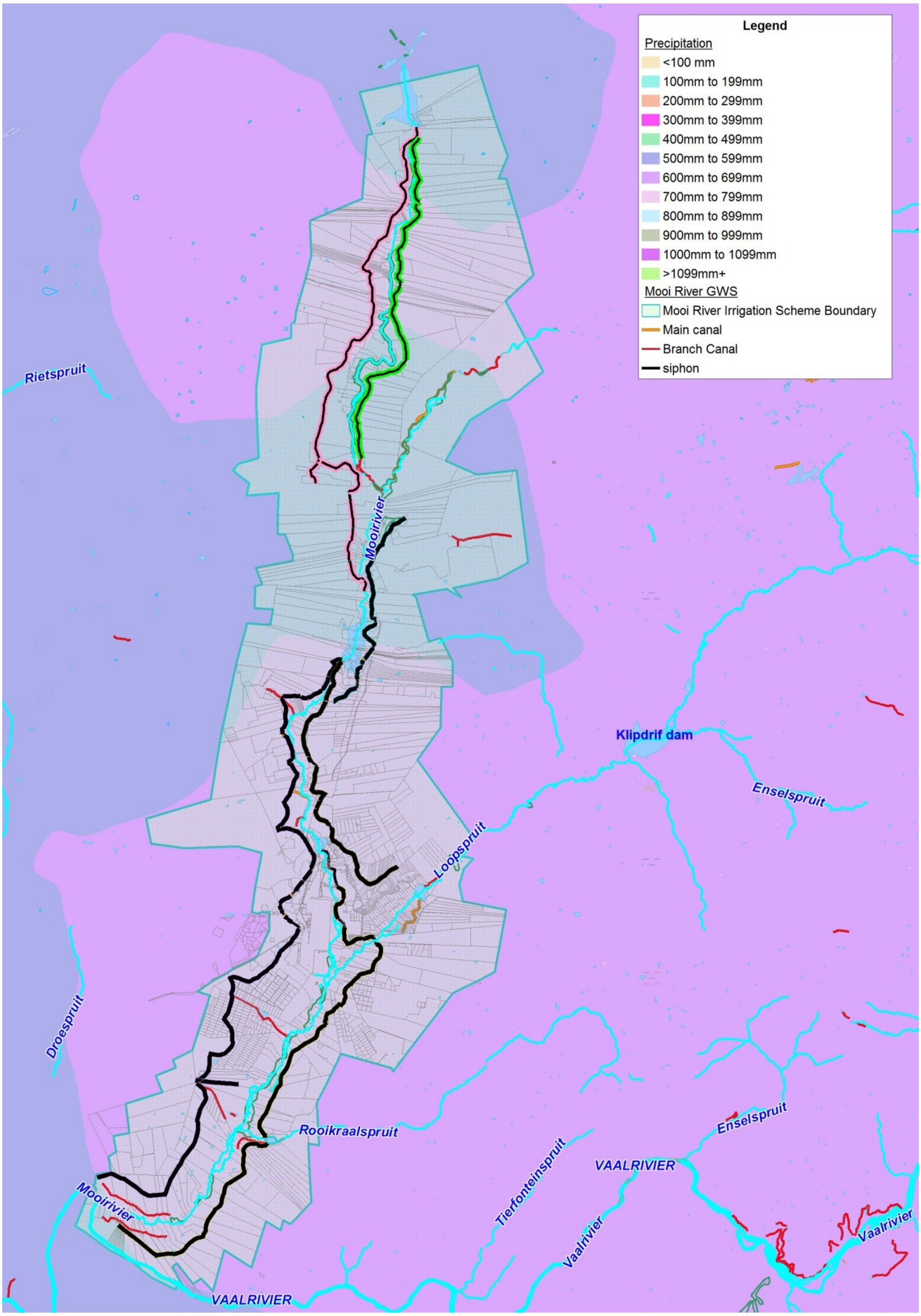

Figure 2:2: Precipitation Map of the Mooi River Irrigation Scheme

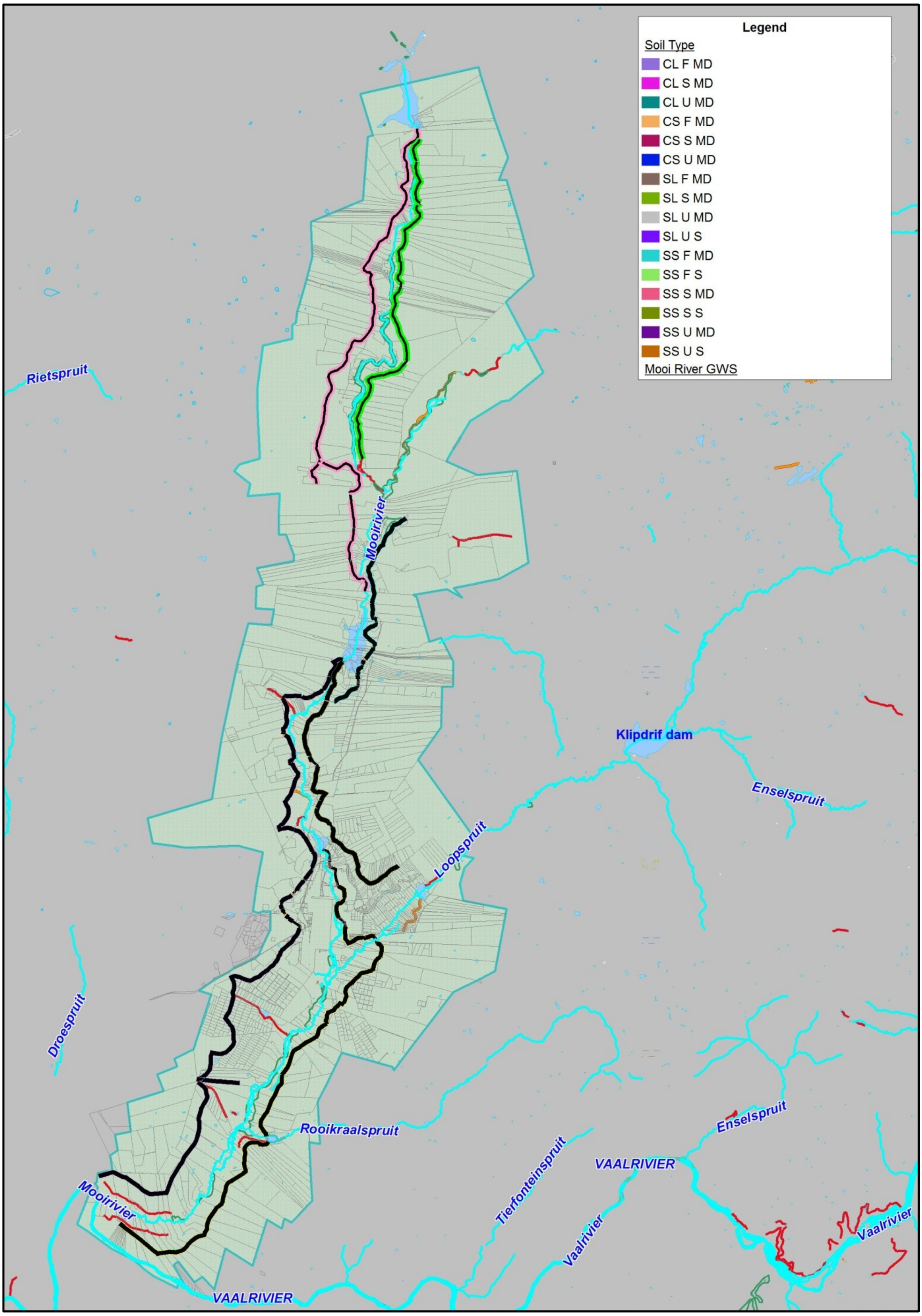

Figure 2:3: Mooi River Irrigation Scheme Soil Map

3 OVERVIEW OF THE MOOI RIVER GOVERNMENT WATER SCHEME

3.1 History of the Mooi River Irrigation Scheme

The Mooi River Government Water Scheme was established in the late 1960's with the construction of Klerkskraal Dam and Boskop Dam. It is situated close to the town of Potchefstroom and receives its water from the Klerkskraal and Boskop Dams in the Mooi River.

Besides the two dams, the Mooi River GWS also receives water from other sources. The other source of supply for the scheme is a weir on Mooirivierloop on a farm known as Gerhardminnebron. The source of this water is the dolomitic aquifers in the area. The yield at the weir is estimated to be 3.98 million m^3/a.

Downstream of the town of Potchefstroom on the left bank of the Mooi River, irrigators are supplied from the Lakeside Dam also known as Potchefstroom Dam.

The main irrigation canals were constructed downstream of the two dams and the Gerhardminnebron as discussed in latter sections of this document. These canals convey the water to the irrigation areas located downstream of the dams and the weir along the Mooi River as indicated **in Figure 3.1** below.

3.2 Scheduled rateable area

The Mooi River Government Water Scheme (GWS) comprises a total of 4 578.1 hectares. The major irrigation area is below the Boskop Dam where the enlisted area is 2 495.2 hectares, which is more than 50% of the scheduled area in the GWS. This is split into the Boskop right bank canal system with a scheduled area of 1 587.5 ha while the Boskop left bank canal system has a scheduled area of 907.7 ha. This section of the irrigation was commissioned in the early 1960's after the construction of the Boskop Dam.

The scheduled area between Klerkskraal Dam and Boskop Dam is approximately 865.4 ha comprising 592.7 ha which is supplied from the Klerkskraal right bank canal while 272.7 ha is supplied from the Klerkskraal left bank canal.

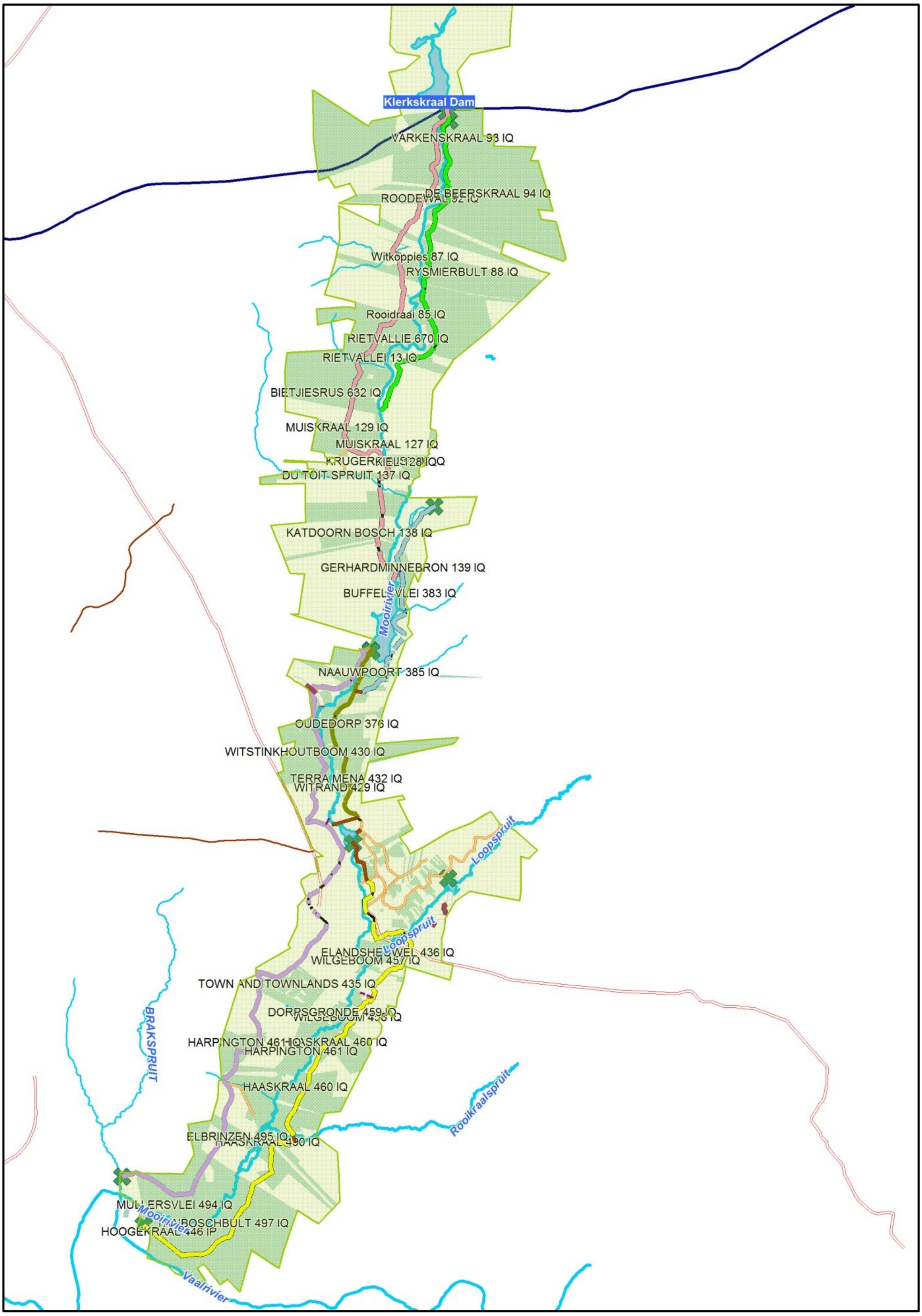

Figure 3:1: Mooi River Government Water Scheme

There is a scheduled area which is dependent on the groundwater from the Gerhardminnebron eye. The scheduled area is approximately 278.3 ha.

Further downstream of the Boskop Dam irrigation sub-scheme is the Lakeside irrigation sub-scheme which is located on the left bank of the Mooi River. The schedule of rateable area in this sub-scheme is approximately 939.2 ha which is supplied from the Lakeside Dam. This is the second largest irrigation sub-scheme of the Mooi River Government Water Scheme.

3.3 Organisational arrangements

The Mooi River Government Water Scheme is a government water scheme (GWS) since establishment. The DWA, through its Infrastructure Branch is responsible for the operation and maintenance of the scheme. As part of the operation of the irrigation scheme, the Infrastructure Branch supplies water not only to the irrigators in the Mooi River Government Water Scheme but also provides the water requirements for municipal water use through the canal infrastructure to the town of Potchefstroom.

The Mooi River Government Water Scheme is managed by a Proto Catchment Management Agency Area Manager who is performs the dual role for the strategic oversight and day to day management of the scheme. There is no Scheme Manager for the Scheme.

3.3.1 Water distribution Section

One of the key functions of the Mooi River GWS is the distribution of irrigation water as required and on time as well as civil and/or mechanical maintenance of the Mooi River Irrigation Scheme (see **Figure 3.2** below).

As part of the water distribution and/or operation of the irrigation scheme, the Mooi River GWS supplies not only the irrigators but also the water requirements of the domestic users in Potchefstroom, through the canal infrastructure.

There are two levels in the water distribution section which include the Water Control Officers; as well as the Water Control Aids (previously known as the canal guards) The Control Water Control Officer and Chief Water Control Officer fall under the Proto CMA but perform the dual role of overseeing the smooth and efficient running of the Government Water Scheme. Their responsibilities are discussed in the following sections.

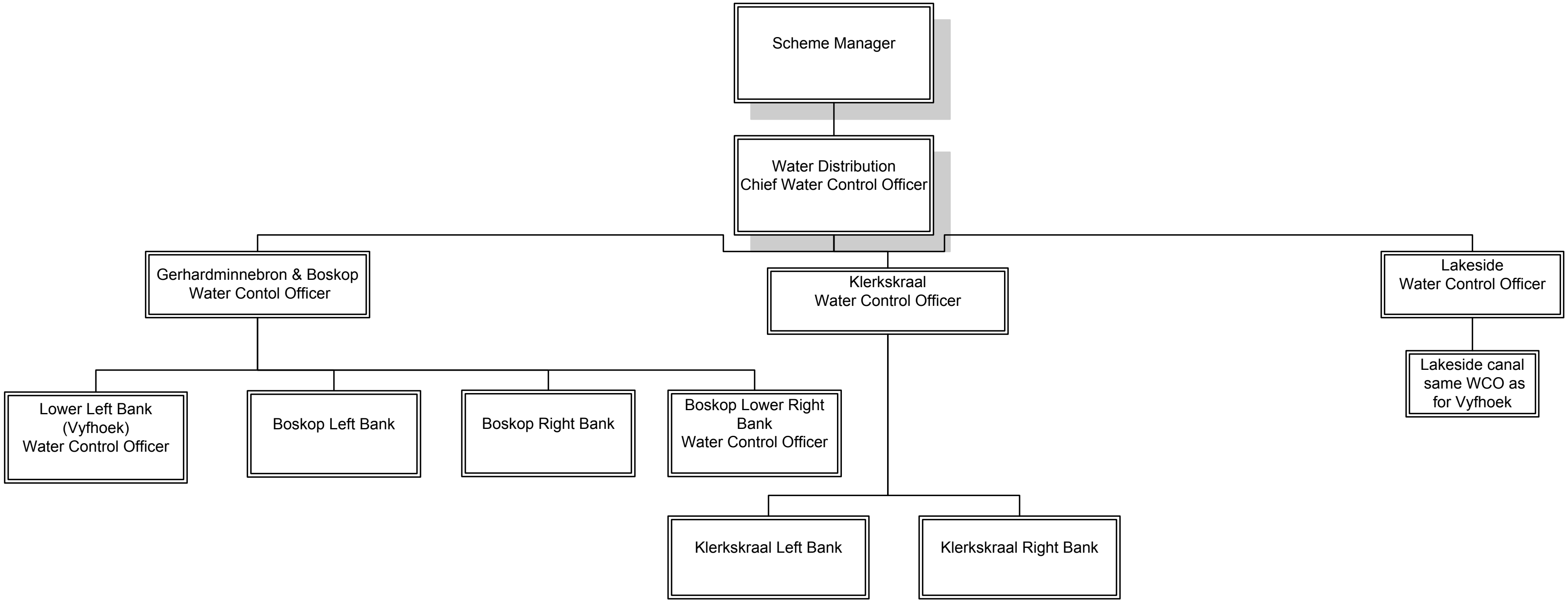

Figure 3:2: Organisational structure for water distribution in the Mooi River Government

3.3.1.1 Chief Water Control Officer

The Mooi River GWS does not have a Chief Water Control officer. There is a Chief Water Control Officer for the Proto CMA who performs the dual role for the operation of the Government Water scheme. He fulfils the dual function of collecting the information provided by the Water Control Officers (WCOs), process it and issue the operational orders to be executed. These include the amount and timing of releases from the Klerkskraal, Boskop, Gerhardminnebron and Lakeside Dams and the setting of the sluice gates and structures to deliver the required amount of irrigation water at the requested time, as requested by the irrigator on a weekly basis.

The job description of the Chief WCO for the Government Water Scheme role is to ideally carry out the following tasks:

(i) Control and approve the weekly water requests from the Water Control Officers (see their job description below);
(ii) Planning the operation of the scheme in order to match the supply as closely as possible with the irrigation water applications (i.e. demand);
(iii) Supervise that the orders provided to the WCOs are executed accurately;
(iv) Coordinate with the WCOs the operation of the main canal gates and the releases required, including the timing of the releases;
(v) Monitoring of the operation (i.e. collection of data related to water use and preparing accounting reports) and preparation of the annual irrigation plans and reports.

3.3.1.2 Water Control Officers

The Mooi River Government Water Scheme is sub-divided into sections. Some of these sections are combined under one Water Control Officer. On the establishment provision is made for four (4) Water Control Officers. The job description of the WCO is mainly to carry out the following tasks:

(i) Compile data such as Dam levels, Rainfall figures, Evaporation, releases out of Dams to the canals and rivers as well as tail end flows for compilation of weekly and monthly water disposal reports.
(ii) Capture all necessary data on the Water Administration System (WAS).
(iii) Transmit the water distribution orders to the Water Control Aids (WCAs) responsible for the different sections.
(iv) Control that the sluice gates are opened and closed as indicated by the Mooi River GWS scheme office;

(v) Receive data from the WCAs as to the required amount of water, and transfer the data to the main office;

(vi) Report to the Chief WCO any malfunctioning of sluice gates and structures and any water thefts;

(vii) Control and report on the state of maintenance of the stretch of canal for which they are responsible.

Manpower requirements

Data from several projects indicate that one WCO can cover 10 - 15km depending on the number of hydraulic structures in the canal. The dam gates at the Klerkskraal Dam and Boskop Dam, which are the release points into the Scheme requires a person to operate each.

In the Mooi River GWS, there are four WCOs. One WCO is responsible for the Boskop Dam canal sub-scheme as well as the Gerhardminnebron canal, which is approximately 75km in length. Another WCO is responsible for the Klerkskraal Dam release gate into the Klerkskraal sub-scheme as well as the canal, which is approximately 63 km in length.

The other two WCOs are responsible for the Vyfhoek sub-section, Mooibank sub-section, Boskop Lower Right Bank sub-section and Lakeside sub-schemes.

3.3.1.3 Water Control Aids

The Water Control Aids (WCAs) are the main communication channel between the scheme management and the farmer. Therefore the success of a smooth relationship between the two parties depends on their capabilities and honesty.

Although the job descriptions of the WCAs may vary slightly, the following are considered to be the usual expected tasks to be carried out:

(i) Distribute and control the flows that each offtake must deliver;

(ii) Open and close offtake sluice gates and valves;

(iii) Collection of the water requests (if necessary);

(iv) Preparation of the daily forms for the water delivery;

(v) Communication to the WCOs of the requests of water;

(vi) Control of the canals and watercourses to avoid unauthorised use of water;

(vii) Compilation of the agricultural and water data as needed;

In the Mooi River Government Water scheme, the water control aids not only perform functions related to the operation of the system, but also maintenance work during the off-season. The added duties during this period include the following:

- Cleaning of the irrigation canals;
- Small repairs in the small hydraulic works (intakes, siphons, joints, etc.);
- Supervision of repair works;
- Repairing and maintaining the sluice gates in their section.

Manpower requirements

The Mooi River GWS has to distribute irrigation water to 4 578 ha with the fourteen Water Control Aid posts.

As illustrated in the **Figure 3.2** above, the Mooi River GWS does not have sufficient resources to carry out the water distribution to the irrigators in all the sub-schemes.

Because ownership of the irrigation infrastructure (i.e. irrigation canals, balancing dams and associated appurtenance works such as sluices and weirs to deliver the water to irrigators) is with the DWA, any major refurbishment of the infrastructure is still undertaken by the Department of Water Affairs through the Infrastructure Branch who are also responsible for the operation and maintenance of the scheme.

3.4 Irrigation water use charge

3.4.1 Overview

The water users dependent on water from the Mooi River Irrigation Scheme pay water charges for different purposes. The water rates paid by the users include the contribution to the infrastructure investment paid to the government for the storage and distribution of water; the management of the resources of the catchments; as well as the water rates to cover the expenses related to the operation, maintenance and administration of the scheme.

3.4.2 Water User Charge for Return on Assets (ROA)

The first water charge paid by water users in the Mooi River Irrigation Scheme is the charge to cover for the depreciation of the infrastructure which includes the dams, Klerkskraal, Boskop and Lakeside as well as the canal and related infrastructure.

The irrigators in the Mooi River Government Water Scheme are charged a water use charge of R9.67 c/m^3, which is equivalent of R744.59 per ha/a. Compared to other irrigation schemes these costs can be considered to be reasonable to ensure irrigation agriculture is a viable option. This water charge includes the return on investment of the capital infrastructure as well as the cost of operation and maintenance.

The WRI charge paid by the domestic and industrial users that are supplied from the Boskop Right Bank Canal for 2010/11 financial year was 66.39 c per m^3 or if compared to agriculture, R5 112.03 per ha/a. This clearly indicates that the water use charge to cover for the depreciation charge and ROA for irrigation agriculture is currently heavily subsidised when compared to the water use charged for domestic and industrial users.

Although the gross replacement costs (GRC) of the existing assets is not known, it would appear that the current water use charge does not generate sufficient returns to exceed or cover the cost of funding the assets.

Each irrigator is responsible for the payment of the water use charge to the Department of Water Affairs (DWA). However the collection is carried out by the Department of Water Affairs (DWA) Head Office.

3.4.3 Water charge for operation, maintenance and administration

The Mooi River Irrigation Scheme is still managed by the government as a GWS. The water charge for the operation, maintenance and administration of the Mooi River GWS has not been separated from the water charge to cover for the ROA. The water charge for operation, maintenance and administration costs are recovered in the water charge based on the ROA.

3.4.4 Water Resource Management Charge

Besides paying for the use of the water released from the Klerkskraal Dam and Boskop Dam, the irrigators in the Mooi River Irrigation Scheme also pay for the water resource management charge of the catchments. The current WRM charge for the Upper Vaal WMA in which the Mooi River GWS is located, is 1.05 c/m^3 or R80.85 per ha/a.

The WRM charge is the same for all water users in the Upper Vaal Water Management Area (WMA) in which the Mooi River Irrigation Scheme is situated. The purpose of the WRM charge is to cover all management activities that are undertaken by a Catchment Management Agency (CMA) or a proto-CMA where one has not been established and to ensure the sustainable water resource management so that all users in the WMA have a fair and equitable share of the available water. The activities that are covered by the WRM charge include the following:

(i) water abstraction control to ensure that all get their fair share of water,

(ii) monitoring and pollution control to keep the rivers healthy,

(iii) planning for development of new schemes and to extend existing schemes,

(iv) clearing of invading alien plants which consume water that should be available for use.

For the irrigators in the Mooi River Irrigation Scheme, the total cost of irrigation water including the management charge amounts to R825.44 per ha/a. This is lower than a number of other irrigation schemes.

3.5 Water use permits / licenses and contracts

The authorisation for the water use, within the Mooi River Government Water Scheme (GWS) area of jurisdiction, lies in the Schedule, for 4 578.11 ha, drawn up in terms of section 88 of the 1956 Water Act, and approved by the Department in 1999. This scheduled use is deemed to be an Existing Lawful Water Use under section 32 of the National Water Act, 1998 and as such, does not require a Licence, but does need to be registered. The irrigators have permission to continue irrigating this scheduled area until licensing takes place, provided they pay all charges due to the DWA.

The permit for domestic water use in Mooi River and surrounding communities supplied by the scheme is held by the Water Services Authorities (WSAs) which is Tlokwe Local Municipality. There is a service level agreement (SLA) between the domestic users and the Mooi River GWS for the delivery of water for domestic purposes through the irrigation canal infrastructure.

The total allocations for the scheme is 35.25 million m^3/a, at 7 700 m^3/ha/a. A review of the Water Use Authorisation and Registration Management System (WARMS) database confirms that the total registered water use in the scheme area is 35.25 million m^3/a, which is supplied from the canal infrastructure.

It is important to note that over the period from 2000/2001 to 2007/08 water years, the annual inflow into the Mooi River GWS, including the allowance for water losses have ranged between 67 million m^3/a and 113 million m^3/a (after patching for missing data) compared to the scheduled quota of 35.25 million m^3/a for irrigation alone.

3.6 Irrigated areas and types of crops

The current irrigated area is 4 578.11 hectares, comprising of 865.4 ha downstream of the Klerkskraal Dam, 2 495.20 ha supplied from the Boskop Dam canal system and 278.3 ha supplied from the Gerhardminnebron canal system and 939.20 ha supplied from the

Lakeside Dam canal system. Each of the irrigators in the Mooi River Irrigation Scheme area is registered individually and the Registration certificates reflect the enlisted area.

The irrigators in the scheme are growing diverse crops which include maize, wheat, sunflower and vegetables. Under irrigation practices, farmers generally grow two harvests per year.

3.6.1 Maize

The planting season for Maize starts in September/October, with harvesting taking place in April. The average maize production is estimated to be 30 tonnes per ha.

3.6.2 Other crops

There are a wide variety of other crops that are irrigated in the Mooi River Scheme area but all these crops are mainly annual crops.

3.7 Historic water use

In order to evaluate the water use of the Mooi River Irrigation Scheme, the scheme was treated as having six sub-schemes namely: (i) Klerkskraal right bank canal, (ii) Klerkskraal left bank canal; (iii) Gerhardminnebron canal; (iv) Boskop right bank canal; (v) Boskop left bank canal and; (vi) Lakeside canal system.

The historic water use of each scheme is provided in the **Table 3.1** to **Table 3.7** below.

3.7.1 Historic water use - Mooi River Government Water Scheme

3.7.1.1 Current operation of the scheme

It is important to describe the current operation of the Mooi River Government Water Scheme because the scheme is operated in a water system where the dams generally spill most of the time. Because of the excess water available in the Mooi River GWS, the scheme diverts more water than is applied for. This is to enable that canal to run at nearly full capacity and provide the flexibility to the scheme operators to meet any additional request during the week. Any excess water is then measured at the canal tailends and returned back to the river system. This additional water diverted has been included in the assessment of the historic water use.

In the upper sections of the irrigation scheme, the canals supply irrigators as well as downstream canals. The water into the downstream canals is taken as a use. This was factored in determining the average total water losses.

3.7.1.2 Historic water use

The historic water use for the whole of the Mooi River GWS is based on two time lines because of gaps in information for the 2004/05 water year. This is provided in **Table 3.1 below**. The seven year data excluding 2004/05 up to 2007/08 demonstrate a range of water use in the Mooi River irrigation scheme. Water use for irrigation has ranged from 7.16 million m^3/a in 2003/04 up to 16.26 million m^3/a in 2002/03, with a seven-year average of 12.1 million m^3/a. This is approximately 34% of the water allocation for the Mooi River GWS of 35.25 million m^3/a.

The other major water use is the municipal water use. This has shown a steady increase in domestic consumption for the last three years of the assessment. Domestic water use has increased from 4.61 million m^3/a in 2003/04 to 7.2 million m^3/a in 2007/08 at a growth rate of approximately 11.7% per year since 2003/04 water year.

The scheme also provides household domestic consumption for the farming communities. The household consumption has been constant over the 7 year period with an average household use on the farms of 1.2 million m^3/a.

The historical records indicate that an average of 29.43 million m^3/a, was supplied to the downstream irrigation canal supplying Boskop Dam and Lakeside Dam. This has been considered a use because it is used to make up irrigation water requirements directly in the scheme area. However the downstream diversion through the canal system back into the Mooi and the Vaal River system was considered a loss from a scheme point of view although it has beneficial use downstream of the scheme.

The average volume of water released into the Mooi River irrigation canals to match the irrigation demands as well as the water losses due to evaporation and seepage losses was 83.01 million m^3/a. When compared to the demands from the canal infrastructure the additional water to meet the water losses including seepage, leakage, evaporation and operational spills is 37% of the total irrigation water released into the Mooi River Government Water Scheme. This is considered very high.

Table 3:1: Historic water use levels (million m^3/a) for the whole of the Mooi River GWS

User	2000/01	2001/02	2002/03	2003/04	2005/06	2006/07	2007/08	Average
Irrigation	12.74	11.02	16.26	7.16	10.00	15.06	12.45	12.10
Household	1.37	1.11	1.56	0.87	1.08	1.22	1.12	1.19
Industrial use	0.18	0.11	0.27	0.13	0.18	0.26	0.23	0.20
Municipal use	9.77	8.54	6.81	4.61	7.72	9.39	7.18	7.72
Other	2.84	1.67	2.58	1.26	1.73	2.01	1.80	1.99
Downstream Canals	40.74	33.96	32.02	18.46	24.55	29.45	26.86	29.43
Total	67.63	56.41	59.50	32.49	45.27	57.40	49.64	52.62
Inflow into the Scheme	101.65	87.62	86.38	53.35	77.21	91.26	83.59	83.01
Gross Water Losses	34.02	31.20	26.89	20.87	31.94	33.87	33.95	30.39
% Water Losses	33%	36%	31%	39%	41%	37%	41%	37%

3.7.2 Historic water use at sub-scheme level

As there were records for the different sub-schemes of the Mooi River Scheme, the water balances of the sub-schemes are indicated in **Table 3.2** to **Table 3.6** below. There are six sub-schemes namely: (i) Klerkskraal right bank canal, (ii) Klerkskraal left bank canal; (iii) Gerhardminnebron canal; (iv) Boskop right bank canal; (v) Boskop left bank canal and; (vi) Lakeside canal system.

3.7.2.1 Historic water use for the Klerkskraal right bank

Table 3.2 below provides the seven (7) year historic water use excluding 2004/05 up to 2007/08 for the Klerkskraal right bank section of the irrigation scheme. With the scheduled quota of 4.563 million m^3/a, the average irrigation water use from the right bank canal had a 7-year average of 1.73 million m^3/a. Only less than half of the allocation, this is approximately 38% of the scheduled quota from the Klerkskraal right bank canal, has been utilised over the 7 year period.

Any irrigation water not utilised for irrigation purposes ends up in the Boskop Dam which supplies the downstream canals where it is utilised. For the same period, approximately 3.62 million m^3/a, was transferred through the Klerkskraal right bank canal to Boskop Dam for use by downstream irrigators.

There are no other major water users from this canal. The scheme however also provides household domestic consumption for the farming communities. The household consumption has been fairly constant over the 7 year period.

Table 3:2: Historic water use levels (million m^3/a) for Klerkskraal right bank canal system

User	2000/01	2001/02	2002/03	2003/04	2005/06	2006/07	2007/08	Ave.
Irrigation	2.07	1.56	1.76	1.55	1.32	1.74	2.10	1.73
Household	0.38	0.34	0.44	0.24	0.32	0.34	0.32	0.34
Municipal use	-	-	-	-	-	-	-	-
Downstream Canals	8.15	6.34	2.56	0.74	2.56	2.62	2.41	3.62
Total	10.60	8.24	4.75	2.53	4.19	4.70	4.83	5.69
Inflow into Scheme	14.82	11.53	6.64	3.88	5.79	6.31	6.53	7.93
Water	4.22	3.29	1.89	1.35	1.60	1.61	1.70	2.24

User	2000/01	2001/02	2002/03	2003/04	2005/06	2006/07	2007/08	Ave.
Losses								
% Water Losses	28%	28%	29%	35%	28%	25%	26%	28%

The average volume of water diverted into the Klerkskraal right bank irrigation canal to match the irrigation demands as well as the water losses due to evaporation and seepage losses was 7.93 million m^3/a. When compared to the demands from the canal infrastructure the additional water to meet the water losses and operational spills is 28% of the total demand. The total demand includes the transfer through the canal system to Boskop Dam. This current practice makes it very difficult to determine the extent of conveyance water losses in the Klerkskraal right bank canal.

3.7.2.2 Historic water use - Klerkskraal left bank canal

The historic water use for the Klerkskraal left bank canal is provided in **Table 3.3** below. There were no historical records available for 2004/05 as well as the last water years of 2008/09 to 2009/10. Therefore the assessment has been undertaken for the seven years of available records since 2000/01.

With the scheduled quota of 2.1 million m^3/a, the average irrigation water use from the left bank canal had a 7-year average of only 0.5 million m^3/a. Only less than a quarter of the allocation, that is approximately 24% of the scheduled quota from the Klerkskraal left bank canal, has been utilised over the 7 year period.

The average inflow into the Klerkskraal left bank irrigation canal during this period, was 5.4 million m^3/a. This includes approximately 3.3 million m^3/a on average which is transferred back to the Mooi River at three tail ends. This in actual fact represents a water loss which has not been accounted for as a water loss. This water is available for the downstream part of the same scheme.

If these spills at the three canal tail ends, for downstream users could have been left in Klerkskraal Dam and/or provide environmental requirements based on natural spills from the Dam, the water losses could have averaged 4.6 million m^3/a or 86% of the total diverted.

There are no other major water users from this canal. The scheme however also provides household domestic consumption for the farming communities. The household consumption has been constant over the 7 year period.

Table 3:3: Historic water use levels (million m^3/a) for Klerkskraal left bank canal system

User	2000/01	2001/02	2002/03	2003/04	2005/06	2006/07	2007/08	Ave.
Irrigation	0.46	0.27	0.58	0.37	0.52	0.63	0.64	0.50
Household	0.35	0.24	0.38	0.21	0.27	0.30	0.27	0.29
Municipal use	-	-	-	-	-	-	-	-
Downstream Canals	4.29	2.86	3.94	2.28	2.88	3.21	3.58	3.29
Total	5.10	3.36	4.90	2.87	3.68	4.13	4.48	4.07
Inflow into Scheme	6.88	4.54	6.64	3.88	4.84	5.35	5.71	5.41
Water Losses	6.07	4.04	5.68	3.30	4.04	4.43	4.80	4.62
% Water losses	26%	26%	26%	26%	24%	23%	22%	25%

3.7.2.3 Historic water use - Gerhardminnebron canal system

The historic water use for the Gerhardminnebron canal is provided in **Table 3.4** below. With the scheduled quota of 2.14 million m^3/a, the average irrigation water use from the dolomitic aquifers at the farm Gerhardminnebron had a 7-year average of only 0.9 million m^3/a. This is approximately 43% of the scheduled quota from the Gerhardminnebron canal that has been utilised over the 7 year period.

The average total water diverted within the Gerhardminnebron irrigation canal during this period, was 18.44 million m^3/a. It is important to note that because the source of water is from the eye, the inflow into the Scheme is uncontrolled and therefore includes approximately 16.0 million m^3/a on average excess water from the dolomitic aquifers which is discharged at three canal tail ends into the Mooi River just upstream of Boskop Dam, the Boskop Dam and downstream of Boskop Dam.

Because of the uncontrolled nature of dolomitic aquifers unless a storage dam had been constructed, the spills at the canal tail ends cannot be considered as a loss as the canal was designed taking into account the volume of water from the dolomitic aquifers. This water is available for the downstream part of the same scheme.

There are no other major water users from this canal. The scheme however also provides household domestic consumption for the farming communities as well as limited industrial water use. The household consumption and industrial use has been fairly constant over the 6 year period.

Table 3:4: Historic water use levels (million m^3/a) for Gerhardminnebron canal system

User	2000/01	2001/02	2002/03	2003/04	2005/06	2006/07	2007/08	Ave
Irrigation	1.59	0.64	1.13	0.69	0.65	0.79	1.03	0.93
Household	0.14	0.14	0.17	0.17	0.13	0.16	0.20	0.16
Industrial use	0.14	0.11	0.19	0.22	-	0.24	0.30	0.17
Downstream Canals	18.43	16.75	19.15	15.12	11.67	13.57	17.29	16.00
Total Demand	20.30	17.65	20.64	16.20	12.46	14.75	18.81	17.26
Inflow into	21.46	18.67	21.82	17.12	13.55	16.09	20.36	18.44

User	2000/01	2001/02	2002/03	2003/04	2005/06	2006/07	2007/08	Ave
Scheme								
Water losses	1.16	1.02	1.18	0.92	1.08	1.34	1.55	1.18
% Water Loss	5%	5%	5%	5%	8%	8%	8%	7%

The average volume of water flowing into the Gerhardminnebron irrigation canal to match the irrigation demands as well as the water losses due to evaporation and seepage losses was 18.44 million m^3/a, which is significantly more than is required because of the excess water from the dolomites.

When compared to the demands from the canal infrastructure the additional water to meet the water losses and operational spills is 7% of the total diverted when the canal tail ends water are taken as a downstream use. The level of water losses is the lowest of all the six sub-schemes making up the Mooi River GWS.

3.7.2.4 Historic water use - Boskop right bank canal

The historic water use for the Boskop right bank canal is provided in **Table 3.5** below. With the scheduled quota of 12.22 million m^3/a, the average irrigation water use from the Boskop right bank canal had a 7-year average of only 4.9 million m^3/a. This is approximately 40% of the scheduled quota from the Boskop right bank canal, over the 7 year period.

The total average inflow into the Boskop right bank irrigation canal during this period, was 29.7 million m^3/a. This includes water transferred back to the Mooi River and Vaal River at the canal tail ends. Not all the water at the canal tailend was taken as a loss because of the additional water put into the canals during wet periods when the dams are spilling. The water is only considered a loss due to the fact that this water could have been stored in the Boskop Dam if it is not spilling.

Domestic water use mainly for the town of Potchefstroom is the other major water user abstracting water from the right bank canal. Domestic water abstraction from the canal system has been increasing at an average rate of 10.1% per year since 2002/03. Current abstraction (that is 2007/08) was 10.02 million m^3/a, and this is expected to continue to increase in future.

Table 3:5: Historic water use levels (million m^3/a) for Boskop Right Bank Canal system

User	2000/01	2001/02	2002/03	2003/04	2005/06	2006/07	2007/08	7 year ave.
Irrigation	4.21	3.40	7.05	2.79	3.65	5.79	4.54	4.49
Household	0.11	0.09	0.13	0.06	0.08	0.09	0.09	0.09
Industrial Use	0.01	0.01	0.01	0.01	0.00	0.03	0.02	0.01
Municipal use	9.65	8.54	6.81	4.61	7.72	9.39	7.18	7.70
Other	2.64	1.60	2.46	1.20	1.69	1.92	1.71	1.89
Diversion of excess water during wet period	3.04	2.89	2.98	1.91	3.17	3.56	3.23	2.97
Total	19.66	16.53	19.44	10.58	16.31	20.78	16.76	17.15
Diversion	30.36	28.89	29.81	19.13	31.69	35.63	32.29	29.69
Water Losses	10.70	12.36	10.37	8.55	15.38	14.85	15.53	12.53
	35%	43%	35%	45%	49%	42%	48%	42%

The average volume inflow into the Boskop right bank irrigation canal to match the irrigation demands as well as the water losses due to evaporation and seepage losses was 29.7 million m^3/a which is significantly more than is required. When compared to the demands from the canal infrastructure the additional water to meet the water losses and operational spills is 42% of the total inflow into scheme when a portion of some of the spills at canal tail ends are taken as water losses.

This is the sub-scheme with the highest water losses by percentage as well as by volume from the conveyance infrastructure at 12.5 million m^3/a, as it is the largest sub-scheme in terms of the length of the canal and the scheduled quota.

3.7.2.5 Historic water use - Boskop left bank canal

The historic water use for the Boskop left bank canal is provided in **Table 3.6** below. With the scheduled quota of 6.99 million m^3/a, the average irrigation water use from the Boskop left bank canal had a 7-year average of only 2.8 million m^3/a. This is approximately 42% of the scheduled quota from the Boskop left bank canal that has been utilised over the 7 year period.

The average inflow into the Boskop left bank irrigation canal during this period, was 13.5 million m^3/a. This includes water transferred to Lakeside Dam and also into the Lakeside canal including into Modder Dam.

There is no other major water user abstracting water from the Boskop left bank canal. However domestic water is abstracted from the canal system for use by the communities on the farms. This is a very small component of the water use from the canal system.

The average volume of water diverted into the Boskop Left bank irrigation canal to match the irrigation demands as well as the water losses due to evaporation and seepage losses was 13.5 million m^3/a, which is significantly more than the water applications for the same period.

When compared to the demands from the canal infrastructure the additional water to meet the water losses and operational spills is 21% of the total inflow into the Scheme when the spills at canal tail ends are taken as water losses.

Table 3:6: Historic water use levels (million m^3/a) for Boskop Left Bank Canal system

User	2000/01	2001/02	2002/03	2003/04	2005/06	2006/07	2007/08	Ave
Irrigation	1.86	2.25	4.50	2.00	2.50	3.75	2.57	2.78
Household	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.01

Industrial use								
Municipal use	-	-	-	-	-	-		-
Downstream Canals	9.95	5.96	8.81	5.82	6.47	9.84	8.15	7.86
Total Demand	11.82	8.22	13.32	7.83	8.97	13.60	10.73	10.64
Inflow into Scheme	15.39	10.52	17.03	10.41	11.83	16.41	12.88	13.50
Water Losses	3.57	2.29	3.72	2.59	2.86	2.82	2.15	2.86
% Losses	23%	22%	22%	25%	24%	17%	17%	21%

3.7.2.6 Historic water use - Lakeside canal

The historic water use for the Lakeside canal is provided in **Table 3.7** below. With the scheduled quota of 7.23 million m^3/a, the average irrigation water use from Lakeside canal had a 7-year average of only 1.8 million m^3/a. This is approximately 25% of the scheduled quota from the Lakeside canal, has been utilised over the 7 year period.

There are no other major water users abstracting water from the Lakeside canal. However domestic water is abstracted from the canal system for use by the household communities on the farms. This is a very small component of the water use from the canal system. There are also some government departments abstracting raw water from the irrigation canal.

The average volume of water diverted into the Lakeside irrigation canal to match the irrigation demands as well as the water losses due to evaporation and seepage losses was 9.61 million m^3/a, which is significantly more than is required. There is a significant volume of spills due to the operation of the scheme with the spills observed at the canal tail ends contributing to the high water losses. The average water losses over the period was 4.54 million m^3/a.

When compared to the demands from the canal infrastructure, the additional water to meet the water losses and operational spills at the canal tail ends was 49% of the total water released into Scheme. This is when some of the spills at canal tail ends are taken as operational spills while a portion of the spills are considered operational use during the wet periods when the dams are spilling.

Table 3:7: Historic water use levels (million m^3/a) for Lakeside Canal system

User	2000/01	2001/02	2002/03	2003/04	2005/06	2006/07	2007/08	Ave
Irrigation	3.00	2.73	1.28	-	1.38	2.36	1.81	1.79
Household	0.34	0.32	0.41	0.23	0.26	0.32	0.29	0.31
Industrial use								#DIV/0!
Municipal use	-	-	-	-	-	-		-
Other	0.11	0.07	0.12	0.05	0.05	0.10	0.10	0.08
Diversion of excess water during wet period	3.97	3.35	2.08	1.55	2.47	3.44	3.31	2.88
Total	7.42	6.48	3.89	1.83	4.15	6.21	5.51	5.07
Diversion	13.23	11.18	6.95	5.16	8.22	11.46	11.04	9.61
Water Losses	5.81	4.71	3.06	3.32	4.07	5.26	5.53	4.54
	44%	42%	44%	64%	50%	46%	50%	49%

4 INVENTORY OF THE EXISTING WATER INFRASTRUCTURE

4.1 Overview

The Mooi River Government Water Scheme comprises three main dams as well as a weir at the Gerhardminnebron eye. There are several lengths of primary and secondary irrigation canal infrastructure, as well as the canal distribution system which delivers the water ordered to the irrigators at their farm turnouts through sluice gates. Water ordered is measured using either Parshall flumes, pressure sluice gates or rectangular measuring weirs.

4.2 Water Supply Sources

4.2.1 Klerkskraal Dam

The first source of water supply for irrigation is from the Klerkskraal Dam which is located in the headwaters of the Mooi River. The dam was built and commissioned in 1965 and has a storage capacity of 7.9 million m^3. Water is released from the Dam into the primary irrigation canal on the right bank of the Mooi River. The canal then splits to the left bank to supply irrigators.

The volume of water to be released is dependent on the requests from irrigators, which is measured downstream of the dam wall. Any excess water from the two canal systems is discharged back to the Mooi River at the canal tail ends of both the right bank and left bank canals.

4.2.2 Boskop Dam

The Boskop Dam was constructed and commissioned in 1959. Its purpose was to address the water shortages and restrictions that the farmers were experiencing in the Mooi River catchment.

The Boskop Dam has a storage capacity of 20.84 million m^3. Water is released to supply irrigators on the right and left banks of the Mooi River. The dam supplies irrigators on the right bank up to the confluence with the Vaal River including supplementing the domestic water requirements of Potchefstroom from the right bank canal. The irrigators on the left bank are supplied up to the Loopspruit.

The volume of water to be released is dependent on the requests from irrigators and domestic consumers in the Mooi River system, which is measured downstream of the dam wall.

4.2.3 Lakeside Dam

The Lakeside Dam was constructed mainly as a source of water supply for the town of Potchefstroom as well as to provide irrigation water to the irrigators downstream of the Dam. The dam is situated in the Mooi River system. The yield of the dam is supplemented by the surplus water from the Boskop irrigation canals.

Besides supplying water for domestic use in Potchefstroom, water is released to supply irrigators downstream of the dam on the left bank of the Mooi River. Water is released from the Lakeside Dam based on the demands of the irrigators based on the weekly orders. The volume of water to be released is dependent on the requests from irrigators in the Mooi River system, which is measured downstream of the dam wall.

4.2.4 Gerhardminnebron eye

The other source of supply for irrigators is the Gerhardminnebron eye. Irrigation water is released from a weir at the eye into the irrigation canal which supplies irrigators on the left bank of the Mooi River.

The excess water from the Gerhardminnebron eye is discharged into the Mooi River and Boskop Dam as well as supplementing the Boskop left bank canal.

4.3 Irrigation conveyance infrastructure

Figure 4.1 below, illustrates the conveyance and distribution infrastructure of the Mooi River Irrigation Scheme. Water, is diverted at the above dams and spring into the main canals, which then bifurcate into the secondary canals, supplying irrigators downstream of the dams. The canal infrastructure comprises primary and secondary canal systems, as well as siphons at road and river crossings. The total length of the main canal systems amounts to approximately 210.62 km, most of which is concrete lined.

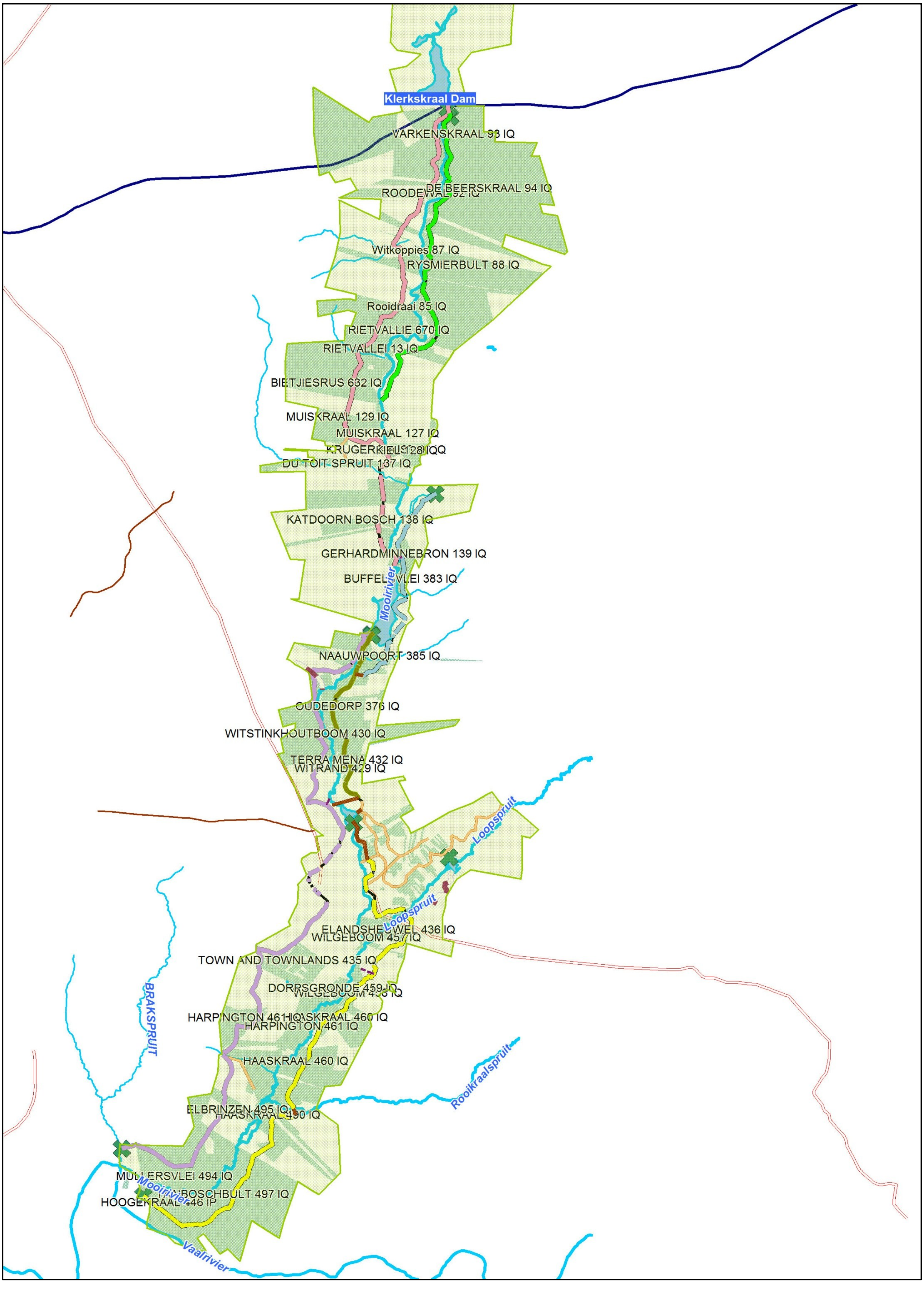

Figure 4:1: Mooi River Irrigation Scheme -Infrastructure

4.3.1 Klerkskraal canal system

Table 4.1 below, lists the canal infrastructure downstream of the Klerkskraal Dam up to the Boskop Dam after the confluence of the Wonderfontein spruit. There is one primary canal from the dam which then bifurcates into the right bank and left canals. The primary canals then provide water at the sluices through some branch canals in this irrigation scheme area. The Klerkskraal canal system comprises the following components:

Table 4:1: Mooi River Irrigation Scheme – Canal Infrastructure on the Klerkskraal Irrigation Scheme area

Item No	Canal Name	Type of canal	Total Length of canal (km)	Canal capacity (m^3/h)	Canal capacity (m^3/s)
1	Primary canal	Concrete lined	0.4	4500	1.25
2	Right bank canal	Primary canal, concrete lined	41.2	3000	0.83
3	Left bank canal	Primary canal, concrete lined	22.48	1500	0.42
	Branch canal right bank	Distribution canal	0	various	
Total length of canal system right bank (km)			63.68		

(i) *Klerkskraal right bank canal*: This is the main canal, which conveys the irrigation water from the Klerkskraal Dam. It supplies irrigators on the right bank of the Mooi River for approximately 41.2 km up to the canal tail ends. The maximum hydraulic capacity of the canal at the headworks is 3 000 m^3/h or 0.83 m^3/s.

(ii) *Branch canals:* There are some branch canals supplying the irrigators in the whole of the Klerkskraal irrigation sub-scheme area.

4.3.2 Gerhardminnebron eye canal system

The Gerhardminnebron canal system comprises approximately14.2 km which is concrete lined (see **Table 4.2** below). The maximum hydraulic capacity of the canal is not known. The canal is parabolic in shape and supplies irrigators downstream of the spring or eye up until the Boskop Dam left bank canal.

Table 4:2: Mooi River Irrigation Scheme – Canal Infrastructure on the Gerhardminnebron and Lakeside sub-scheme areas

Item No	Canal Name	Type of canal	Total Length of canal (km)	Hydraulic Capacity	
				m^3/h	m^3/s
1	Gerhardminnebron Canal	Primary canal, concrete lined	14.15		-
2	Lakeside Canal	Primary canal, concrete lined	41.12		-
	Branch canals	Distribution canal			-
Total length of canal system right bank (km)			55.27		

4.3.3 Boskop irrigation canal system

Table 4.3 below, lists the canal infrastructure downstream of Boskop Dam. This is where most of the irrigation scheme scheduled area is situated. Downstream of the Boskop Dam there are two primary canals one of the right bank and the other on the left bank of the Mooi River, and a series of branch canal systems with a total length of 91.7 km of canals and siphon infrastructure which includes the following:

(i) *Boskop right bank canal:* Irrigation water supplies from Boskop Dam, is released into this main canal on the right bank of the Mooi River. It comprises approximately 49.5 km of concrete lined canal infrastructure. The main canal is the largest primary canal, with a maximum design capacity of 7 000 m^3/h or 1.94 m^3/s. The canal supplies excess water to the Lakeside Dam which is the main source of domestic water supply for the town of Potchefstroom.

(ii) *Boskop left bank canal*: This is the canal which conveys the irrigation water for the farmers on the left bank of the Mooi River downstream of the Boskop Dam. It is estimated that there is 14.5 km of concrete lined canal infrastructure with a maximum hydraulic capacity ranging from 3 600 m^3/h or 1.00 m^3/s. The canal also supplies excess water to the Lakeside dam as well as provides water to the downstream Lakeside irrigation canal.

(iii) *Branch canals:* There are several branch canals supplying the water users with their allocations. The branch canals are concrete lined canal systems with various maximum hydraulic capacities.

Table 4:3: Canal Infrastructure on the Boskop Irrigation Scheme

Item No	Canal Name	Type of canal	Total Length of canal (km)	Hydraulic capacity	
				m^3/h	m^3/s
1	Boskop right bank canal	Primary canal, concrete lined	49.5	7000	1.94
2	Boskop left bank canal	Primary canal, concrete lined	14.5	3600	1.00
	Branch canals	Distribution canal	27.67		-
Total length of canal system right bank (km)			91.67		

4.3.4 Lakeside Dam canal system

Downstream of the Lakeside Dam there is a main canal which supplies irrigators on the left bank of the Mooi River. The total length of the canal system 41.12 km which is all concrete lined (see **Table 4.2** above) The maximum design capacity of the canal is 2 200 m^3/h or 0.61 m^3/s:

4.4 Irrigation storage and regulation system

4.4.1 General

The Mooi River Irrigation scheme does have storage dams and/or weirs which regulate the flows to the downstream water users. The regulation infrastructure includes the Klerkskraal, Boskop and Lakeside Dams as well as the Gerhardminnebron weir. These can be considered as balancing dams as they are situated within the scheme area. Their location provides for balancing storage for the downstream sections of the Mooi River Government Water Scheme although they were not built for balancing water for downstream supplies per se.

4.5 Irrigation infrastructure distribution system

As illustrated in **Figure 4.1** and **Tables 4.1** to **Table 4.3** above, there are several kilometres of branch canals in the Mooi River irrigation scheme which distribute the irrigation water to the sluice gates. The flows past these sluice gates are measured using either Parshall flumes, rectangular weirs or pressure sluice gates.

The entire distribution canal infrastructure is concrete lined. No information with respect to the hydraulic capacity of the different distribution canal infrastructure was available; to compare with the maximum and average demands expected in the different irrigation sections.

4.6 Flow Measurement and telemetry system

4.6.1 Measurement of flow into the scheme area

Figure 4.2 below provides the location of the existing flow measurement system as well as the location of the additional flow measurements required to manage the irrigation water requirements in the Mooi River Irrigation Scheme effectively.

As illustrated, there are flow measurement structures at all the diversions from the dams and/or weir into the canals. These are used to determine the flow rates and volume of water required to meet the demands for irrigation and domestic users on a weekly, monthly and annual basis.

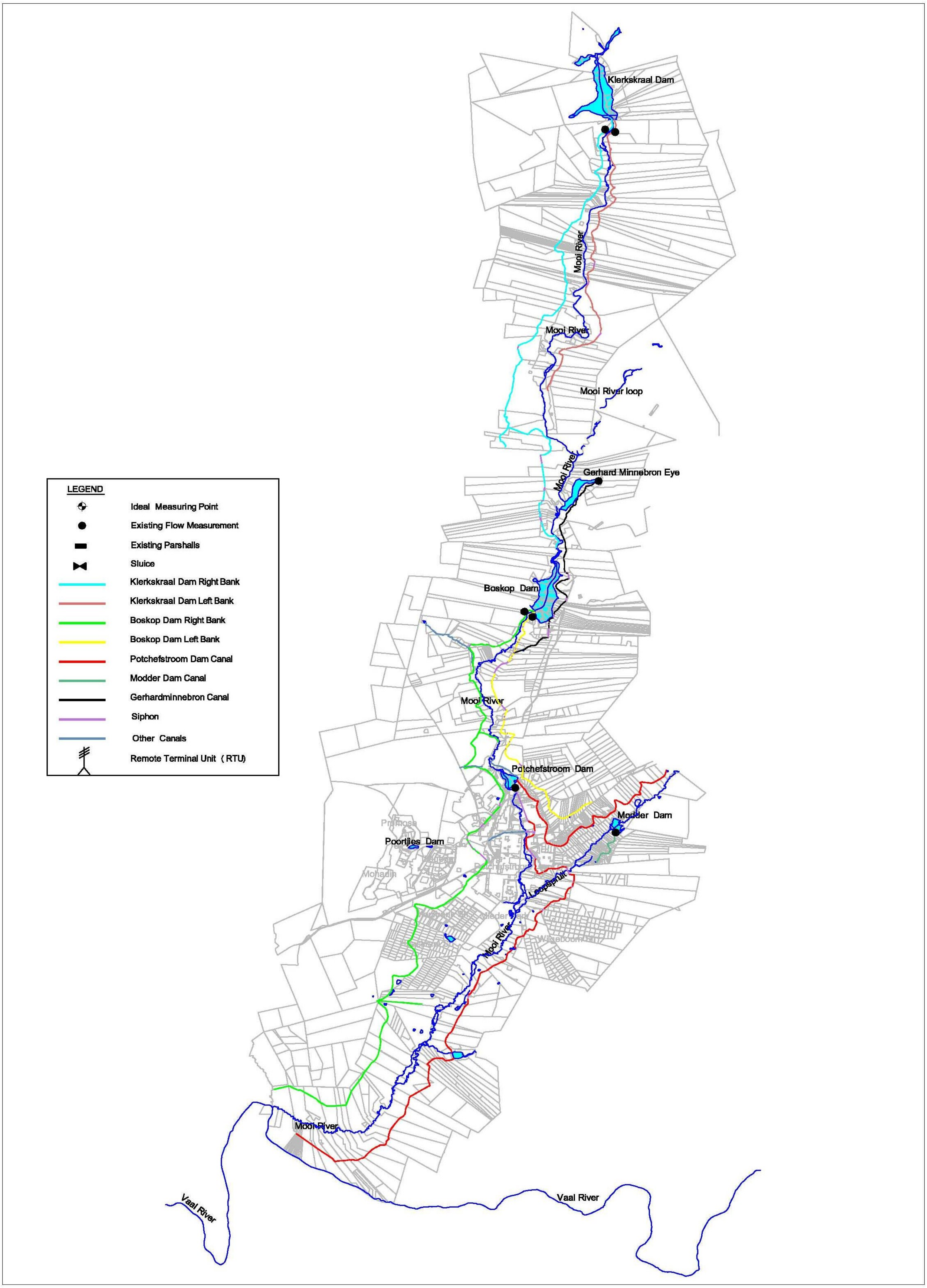

Figure 4:2: Schematic layout of the Mooi River Government Water Scheme with the existing water measurement system

4.6.2 Measurement into the various canal systems

The Mooi River Irrigation Scheme has six main irrigation canals, namely the Klerkskraal right and left bank canals which supplies irrigators downstream of Klerkskraal Dam, the Gerhardminnebron eye canal; the Boskop right bank and left bank canals which supplies irrigators downstream of the dam including domestic water for Potchefstroom town, and the Lakeside canal supplying the water users on the left bank of the Mooi River up to the confluence with the Vaal River.

There are flow measuring structures at the outlet of Klerkskraal Dam and two flow measuring structures at the outlet of the Boskop Dam to measure flows into the left and right bank canals.

There are approximately 14 canal tail ends to measure the water returning back to either the downstream dams or the Mooi or Vaal River.

Based on the current WUEAR reports, no direct measurements of operational spills at canal tail ends are currently being performed by the scheme managers. The spills are currently being estimated. There are flow measurement structures at a number of these canal tail ends.

4.6.3 Measurement at user outlets

The Mooi River Government Water Scheme measures the weekly volume of water delivered to the water users at the farm gate using pressure control sluices. The sluice gates are adjusted depending on the water application by the irrigators.

There are four streams which can be delivered to the irrigator by adjusting the pressure controlled sluice gates. These are 50 m^3/h; 100 m^3/h; 150 m^3/h and 200 m^3/h.

Flow measurements are also conducted using Parshall flumes and rectangular weirs.

4.6.4 Telemetry system

The Mooi River Irrigation Scheme has no telemetry system and relies on manual flow measurements by water control officers to monitor the flow at various sites of the scheme.

5 INFRASTRUCTURE CONDITION ASSESSMENT

5.1 Overview

In order to determine the condition of the canal infrastructure, a methodology has been developed known as the Rapid Assessment Tool (RAT). This is a combination of methodologies designed to provide a quick and cost-effective analysis of condition within an irrigation scheme.

The main objective of undertaking condition assessment is to define the extent and seriousness of problems contributing to poor conveyance efficiency.

RAT methodologies include surveys, rating of infrastructure, flow measurement, seepage loss tests, and GIS-based mapping and analysis, among other activities. These methodologies are still evolving. Two visual rating procedures have been developed:

- water supply conditions (“head conditions”);
- canal conditions.

The overall goal of this effort is to provide information which will allow decision makers involved in irrigation resource management to assess and compare the rehabilitation needs of irrigation networks.

5.2 Canal Condition Evaluation

It was not possible to undertake condition assessment of the irrigation canals of the Mooi River Irrigation Scheme, because at the time of developing the WMP, there were no dry periods to inspect the canals.

However, a list of criteria for undertaking canal condition assessment was developed for use, during the implementation phase. The Canal Condition Evaluation component of RAT includes visual rating methodologies on:

- the general condition of the canal;
- conditions which indicate seepage or structural problems.

There are service factors that are used in this procedure which may be grouped as follows:

- general condition of the canals;
- presence of cracks (hairline, pencil-size, and large);

- amount of patchwork;
- vegetation in canal and along embankment.

Tables 5.1 - 5.5 provide details on the rating factors and definition of numerical values that are recommended to be used during the dry periods.

Table 5:1: General Condition rating

Rating	Definition
1	Excellent – no visible cracks or vegetation
2	Good – having cracks greater than 3.0 m apart and some weeds
3	Fair – cracks 1.5-3.0 m apart, with moderate vegetation in canal and drainage ditch
4	Poor – cracks 1.0-1.5 m apart, with dense vegetation in canal and drainage ditch
5	Serious Problems – visible large cracks less than 1.0m apart with lush vegetation

Table 5:2: Criteria for hairline, pencil size and large cracks

Rating	Definition
1	None to Sparse
2	Greater than 3.0 m apart
3	1.5 – 3.0 m apart
4	1.0 – 1.5 apart
5	Less than 1.0 m apart

Table 5:3: Noticeable amounts of maintenance and repair (patchwork)

Rating	Definition
1	None to a few areas
2	A few areas
3	Sparse
4	Moderate
5	Severe

Table 5:4: Vegetation growing in canal lining

Rating	Definition
0	None
1	Sparse
2	Moderate
3	Dense

Table 5:5: Vegetation in drainage canals and along the outer embankment of the levee

Rating	Definition
1	Normal; rain-fed weeds only
2	Canal fed grass or small weeds only
3	Moderate; bushes & some small trees with no water near levee or drain

Rating	Definition
4	Dense; more bushes & larger trees, little or no standing water, little or no aquatic vegetation
5	Dense and lush; bushes, trees, lots of aquatic vegetation with standing water

5.3 Results and analysis of preliminary assessment

5.3.1 Overview

The assessment that was conducted during the three site visits indicated that the condition of the canal system in the Mooi River Government Water Scheme ranged from fair to poor with some sections of the canals, particularly the Lakeside canal and Boskop Right bank canal being very poor. This is illustrated in **Figure 5.1** below.

In the Lakeside canal system the canal has deteriorated so badly that it will require complete renewal or rebuilding of some sections of the canal system as discussed in the later sections.

5.3.2 Condition evaluation of the main canals

Although no detailed condition assessment could be undertaken on the Mooi River GWS because the canals were operational, some information was gathered during the site visit. This was work conducted by the WCOs which indicated their assessment of the condition of the six main canal systems of the scheme.

Photos 5.1 to 5.5 contain photographs which illustrate some of the conditions of the canal infrastructure based on the site visit to the Mooi River Irrigation Scheme. These are discussed below.

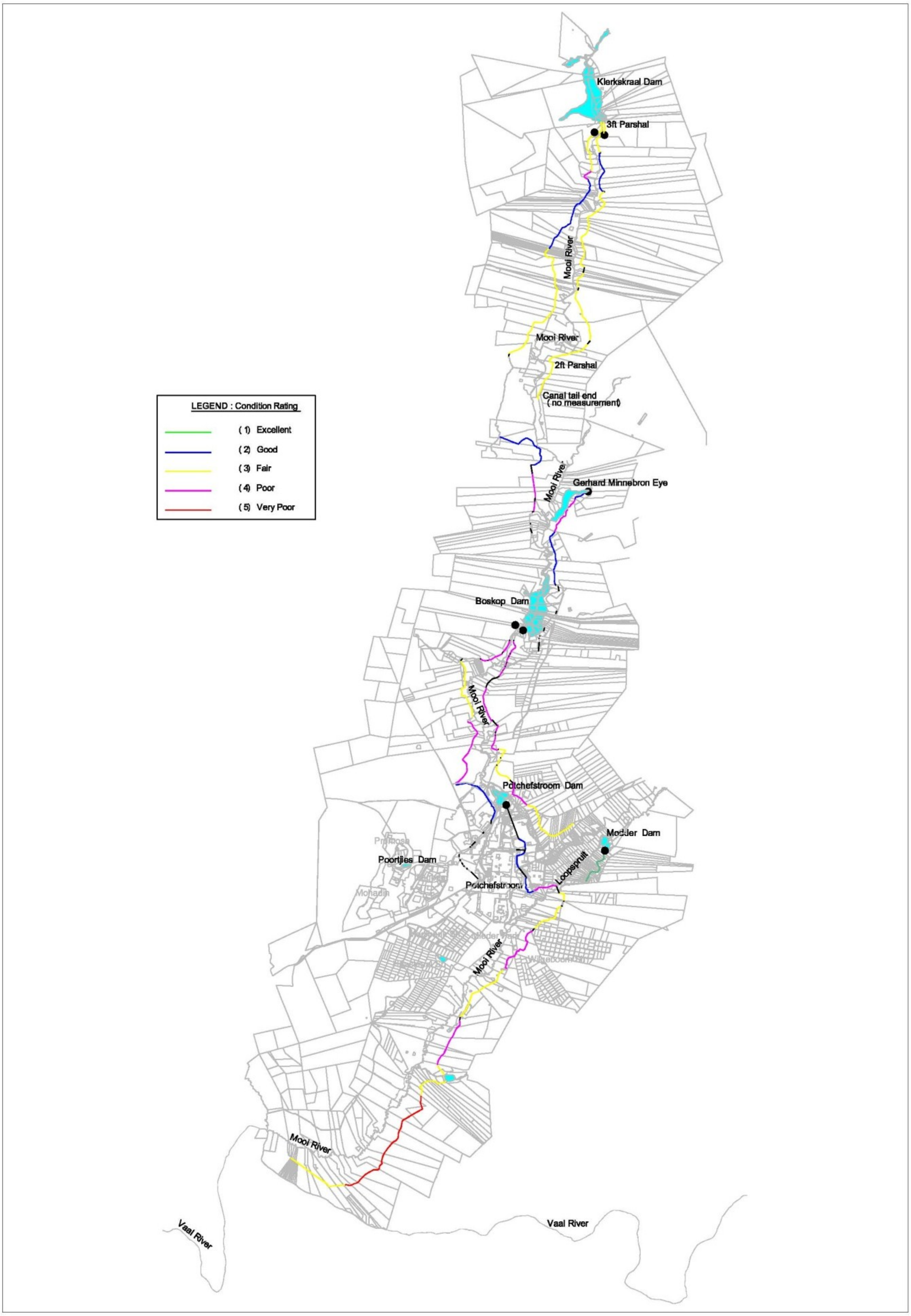

Figure 5:1: Preliminary condition assessment of the Mooi River GWS Canal infrastructure

Photo 5.1 below indicates the high algae build up in the Mooi River system. As illustrated in the photo, the Gerhardminnebron Eye canal which diverts the irrigation water requirements downstream of the eye, indicates significant algae growth from the land-use practices upstream. This has a significant impact on the hydraulic capacity of the canal. This means that there is a likelihood of overflow from the canal and increasing water losses due to leakage.

The condition of the weir structure can however be considered to be in good condition. The general condition of the weir was given a rating of 3 because of the vegetation growth in the weir and the sediment build up.

Photo 5:1: Algae growth at the Gerhardminnebron eye

5.3.3 Condition evaluation of the Boskop Dam right bank canal section

Photo 5.2 below provides an indication of the poor condition of some sections of the Boskop right bank canal. As illustrated in the photograph, the concrete panels have lifted out because of the expansive clay soils in the area.

Because of the very poor condition of the canal the condition rating given by the scheme managers for the Boskop Dam right bank canal was a 4. At the time of the site visit the section of the canal was being refurbished.

Photo 5:2: Photo of the Boskop Dam right bank canal illustrating the poor condition because of the expansive soils

5.3.4 Condition evaluation of other canals

Photo 5.3 below indicates the pencil size marks and patchwork on some sections of the canal. However, there was no structural damage that could be identified during the site visit.

The Lakeside canal was found to have significant canal breaks which confirmed the high water losses identified in the Lakeside canal as discussed in the later chapters. **Photo 5.4** below illustrates the canal breaks at some of the canal sections that were identified during the field site visit.

5.3.5 Condition evaluation of the siphons

The Boskop left bank canal supplies to the Potchefstroom Water works and has no air valves.

The siphon on the right bank canal through the industrial area is blocked exacerbating the algae build up.

Photo 5:3: Cracks on canal concrete panels

Photo 5:4: Canal leakage on the Lakeside canal

6 SCHEME OPERATIONS AND OPERATING PROCEDURES

6.1 General scheme options

An Operation Service has as its chief objective the timely delivery of the irrigation water necessary to satisfy crop water requirements. The accomplishment of this objective implies the following main activities:

(i) Planning the Operation (preparation of the so-called Irrigation Plans)

(ii) Implementation of the Plan (actual water distribution)

(iii) Monitoring of the Operation (collection of data related to water use and preparation of the corresponding reports).

The Mooi River State Water Scheme is dependent on the storage dams in the Mooi River as its source of supply, as well as the dolomitic aquifers north east of the scheme. The Gerhardminnebron eye is a source of water supply for downstream irrigators. The supply from the eye cannot be regulated.

Water is diverted into the six main canals downstream of the four sources of supply in the Mooi River with water abstracted at the sluices by irrigators according to their water applications provided to the scheme operators.

Since the Mooi River Government Water Scheme became operational, the irrigation scheme has experienced some water restrictions but not frequently, where the scheduled quotas have not been delivered to the farmers.

The Mooi River GWS is owned and operated by the Department of Water Affairs (DWA). Water is only released from the dams for two reasons;

(i) to meet the environmental water requirements (EWR) of the Mooi River; and

(ii) releases for Mooi River Government Water Scheme to meet the irrigation water requirements as well as domestic water use, based on the weekly requested demands from users in the scheme area.

6.2 Water ordering and delivery procedures

6.2.1 Overview

In order to ensure that the irrigators receive their scheduled quota as and when required, the Mooi River GWS operates the irrigation scheme based on “delivery on request” where each water user (irrigator) must submit a written request on a weekly basis and the water is delivered to the abstraction points along the canal systems.

6.2.2 Operation of matching irrigation supply and demand

The procedures followed by the irrigators in ordering their water requirements are as follows:

(1) Each irrigator determines how much water they need to order for the following week from the scheme, based on their irrigation scheduling as well as their scheduled quota.

(2) The irrigators submit their requests to the Mooi River GWS, by the close of business on Thursday, for their total water requirements, to be delivered the following week. Irrigators must specify their needs clearly on the request form and the GWS will endeavour to supply the water, as requested.

(3) The management at the Mooi River GWS then reconcile the total requested volume from the beginning of the water year with each irrigator's scheduled quota to ensure the irrigator does not use more water than the quota allocated to that property. The total volume of water required in each branch canal, is then calculated to determine how much water should be supplied in each of the different sections of canal systems based on the requests. This is compared with the hydraulic capacity of the canal section to ensure that the volume of water ordered does not exceed the hydraulic capacity of the canal system, including the expected canal losses.

(4) The above process is repeated from the branch canals up to the main canal to determine how much water needs to be diverted at the Klerkskraal Dam, Boskop Dam, Gerhardminnebron eye and Lakeside Dam. This includes the total compensation losses required to deliver the requested water.

(5) The requested water, including the compensation losses are then reconciled with the available water in the dam and the volume of water required to be released from the dams. Water is then released from Klerkskraal Dam, Lakeside Dam, Gerhardminnebron eye and Boskop Dam in time to meet the requested water for the following week.

(6) In the event that the requested volume exceeds the maximum hydraulic capacity of the canal systems, the requested volumes will be reduced proportionally to the determined hydraulic capacity of the canal infrastructure, taking into account the estimated water losses (Maximum Abstraction Right MAR).

(7) In order to reduce the water losses, the Mooi River GWS also determines the minimum volume of water that can be delivered in each canal system without

significant water losses. If the requests amount to less than the minimum threshold for release, then the irrigators in that particular section will not receive their requests.

(8) The Water Control Department (WCD) of Mooi River GWS sets up a flow chart of the streams to be used at each pressure controlled sluice gate to meet the requested water by the irrigator. This also includes the time the stream will flow during the week.

(9) Based on the availability and priorities, decisions are then made to release from Klerkskraal Dam, Boskop Dam, Gerhardminnebron and Lakeside Dam into the different canals based on the calculated volumes for the week to be delivered continuously during the week. The cycle commences on the Monday morning and ends on the Friday evenings, when the cycle of 108 hours is completed.

(10) The information regarding the volume of water allocated to each user is then communicated back by the WCOs to the consumers.

The above water ordering and delivery procedures have been formally documented. Therefore this enables all irrigators as well as the water control officers to be aware of the responsibilities of each stakeholder in ensuring effective and efficient delivery of water to the consumers. This will be useful particularly for new irrigators and WCOs to understand the process.

The water is supplied through pressure control sluice gates to the irrigators with measurements taken as part of the monitoring to ensure that each irrigator does not exceed his/her schedule quota. The individual offtakes are installed with sluice gates and Parshall flumes to measure the flows.

The stop and start nature of the operation of the canals and laterals in the sections of the Mooi River GWS areas increases the extent of evaporation as well as leakage and seepage losses due to changes in the capillary forces and gravity as well as changes in the water table.

Due to the pressure variance in the canal system the pressure sluices have been calibrated to provide 10% more water than requested. Thus if there is any problem with the constant head being less than optimal the user will still receive water as requested.

6.3 Procedures during water supply shortages

Although there have not been frequent water shortages since the construction of the two dams, there are procedures that are followed to address any water supply shortages. These include the following:

(i) At the start of the water year, the available water from Klerkskraal, Lakeside and Boskop Dams that can be supplied to irrigators is reconciled with the scheduled quota. Where it is envisaged that less water is available, the allocations to irrigators are reduced equitably regardless of the types of crops irrigated.

(ii) Priority is given to supply domestic water users in the event of water shortages.

(iii) The available water allocation to each irrigator is then supplied based on the delivery on request basis

(iv) The available water is reviewed during the course of the water year depending on the rainfall and any necessary changes are then made to the annual water allocation.

6.4 Water trading - Temporary water transfers

There may be periods when existing irrigators exhaust their scheduled quota before the end of the water year and may require additional irrigation water. The current practice is as follows:

(i) Irrigators cannot make a temporary transfer to lands that do not have any water rights. This is because the canals were designed to supply the existing water entitlements and are not likely to meet the additional demand.

(ii) Irrigators can however transfer water temporarily to another land which has a water use entitlement if there are shortages. However the transfer is subject to the canal having sufficient capacity for the additional stream.

(iii) Furthermore the temporary transfer can only be supplied during those periods that the canal feeding existing irrigators is not being required by other irrigators. This should however be arranged with the WCO prior to delivery.

The irrigators then approach the Mooi River GWS to facilitate the temporary transfer with the Department of Water Affairs (DWA) based on whether there is sufficient hydraulic capacity of the irrigation canal system for the transfer to be delivered to the temporary user.

6.5 Water pricing structure

6.5.1 Structure of irrigation

The water rate structure of the Mooi River Government Water scheme is based on a single tariff structure. The structure is an area based fixed charge which has been structured that irrigators are charged a flat rate regardless of how much water they use during the year. The water users therefore are charged the full amount for their scheduled allocation whether they use the water or not.

In the case of the Mooi River GWS, water users such as canal irrigators are required to pay 100% of their R962.50 per hectare per annum regardless of whether they use the water or not.

The current water pricing structure for the Mooi River Irrigation Scheme does not provide any means of providing incentives for water users to improve their efficiency.

6.5.2 Collection of the irrigation water use charges

The Mooi River GWS managers, which is the DWA Infrastructure Branch is responsible for collection of the water use charges which includes the money which it uses to pay for the operation and maintenance of the irrigation scheme. Irrigators, domestic and industrial users are also billed directly by DWA for the WRM charges.

7 UNAVOIDABLE WATER LOSSES IN MOOI RIVER IRRIGATION SCHEME

7.1 OVERVIEW

Before determining the irrigation water use efficiency of the Mooi River Irrigation Scheme, it was important to assess the expected seepage and evaporation losses based on the premise that the irrigation scheme infrastructure is being maintained as well as taking into account the useful life of the canal system infrastructure.

This is discussed in the following sections of this chapter.

7.2 Water losses Best Management Practice

7.2.1 Overview

According to Howell (2001), there are four basic losses that can result when water is diverted for irrigation, as follows:

1) Part of the water is consumed in evaporation (e.g. from channels) and transpiration (e.g. vegetation growing next to the channel).
2) Some water percolates to surface or subsurface areas (e.g. canal seepage or deep percolation) and cannot be recaptured (e.g. in the vadose zone, the ocean, or a salt sink) or can be recaptured (e.g. interceptor drains into a drainage canal or a drainage well) and used as an additional supply.
3) The drainage water becomes polluted with salts or chemicals (e.g. nutrients or pesticides) that are so concentrated that the water can no longer be used and must be discharged to a sink for disposal.
4) Untimely deliveries of water that cannot be used.(In the case of this section of the scheme, either operational spills at the canal tail ends representing a loss to the scheme or excess water which is delivered to downstream storages or canals within the scheme).

Quantifying these losses is the first step in determining the efficiencies of the conveyance and distribution systems and to compare with the Best Management Practices (BMP) for each of the water losses.

In order to establish the generally accepted practice that results in more efficient use, conservation or management of water, the estimate of the level of acceptable water losses due to seepage, evaporation and leakage was determined as part of setting the Best Management Practices (BMP) for acceptable water losses for the Mooi River Government Water Scheme.

7.2.2 Unavoidable losses due to expected seepage through concrete lining:

Canals continue to be the major conveyance systems for delivering water for irrigation agriculture. The seepage losses from irrigation canals constitute a substantial percentage of usable irrigation water. Therefore computation of the canal seepage losses is an important aspect of determining the best management practices for sustainable irrigation water management practices for the scheme.

Canals are often lined to reduce the seepage losses as is the case in the Mooi River Irrigation Scheme. A perfect canal lining which is well maintained reduces significantly the amount of seepage although the canal lining deteriorates with time and becomes ineffective in controlling the seepage.

Seepage losses from concrete lined, and unlined canals are normally expressed in l/s per 1 000 m^2 of wetted area and appear to fluctuate between approximately 0.35 l/s per 1 000 m^2 wetted area and 1.9 l/s per 1 000 m^2 (Reid, Davidson and Kotze (1986). For design purposes Butler (1980) suggested a value of 1.9 l/s per 1 000 m^2 wetted area. Therefore depending on the wetted area, this could result in an unavoidable loss rate of up to 15% of the inflow into an irrigation canal.

The seepage losses from concrete lined canal system depend on a number of driving factors among which the following can be said to have a marked influence:

(i) The hydraulic conductivity of the canal lining which is the concrete;
(ii) Subsurface condition in so far as they affect drainage and the groundwater table;
(iii) The age of the canal and the amount and fineness of the material carried in suspension;
(iv) The flow of water in the canal and its depth and velocity;
(v) The relation between the wetted perimeter and other hydraulic elements of the canal, particularly the discharge;
(vi) The temperature of the water.

In order to determine the seepage losses of the Mooi River GWS canal system, the geometry of the six canals were collected and used to determine the wetted perimeter and flow area of each segment of the canal. The formula used to calculate the seepage losses for curvilinear canal systems (i.e. parabolic canal geometry) is expressed as follows:

$q_s = k*y*F$ (1)

where q_s = seepage discharge per unit length of canal (m_2/s); *k* = hydraulic conductivity of the lining (m/s); *y* = depth of water in the canal (m); *F* = function of channel geometry (dimensionless); and *yF* = width of seepage flow at the infinity. The seepage function, F for parabolic canals was taken as

$F = (T/y) + Pi^{\wedge 2}/4G$ (2)

Where

T =top width of the channel at the water surface (m); y= flow depth of water (m); and G = 0.915965594, known as Catalan's Constant.

The seepage loss per unit length was then calculated using the hydraulic conductivity of the concrete lining; the canal geometry and the seepage rate based on the wetted perimeter.

It has been determined that because nearly all the canal infrastructure in the Mooi River Irrigation Scheme is lined, the average BMP unavoidable seepage losses was calculated to vary between 0.04 $m^3/s/m^2$ to 0.1798 $m^3/s/m^2$ for the entire Mooi River canals assuming the canal infrastructure was in a very good condition. This is based on calculating the seepage losses based on the geometry of the canal infrastructure, the manning's n, the estimated flowrate of each canal assumed to be flowing at maximum capacity and the calculated wetted area.

As illustrated in **Table 7.1** below, the minimum seepage losses expected in the Mooi River Government Water Scheme canal system is 5.720 million m^3/a in order to supply the scheduled allocation of 35.25 million m^3/a.

As a percentage of the current average annual water released into the canals, the minimum seepage losses that should be provided as additional to the scheduled allocation are 6.9% of the current diversion.

Table 7:1: Expected seepage losses in the Mooi River canal system

Canal Name	Max Hydraulic Capacity (m^3/hr)	Seepage Rate ($m^3/s/m^2$)	Canal Length (km)	Expected Seepage losses (million m^3/a)
Klerkskraal right bank		0.0408	41.20	0.564
Klerkskraal left bank		0.0374	22.48	0.282
Boskop right bank		0.1448	49.50	2.408
Boskop left bank		0.1448	14.50	0.705
Branch canals		0.0289	27.67	0.268
Gerhardminnebron		0.1204	14.15	0.572
Lakeside		0.0665	41.12	0.918.
Vyfhoek	Incl. in Lakeside		-	
Total Seepage Losses Mooi River Canal system			**127.68**	**5.720**

7.2.3 Unavoidable water losses due to evaporation from irrigation canals and balancing dams

The evaporation loss, expressed as a percentage of total inflow was determined based on the total surface area of the irrigation canals, the mean annual evaporation (MAE) based on the A-pan evaporation figure for the 1957 - 1979 hydrological record. The total annual evaporation from the irrigation canal surface area was determined to be 1.02 million m^3/a. This was taken as the average over the seven years records.

Based on the calculated evaporation losses, the evaporation losses as a percentage of the total inflows was determined to be 1.3%. This is much higher than the estimated evaporation losses at approximately 0.3% of total inflow volume (Reid, Davidson and Kotze; 1986).

Therefore the BMP evaporation loss in the Mooi River Irrigation Scheme area that was used was 1.3% of the total inflows which was taken as the unavoidable evaporation losses for the scheme area.

8 MOOI RIVER GOVERNMENT WATER SCHEME - WATER BALANCE ASSESSMENT

8.1 Overview

The previous chapter 7 described the Best Management Practice (BMP) for irrigation water management in the Mooi River. This chapter describes the findings of the water balance assessment and the level of water losses for the whole of the Mooi River Government Water Scheme. The key aspects in developing and implementing water management plans (WMP) in the agricultural sector, is to understand:

- how much water is released into the irrigation scheme area;
- how much water is delivered to the various sub-schemes or sections of the irrigation scheme;
- how much water is delivered to the irrigators in the various sub-schemes, and
- how much water is returned to the river/water resource, as spills or canal tail end returns.

This approach provides the irrigation water budget to account for any inefficiency in irrigation water management in the scheme. The Mooi River Irrigation Scheme uses the Water Administration System (WAS) to account for the water used by the scheme and the water use efficiency accounting report (WUEAR) for reporting on matching irrigation supply and demand (MISD).

The purpose of calculating the water balance and water budget is to help Mooi River Irrigation Scheme to answer three questions:

1) Is the water being distributed equitably among the irrigators and domestic and industrial consumers in the scheme?
2) How efficiently is water being used within the scheme area?
3) Is the scheme receiving its target allocation of water from the sources of supply?

The irrigation water budget for the Mooi River Irrigation Scheme was undertaken at two levels. The first level was to determine the overall water budget, with a view to determining the extent of water losses at an irrigation scheme level. The second level, which is discussed later in this chapter, was to determine the water balance for the six sub-schemes of the Mooi River GWS, namely the Klerkskraal right bank and left bank canals, the Gerhardminnebron canal, the Boskop right bank and left bank canals and the Lakeside canal.

8.2 Quality and integrity of the available information

8.2.1 Sources of information

It is important to note that the available records from the WUEAR reports that were used to conduct the water budget for the six sections in the Mooi River irrigation scheme are for the period 2000/2001 to the period 2007/08. There were however monthly records that were missing for the period. Another source of information for the volume of water diverted from the dams was from the DWA, hydrological branch. This was used to compare with the inflows into the Mooi River irrigation scheme.

There is a need for the information from the recent water years to be made available in order to review whether there have been any significant changes in the irrigation scheme water use efficiency. This will be used to update the current data once the information is made available for analysis.

8.2.2 Integrity of the available data and information

The data and information used to date to carry out the water budgets for the Mooi River irrigation scheme was from the available WUEAR reports prepared by the DWA Infrastructure Branch operating the scheme. The data used to prepare the WUEAR reports were based on measured data of the inflows into the irrigation canal; measured data at the outlet of Klerkskraal Dam, Lakeside Dam, Gerhardminnebron eye, and Boskop Dam at the beginning of the irrigation cycle; data from the water applications and supplied at the sluices of each irrigator. All other information was estimated in the WUEAR report and therefore not necessarily used.

Not all canal tail ends are measured. However, some of the canal tail ends end at the downstream dams and any spills may have been accounted as inflow to the downstream canals. There are also canal tail ends which end at irrigator's dams and which are measured at the Parshall as the water delivered to the irrigator through the sluice.

The water balance assessment has not included any precipitation figures during the period of delivery of water to irrigators. The assumption made is that the amount of precipitation during delivery of irrigation water is negligible and/or has been taken into account by irrigators as part of their irrigation scheduling. This may not be the case during the rainy season and consideration of incorporating information regarding precipitation should be made in future irrigation water use accounting if the irrigators are not taking this into account in their water applications.

There were gaps in monthly records from the WUEAR reports in some of the years. In order to evaluate the full year a process of patching using average monthly records for the year was conducted. This has resulted in patching some of the records to determine the total annual inflow and outflow from the sub-schemes.

8.3 Evaluation of the operational losses

8.3.1 Overview

The determination of operational losses (and mechanisms to minimise it) is one of the most important tools for improving irrigation water use efficiency levels. Higher accuracy in determining these losses, can underpin the efforts to decrease losses over the extent of the whole canal distribution system. Decreasing "avoidable losses" from irrigation canals is often the only "relatively" inexpensive method available when contemplating water management measures.

Avoidable losses occur as a result of inefficient management in the operation of the canal system and can mainly be attributed to poor canal maintenance (leaks), incorrect release pressures and inefficient runtime release determination, inaccurate water measuring structures and other restricting factors such as algae growth, etc.

Unavoidable losses from canal systems can be attributed to seepage and leakage and is related to the surface area of water in the canal, wetted perimeter area of the canal and to the structural condition of the canal network. These were used to estimate the seepage and deep percolation of irrigation water.

8.3.2 Determination of the water losses

An irrigation water balance was developed for the Mooi River Irrigation Scheme. The water balance assessment was based on information from the WUEAR reports, where records of inflows and water applications were provided. The records of inflows which consist of all the sources of water supply to the Mooi River Irrigation Scheme were provided on a weekly basis. These flows were converted to monthly records.

The water demand consists of all the water that is used on the scheme. This includes delivery to the irrigators and other users as well as deliveries to downstream canals. The rest of the water not accounted for such the canal seepage, operational spills, evaporation from the canals and percolation was taken as gross water losses of the scheme or section of the irrigation scheme.

The water budget is an important tool for analysing the water management issues provided adequate and reliable data is available. At a scheme level, there was sufficient data to determine a water budget, based on the WUEAR reports.

8.4 Overall scheme level Water Balance Assessment - Mooi River Irrigation Scheme

8.4.1 Overview

The Mooi River irrigation scheme was analysed on the basis that it comprises six irrigation sub-schemes namely the Klerkskraal Dam right bank and left bank canals, Gerhardminnebron eye canal, Boskop Dam right bank and left bank canals and Lakeside Dam canal. However before discussing the findings of the six sub-scheme water balance assessments, the findings of the scheme level water balance assessment are discussed in the following section.

8.4.2 Inflows into the Mooi River scheme

There are four sources of supply where the water is released into the Mooi River Irrigation Scheme canals. Flow measurement takes place immediately downstream of the three dams, Klerkskraal, Boskop and Lakeside where there are weirs to measure the flows into the five main canals. The other flow measurement is taken at a weir at Gerhardminnebron where the water from the dolomites is diverted into the Gerhardminnebron eye canal.

Daily and weekly flow records of the inflows into the main canals are being taken and used in the WUEAR reports. The records were aggregated into monthly records. Monthly records from 2000/01 water year to 2007/08 water year were generated as illustrated in **Figure 8.1** below.

The total average annual inflow into the Mooi River Scheme for the seven year period, was determined to be 83.14 million m^3/a. The maximum inflow took place in the 2000/01 water year when the total inflow for the year was approximately 101.65 million m^3/a. The water allocation for 4 578.1ha enlisted area for irrigation is 35.25 million m^3/a. The high inflow is based on matching the demand for irrigation water use and domestic use taking into account the water losses required to deliver the water demand. The average volume of water delivered to downstream canals which include into Boskop Dam and Lakeside is 29.43 million m^3/a.

The lowest volume of irrigation water diversion occurred in the 2001/02 water year when 53.54 million m^3/a, was released from the different dams and eye into the main irrigation canals. This is because of a lack of data for some of the months of this water year.

WATER YEAR	MONTH	INFLOWS					DEMANDS								GROSS WATER LOSSES			NON BENEFICIAL WATER LOSSES			BENEFICIAL WATER LOSSES			UTILISATION
		Mooi River	Other Supplements	Balancing Dam	Precipitation	Total inflows	Irrigation water application	Households/Stock Consumption	Industrial	Municipality	Government	Free Water	Other Canals	Total Outflows	Total water losses	% of inflow	Water Use Index	Evaporation	Seepage	Unavoidable water losses	Canal End Point	Seepage & Leakage	% avoidable water losses	% of scheduled volume
1999/2000																		1.3%	7%					
	October	-	-			-	-	-	-	-	-	-	-	-	-	#DIV/0!	#DIV/0!	-	-	-	-	-	#DIV/0!	
	November	-	-			-	-	-	-	-	-	-	-	-	-	#DIV/0!	#DIV/0!	-	-	-	-	-	#DIV/0!	
	December	-	-			-	-	-	-	-	-	-	-	-	-	#DIV/0!	#DIV/0!	-	-	-	-	-	#DIV/0!	
	January	-	-			-	-	-	-	-	-	-	-	-	-	#DIV/0!	#DIV/0!	-	-	-	-	-	#DIV/0!	
	February	-	-			-	-	-	-	-	-	-	-	-	-	#DIV/0!	#DIV/0!	-	-	-	-	-	#DIV/0!	
	March	712.50	-			712.50	77.70	-	-	-	-	-	479.40	557.10	155.40	21.8%	1.28	8.91	49.88	58.78	-	96.62	13.6%	
	April	-	-			-	-	-	-	-	-	-	-	-	-	#DIV/0!	#DIV/0!	-	-	-	-	-	#DIV/0!	
	May	7 656.80	-	-		7 656.80	329.10	-	15.10	-	26.10	183.60	4 068.10	4 622.00	3 034.80	39.6%	1.66	95.71	535.98	631.69	1 880.80	2 403.11	31.4%	
	June	7 934.60	60.50			7 995.10	794.70	119.90	3.30	543.80	30.30	367.20	4 306.00	6 165.20	1 829.90	22.9%	1.30	99.94	559.66	659.60	648.10	1 170.30	14.6%	
	July	-	-			-	-	-	-	-	-	-	-	-	-	#DIV/0!	#DIV/0!	-	-	-	-	-	#DIV/0!	
	August	8 926.10	64.80			8 990.90	1 710.90	107.80	16.50	879.60	89.70	183.60	3 935.30	6 923.40	2 067.50	23.0%	1.30	112.39	629.36	741.75	637.80	1 325.75	14.7%	
	September	7 917.90	43.20			7 961.10	1 698.70	94.90	21.30	938.70	89.70	183.60	3 499.60	6 526.50	1 434.60	18.0%	1.22	99.51	557.28	656.79	336.80	777.81	9.8%	
		33 147.90	168.50	-	-	33 316.40	4 611.10	322.60	56.20		235.80	918.00	16 288.40	24 794.20	8 522.20	25.6%	1.34	416.46	2 332.15	2 748.60	3 503.50	5 773.60	17.3%	13%
2000/01																								
	October	11 323.70	43.20			11 366.90	1 754.90	125.40	26.00	1 042.70	9.00	183.60	3 752.30	6 893.90	4 473.00	39.4%	1.65	142.09	795.68	937.77	2 320.10	3 535.23	31.1%	
	November	7 685.80	43.20			7 729.00	956.00	106.30	14.10	875.30	53.10	183.60	3 163.20	5 351.60	2 377.40	30.8%	1.44	96.61	541.03	637.64	929.70	1 739.76	22.5%	
	December	8 764.40	43.20			8 807.60	617.00	119.90	22.40	753.90	35.70	183.60	3 629.40	5 361.90	3 445.70	39.1%	1.64	110.10	616.53	726.63	862.50	2 719.07	30.9%	
	January	11 274.60	54.00			11 328.60	3 207.20	146.20	7.50	1 036.00	113.30	183.60	2 770.60	7 464.40	3 864.20	34.1%	1.52	141.61	793.00	934.61	1 647.10	2 929.59	25.9%	
	February	9 270.50	43.20			9 313.70	2 289.40	109.70	27.30	984.60	111.90	183.60	3 326.70	7 033.20	2 280.50	24.5%	1.32	116.42	651.96	768.38	458.80	1 512.12	16.2%	
	March	9 972.90	43.20			10 016.10	1 339.50	119.90	11.20	1 015.10	111.90	183.60	3 560.10	6 341.30	3 674.80	36.7%	1.58	125.20	701.13	826.33	1 708.50	2 848.47	28.4%	
	April	8 427.90	43.20			8 471.10	263.70	119.90	11.30	885.40	34.50	183.60	3 942.90	5 441.30	3 029.80	35.8%	1.56	105.89	592.98	698.87	1 381.50	2 330.93	27.5%	
	May	8 902.50	54.00			8 956.50	391.90	133.80	11.10	800.70	81.90	183.60	4 167.40	5 770.40	3 186.10	35.6%	1.55	111.96	626.96	738.91	1 479.70	2 447.19	27.3%	
	June	8 090.00	43.20			8 133.20	589.50	121.30	10.90	793.60	59.10	183.60	4 050.60	5 808.60	2 324.60	28.6%	1.40	101.67	569.32	670.99	756.00	1 653.61	20.3%	
	July	8 054.20	43.20			8 097.40	624.50	123.70	19.80	793.60	59.10	229.50	3 890.60	5 740.80	2 356.60	29.1%	1.41	101.22	566.82	668.04	798.50	1 688.56	20.9%	
	August	9 390.60	43.20			9 433.80	705.50	139.50	16.10	793.60	59.10	229.50	4 484.00	6 427.30	3 006.50	31.9%	1.47	117.92	660.37	778.29	1 194.50	2 228.21	23.6%	
	September	-	-			-	-	-	-	-	-	-	-	-	-	#DIV/0!	#DIV/0!	-	-	-	-	-	#DIV/0!	
	Subtotal	101 157.10	496.80			101 653.90	12 739.10	1 365.60	177.70	9 774.50	728.60	2 111.40	40 737.80	67 634.70	34 019.20	33.5%	1.50	1 128.59	6 320.09	7 448.68	11 216.80	22 097.52	21.7%	36%
2001/02																								
	October	10 744.60	43.20			10 787.80	1 848.70	141.60	-	826.10	58.50	183.60	4 322.90	7 381.40	3 406.40	31.6%	1.46	134.85	755.15	889.99	1 433.00	2 516.41	23.3%	
	November	-	-			-	-	-	-	-	-	-	-	-	-	#DIV/0!	#DIV/0!	-	-	-	-	-	#DIV/0!	
	December	-	-			-	-	-	-	-	-	-	-	-	-	#DIV/0!	#DIV/0!	-	-	-	-	-	#DIV/0!	
	January	7 244.80	43.20			7 288.00	1 805.60	106.30	12.50	907.00	-	-	2 190.90	5 022.30	2 265.70	31.1%	1.45	91.10	510.16	601.26	943.90	1 664.44	22.8%	
	February	7 685.80	43.20			7 729.00	956.40	106.30	17.90	831.50	53.40	-	3 159.50	5 125.00	2 604.00	33.7%	1.51	96.61	541.03	637.64	1 156.60	1 966.36	25.4%	
	March	10 676.10	43.20			10 719.30	576.60	106.30	18.90	781.00	3.00	183.60	4 620.50	6 289.90	4 429.40	41.3%	1.70	133.99	750.35	884.34	2 454.60	3 545.06	33.1%	
	April	10 078.80	43.20			10 122.00	1 364.30	106.30	10.70	990.60	10.80	183.60	4 078.50	6 744.80	3 377.20	33.4%	1.50	126.53	708.54	835.07	1 544.90	2 542.14	25.1%	
	May	7 561.50	43.20			7 604.70	449.50	108.70	24.90	803.00	16.20	183.60	3 064.50	4 650.40	2 954.30	38.8%	1.64	95.06	532.33	627.39	1 647.20	2 326.91	30.6%	
	June	9 521.80	43.20			9 565.00	336.00	108.70	19.40	877.70	31.00	183.60	4 270.60	5 827.00	3 738.00	39.1%	1.64	119.56	669.55	789.11	1 978.80	2 948.89	30.8%	
	July	8 019.00	43.20			8 062.20	887.20	108.70	0.20	829.40	14.40	183.60	3 155.60	5 179.10	2 883.10	35.8%	1.56	100.78	564.35	665.13	1 370.50	2 217.97	27.5%	
	August	7 596.20	43.20			7 639.40	1 202.10	108.70	1.10	847.30	7.80	183.60	2 134.40	4 485.00	3 154.40	41.3%	1.70	95.49	534.76	630.25	1 642.70	2 524.15	33.0%	
	September	8 054.85	43.20			8 098.05	1 590.80	112.50	1.10	847.30	7.80	183.60	2 963.20	5 706.30	2 391.75	29.5%	1.42	101.23	566.86	668.09	17 784.80	1 723.66	21.3%	
Sub-total		87 183.45	432.00	-	-	87 615.45	11 017.20	1 114.10	106.70	8 540.90	202.90	1 468.80	33 960.60	56 411.20	31 204.25	35.6%	1.55	1 095.19	6 133.08	7 228.27	31 957.00	23 975.98	27.4%	31%
2002/03																								
	October	8 969.52	54.00			9 023.52	2 531.00	150.00	26.10	1 004.10	56.00	183.60	3 077.50	7 028.30	1 995.22	22.1%	1.28	112.79	631.65	744.44	17 925.10	1 250.78	13.9%	
	November	7 971.62	54.00			8 025.62	2 018.90	150.00	25.50	-	48.00	183.60	2 825.00	5 251.00	2 774.62	34.6%	1.53	100.32	561.79	662.11	18 853.10	2 112.51	26.3%	
	December	7 995.22	54.00			8 049.22	1 219.10	150.00	24.40	-	22.80	183.60	3 242.20	4 842.10	3 207.12	39.8%	1.66	100.62	563.45	664.06	19 279.20	2 543.06	31.6%	
	January	6 654.12	43.20			6 697.32	1 508.40	119.90	23.50	-	21.00	183.60	2 032.60	3 889.00	2 808.32	41.9%	1.72	83.72	468.81	552.53	19 122.80	2 255.79	33.7%	
	February	6 654.12	43.20			6 697.32	1 615.30	119.90	22.20	-	23.40	183.60	2 108.30	4 072.70	2 624.62	39.2%	1.64	83.72	468.81	552.53	18 939.10	2 072.09	30.9%	
	March	6 654.12	43.20			6 697.32	1 744.20	119.90	22.00	-	13.80	183.60	2 210.30	4 293.80	2 403.52	35.9%	1.56	83.72	468.81	552.53	18 718.10	1 850.99	27.6%	
	April	6 688.72	43.20			6 731.92	733.20	119.90	21.00	1 087.40	10.80	183.60	2 605.90	4 761.80	1 970.12	29.3%	1.41	84.15	471.23	555.38	18 277.10	1 414.74	21.0%	
	May	7 734.02	54.00			7 788.02	640.50	150.00	18.70	983.40	40.20	183.60	3 481.20	5 497.60	2 290.42	29.4%	1.42	97.35	545.16	642.51	18 419.40	1 647.91	21.2%	
	June	7 734.02	54.00			7 788.02	455.40	150.00	20.30	868.70	43.20	183.60	3 583.80	5 305.00	2 483.02	31.9%	1.47	97.35	545.16	642.51	18 612.10	1 840.51	23.6%	
	July	6 599.75	43.20			6 642.95	890.30	119.90	19.80	945.10	30.40	183.60	2 684.20	4 873.30	1 769.65	26.6%	1.36	83.04	465.01	548.04	17 474.40	1 221.61	18.4%	
	August	6 599.75	43.20			6 642.95	1 200.10	116.10	28.00	958.80	33.60	183.60	2 605.40	5 125.60	1 517.35	22.8%	1.30	83.04	465.01	548.04	17 222.00	969.31	14.6%	
	September	5 565.69	32.40			5 598.09	1 702.70	90.00	21.10	961.70	33.60	183.60	1 563.40	4 556.10	1 041.99	18.6%	1.23	69.98	391.87	461.84	16 305.70	580.15	10.4%	
Sub-total		85 820.67	561.60	-	-	86 382.27	16 259.10	1 555.60	272.60	6 809.20	376.80	2 203.20	32 019.80	59 496.30	26 885.97	31.1%	1.45	1 079.78	6 046.76	7 126.54	219 148.10	19 759.43	22.9%	46%
2003/04																								
	October	2 431.60	-			2 431.60	550.80	9.80	0.70	919.90	21.60	183.60	-	1 686.40	745.20	30.6%	1.44	30.40	170.21	200.61	203.00	544.59	22.4%	
	November	6 251.80	43.20			6 295.00	465.90	110.10	19.10	-	13.00	-	2 933.70	3 541.80	2 753.20	43.7%	1.78	78.69	440.65	519.34	1 397.10	2 233.86	35.5%	
	December	7 995.22	54.00			8 049.22	1 219.10	150.00	27.00	-	36.60	183.60	3 238.70	4 855.00	3 194.22	39.7%	1.66	100.62	563.45	664.06	19 266.30	2 530.16	31.4%	
	January	6 654.12	43.20			6 697.32	1 508.40	119.90	26.10	1 142.50	39.60	183.60	2 028.50	5 048.60	1 648.72	24.6%	1.33	83.72	468.81	552.53	17 962.70	1 096.19	16.4%	
	February	6 654.12	43.20			6 697.32	1 810.30	119.90	16.90	933.60	34.00	183.60	2 114.00	5 212.30	1 485.02	22.2%	1.28	83.72	468.81	552.53	17 799.50	932.49	13.9%	
	March	6 674.12	43.20			6 717.32	718.20	119.90	10.90	837.10	-	183.60	2 017.90	3 887.60	2 829.72	42.1%	1.73	83.97	470.21	554.18	18 835.20	2 275.54	33.9%	
	April	6 688.72	43.20			6 731.92	201.70	110.10	13.90	-	-	-	2 838.70	3 164.40	3 567.52	53.0%	2.13	84.15	471.23	555.38	343.70	3 012.14	44.7%	
	May	9 680.60	54.00			9 734.60	689.10	130.20	16.30	775.20	9.00	183.60	3 289.00	5 092.40	4 642.20	47.7%	1.91	121.68	681.42	803.10	2 758.90	3 839.10	39.4%	
	June	-	-			-	-	-	-	-	-	-	-	-	-	#DIV/0!	#DIV/0!	-	-	-	-	-	#DIV/0!	
	July	-	-			-	-	-	-	-	-	-	-	-	-	#DIV/0!	#DIV/0!	-	-	-	-	-	#DIV/0!	
	August	-	-			-	-	-	-	-	-	-	-	-	-	#DIV/0!	#DIV/0!	-	-	-	-	-	#DIV/0!	
	September	-	-			-	-	-	-	-	-	-	-	-	-	#DIV/0!	#DIV/0!	-	-	-	-	-	#DIV/0!	
Sub-total		53 030.30	324.00	-	-	53 354.30	7 163.50	869.90	130.90	4 608.30	153.80	1 101.60	18 460.50	32 488.50	20 865.80	39.1%	1.64	666.93	3 734.80	4 401.73	78 566.40	16 464.07	30.9%	20%
2004/05																								
	October	-	-			-	-	-	-	-	-	-	-	-	-	#DIV/0!	#DIV/0!	-	-	-	-	-	#DIV/0!	
	November	-	-			-	-	-	-	-	-	-	-	-	-	#DIV/0!	#DIV/0!	-	-	-	-	-	#DIV/0!	
	December	-	-			-	-	-	-	-	-	-	-	-	-	#DIV/0!	#DIV/0!	-	-	-	-	-	#DIV/0!	
	January	-	-			-	-	-	-	-	-	-	-	-	-	#DIV/0!	#DIV/0!	-	-	-	-	-	#DIV/0!	
	February	-	-			-	-	-	-	-	-	-	-	-	-	#DIV/0!	#DIV/0!	-	-	-	-	-	#DIV/0!	
	March	-	-			-	-	-	-	-	-	-	-	-	-	#DIV/0!	#DIV/0!	-	-	-	-	-	#DIV/0!	
	April	7 634.60	43.20			7 677.80	283.20	119.90	16.20	952.00	12.00	183.60	3 118.20	4 685.10	2 992.70	39.0%	1.64	95.97	537.45	633.42	1 536.20	2 359.28	30.7%	
	May	7 610.00	43.20			7 653.20	521.90	90.20	18.00	748.10	6.00	183.60	2 793.30	4 361.10	3 292.10	43.0%	1.75	95.67	535.72	631.39	1 856.40	2 660.71	34.8%	
	June	7 922.90	43.20			7 966.10	492.20	110.10	17.00	877.80	5.40	183.60	2 735.20	4 421.30	3 544.80	44.5%	1.80	99.58	557.63	657.20	2 023.80	2 887.60	36.2%	
	July	10 235.40	54.00			10 289.40	911.40	150.00	15.60	859.20	1 066.20	183.60	3 838.90	7 024.90	3 264.50	31.7%	1.46	128.62	720.26	848.88	1 319.40	2 415.62	23.5%	
	August	5 565.69	32.40			5 598.09	1 702.70	90.00	17.70	1 034.00	45.00	183.60	1 567.00	4 640.00	958.09	17.1%	1.21	69.98	391.87	461.84	16 221.70	496.25	8.9%	
	September	5 565.69	32.40			5 598.09	1 702.70	90.00	17.70	1 034.00	45.00	183.60	1 567.00	4 640.00	958.09	17.1%	1.21	69.98	391.87	461.84	16 221.70	496.25	8.9%	
Sub-total		44 534.28	248.40	-	-	44 782.68	5 614.10	650.20	102.20	5 505.10	1 179.60	1 101.60	15 619.60	29 772.40	15 010.28	33.5%	1.50	559.78	3 134.79	3 694.57	39 179.20	11 315.71	25.3%	16%

Figure 8:1: Mooi River Irrigation Scheme - Water Balance

		INFLOWS					DEMANDS								GROSS WATER LOSSES			NON BENEFICIAL WATER LOSSES			BENEFICIAL WATER LOSSES			UTILISATION
WATER YEAR	MONTH	Mooi River	Other Supplements	Balancing Dam	Precipitation	Total inflows	Irrigation water application	Households/Stock Consumption	Industrial	Municipality	Government	Free Water	Other Canals	Total Outflows	Total water losses	% of inflow	Water Use Index	Evaporation	Seepage	Unavoidable water losses	Canal End Point	Seepage & Leakage	% avoidable water losses	% of scheduled volume
2005/06																								
	October	-	-			-	-	-	-	-	-	-	-	-	-	#DIV/0!	#DIV/0!	-	-	-	-	-	#DIV/0!	
	November	-	-			-	-	-	-	-	-	-	-	-	-	#DIV/0!	#DIV/0!	-	-	-	-	-	#DIV/0!	
	December	-	-			-	-	-	-	-	-	-	-	-	-	#DIV/0!	#DIV/0!	-	-	-	-	-	#DIV/0!	
	January	7 625.10	43.20			7 668.30	1 529.70	117.50	15.10	1 207.10	6.60	183.60	2 400.10	5 459.70	2 208.60	28.8%	1.40	95.85	536.78	632.63	733.70	1 575.97	20.6%	
	February	7 816.40	32.40			7 848.80	1 895.50	104.20	16.80	958.60	7.80	183.60	1 754.20	4 920.70	2 928.10	37.3%	1.60	98.11	549.42	647.53	1 579.20	2 280.57	29.1%	
	March	6 452.10	243.50			6 695.60	802.30	112.10	20.10	776.50	3.60	183.60	2 058.50	3 956.70	2 738.90	40.9%	1.69	83.70	468.69	552.39	981.10	2 186.51	32.7%	
	April	8 533.20	59.20			8 592.40	308.40	142.20	14.70	807.50	2.40	183.60	3 521.50	4 980.30	3 612.10	42.0%	1.73	107.41	601.47	708.87	2 006.80	2 903.23	33.8%	
	May	9 679.80	54.00			9 733.80	712.80	150.00	23.50	803.30	5.40	183.60	3 178.60	5 057.20	4 676.60	48.0%	1.92	121.67	681.37	803.04	2 310.00	3 873.56	39.8%	
	June	8 194.10	43.20			8 237.30	364.10	96.00	17.00	661.10	3.60	183.60	2 557.30	3 882.70	4 354.60	52.9%	2.12	102.97	576.61	679.58	2 620.60	3 675.02	44.6%	
	July	8 104.10	43.20			8 147.30	696.30	119.90	24.50	719.70	5.40	183.60	3 005.50	4 754.90	3 392.40	41.6%	1.71	101.84	570.31	672.15	1 381.60	2 720.25	33.4%	
	August	10 141.50	32.40			10 173.90	1 419.80	131.20	22.30	841.40	1.80	183.60	3 530.20	6 130.30	4 043.60	39.7%	1.66	127.17	712.17	839.35	2 151.30	3 204.25	31.5%	
	September	10 033.20	81.20			10 114.40	2 275.00	108.30	28.30	944.40	44.40	183.60	2 544.30	6 128.30	3 986.10	39.4%	1.65	126.43	708.01	834.44	1 136.60	3 151.66	31.2%	
Sub-total		76 579.50	632.30	-	-	77 211.80	10 003.90	1 081.40	182.30	7 719.60	81.00	1 652.40	24 550.20	45 270.80	31 941.00	41.4%	1.71	965.15	5 404.83	6 369.97	14 900.90	25 571.03	33.1%	28%
2006/07																								
	October	3 217.50	43.20			3 260.70	1 506.30	31.70	-	-	10.20	-	1 260.70	2 808.90	451.80	13.9%	1.16	40.76	228.25	269.01	43.20	182.79	5.6%	
	November	7 846.80	43.20			7 890.00	2 065.40	88.70	33.50	1 060.70	16.80	183.60	2 786.00	6 234.70	1 655.30	21.0%	1.27	98.63	552.30	650.93	828.70	1 004.38	12.7%	
	December	-	-			-	-	-	-	-	-	-	-	-	-	#DIV/0!	#DIV/0!	-	-	-	-	-	#DIV/0!	
	January	8 414.10	43.20			8 457.30	1 691.10	119.90	24.20	904.40	10.20	183.60	2 366.00	5 299.40	3 157.90	37.3%	1.60	105.72	592.01	697.73	1 379.10	2 460.17	29.1%	
	February	9 141.50	43.20			9 184.70	2 076.10	119.90	29.70	1 048.50	24.00	183.60	1 916.00	5 397.80	3 786.90	41.2%	1.70	114.81	642.93	757.74	1 846.00	3 029.16	33.0%	
	March	8 851.10	37.10			8 888.20	1 709.40	119.90	30.80	959.60	27.60	183.60	2 858.40	5 889.30	2 998.90	33.7%	1.51	111.10	622.17	733.28	1 133.30	2 265.62	25.5%	
	April	8 056.30	47.50			8 103.80	339.60	119.90	16.10	970.30	20.40	183.60	2 783.00	4 432.90	3 670.90	45.3%	1.83	101.30	567.27	668.56	2 082.70	3 002.34	37.0%	
	May	9 679.80	54.00			9 733.80	712.80	150.00	25.60	864.80	4.20	183.60	3 310.30	5 251.30	4 482.50	46.1%	1.85	121.67	681.37	803.04	2 776.90	3 679.46	37.8%	
	June	6 829.40	43.20			6 872.60	364.10	96.00	22.60	824.20	3.60	183.60	2 505.20	3 999.30	2 873.30	41.8%	1.72	85.91	481.08	566.99	1 607.80	2 306.31	33.6%	
	July	8 073.40	43.20			8 116.60	696.30	119.90	22.30	864.20	7.80	183.60	3 031.00	4 925.10	3 191.50	39.3%	1.65	101.46	568.16	669.62	1 706.40	2 521.88	31.1%	
	August	10 586.50	54.00			10 640.50	1 620.00	141.60	25.30	888.60	22.80	183.60	4 064.30	6 946.20	3 694.30	34.7%	1.53	133.01	744.84	877.84	2 408.00	2 816.46	26.5%	
	September	10 033.20	81.20			10 114.40	2 275.00	108.30	34.10	1 008.40	27.60	183.60	2 574.00	6 211.00	3 903.40	38.6%	1.63	126.43	708.01	834.44	1 969.80	3 068.96	30.3%	
Sub-total		90 729.60	533.00	-	-	91 262.60	15 056.10	1 215.80	264.20	9 393.70	175.20	1 836.00	29 454.90	57 395.90	33 866.70	37.1%	1.59	1 140.78	6 388.38	7 529.16	17 781.90	26 337.54	28.9%	43%
2007/08																								
	October	9 792.00	43.20			9 835.20	491.40	84.70	52.60	905.40	26.20	183.60	3 373.00	5 116.90	4 718.30	48.0%	1.92	122.94	688.46	811.40	2 574.80	3 906.90	39.7%	
	November	12 752.30	54.00			12 806.30	3 931.70	150.00	23.40	886.00	39.60	183.60	4 076.20	9 290.50	3 515.80	27.5%	1.38	160.08	896.44	1 056.52	2 140.80	2 459.28	19.2%	
	December	9 459.90	54.00			9 513.90	1 145.80	150.00	36.90	-	18.00	183.60	3 689.10	5 223.40	4 290.50	45.1%	1.82	118.92	665.97	784.90	18 501.10	3 505.60	36.8%	
	January	9 338.20	43.20			9 381.40	1 690.80	119.90	41.70	955.60	14.40	183.60	2 486.20	5 492.20	3 889.20	41.5%	1.71	117.27	656.70	773.97	2 053.20	3 115.23	33.2%	
	February	9 141.50	43.20			9 184.70	2 076.10	119.90	17.20	923.60	8.40	183.60	1 937.30	5 266.10	3 918.60	42.7%	1.74	114.81	642.93	757.74	1 987.60	3 160.86	34.4%	
	March	8 851.10	37.10			8 888.20	1 709.40	119.90	19.30	930.50	9.00	183.60	2 868.90	5 840.60	3 047.60	34.3%	1.52	111.10	622.17	733.28	1 305.70	2 314.32	26.0%	
	April	10 150.90	59.00			10 209.90	438.20	150.00	13.80	809.30	12.00	183.60	3 754.70	5 361.60	4 848.30	47.5%	1.90	127.62	714.69	842.32	3 157.40	4 005.98	39.2%	
	May	7 844.80	43.40			7 888.20	536.30	119.90	10.60	874.20	16.20	183.40	2 671.20	4 411.80	3 476.40	44.1%	1.79	98.60	552.17	650.78	2 083.90	2 825.62	35.8%	
	June	5 836.00	43.20			5 879.20	431.70	102.50	17.00	894.80	7.80	183.60	2 001.30	3 638.70	2 240.50	38.1%	1.62	73.49	411.54	485.03	1 180.30	1 755.47	29.9%	
	July	-	-			-	-	-	-	-	-	-	-	-	-	#DIV/0!	#DIV/0!	-	-	-	-	-	#DIV/0!	
	August	-	-			-	-	-	-	-	-	-	-	-	-	#DIV/0!	#DIV/0!	-	-	-	-	-	#DIV/0!	
	September	-	-			-	-	-	-	-	-	-	-	-	-	#DIV/0!	#DIV/0!	-	-	-	-	-	#DIV/0!	
Sub-total		83 166.70	420.30	-	-	83 587.00	12 451.40	1 116.80	232.50	7 179.40	151.60	1 652.20	26 857.90	49 641.80	33 945.20	40.6%	1.68	1 044.84	5 851.09	6 895.93	34 984.80	27 049.27	32.4%	35%

Figure 8:2: Mooi River Irrigation Scheme - Water Balance

No data was available on the monthly rainfall in the Mooi River Irrigation Scheme area for the same period. Therefore the precipitation was not included as an input into the water budget.

Because there are no balancing dams in the Mooi River section of irrigation scheme, there are no net inflows or outflows to include from balancing dams

8.4.3 Water Demands from Mooi River scheme

The supply to individual water users is measured (or rather administered) through the head and hence the variable water pressure at different outlets at the pressure sluice gates at each of the farm turnouts that has an allocation from the scheme. The WCAs measure the head and the resultant pressure at the sluice gate is then related to a specific volume of water (e.g. 50 m^3/h, 100 m^3/h, 150 m^3/h and 200 m^3/h). The sluices are adjusted by hand in increments based on the irrigation application for the week.

Due to the water level and hence pressure variance in the canal system, there is a margin of error in the volume of water delivered to the water user and water users are requested to accept a margin of error of 10%. The monthly data on releases at the individual sluices are aggregated in the WUEAR reports to provide monthly records of water requested and used by the irrigators.

This was taken as the crop evapo-transpiration (ET). Records of monthly deliveries to other water users, namely Potchefstroom Local Municipality for domestic supply was included in the water use.

8.4.3.1 Irrigation water demands

The volume of water applied for by the irrigators in the Mooi River Irrigation Scheme area varies from year to year, as does the cropping pattern for each year. For the past 7 water years the irrigation water application has ranged from 7.16 million m^3/a in 2003/04 water year to 16.26 million m^3/a in 2002/03. Over the past seven years, the average irrigation water demands was 12.10 million m^3/a. When compared with the scheduled quota for canal irrigators this represents on average approximately 34% of the scheduled area was irrigated over the period.

8.4.3.2 Other demands

Besides irrigation water demands, the Mooi River Irrigation Scheme also supplies domestic water supply to Potchefstroom Local Municipality for the town of Potchefstroom and the surrounding communities.

The domestic water demand from the irrigation canal infrastructure has been growing significantly over the past four years. The raw water abstraction from the canal system in 2003/04 was 4.61 million m^3/a rising to 7.18 million m^3/a in 2007/08, which is an average growth rate of 11.7% per year for the period.

8.4.3.3 Delivery to downstream canals

The Mooi River Government Water Scheme is well regulated with three main dams supplying the irrigators. However some of the excess water from the upstream canals delivers water to downstream canals. The average water delivered to downstream canals over the seven year period was 29.43 million m^3/a.

The total average water demand from the Mooi River Irrigation Scheme, dependent on the canal infrastructure, delivered to the water users excluding delivery to downstream canals was 23.19 million m^3/a over the last seven years from 2000/01 to 2007/08 water year.

8.4.4 Comparison of monthly diversions with monthly demands

There is some correlation between the monthly inflow into the Mooi River irrigation canals with the monthly demands as illustrated in **Figure 8.3** below. The irrigation water supplied is more than the water requested by irrigators and other water users in the scheme including delivery to downstream canals as the scheme has tried to match the irrigation supplies with the irrigation demands.

The difference in matching the supply to the demand is to take into account the losses needed to deliver the water required by the irrigators. However in the case of the Mooi River irrigation scheme there is excess water supplied that is delivered through the canals. Without actual measurements of the amount of water delivered to downstream canals the current operational regime may have an impact on the level of conveyance efficiency of the scheme.

As illustrated in **Figure 8.3** below, there is a significant difference in trying to match the irrigation supply to the irrigation water demands, as significantly more water needs to be released into the Scheme to meet the irrigated water ordered.

The seven year average percentage of water losses in order to meet the irrigation demands and downstream canals was determined to be 36% of the total inflow into the Scheme. The additional water can be attributed to irrigation water losses owing to leakage losses in the irrigation canals, and evaporative losses from the open irrigation canal infrastructure and spills due to aquatic weeds. The above average percentage has been benchmarked against best management practice (BMP) in order to determine the extent required to meet the BMP for irrigation operation of the Mooi River Irrigation Scheme.

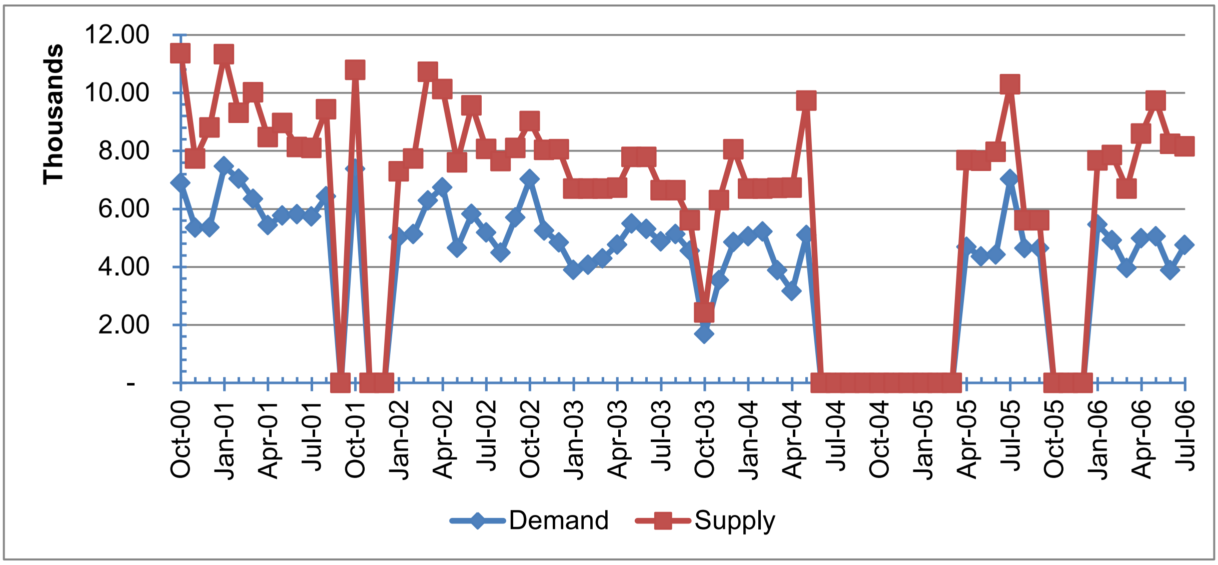

Figure 8:3: Comparison of deliveries and the demands

8.4.5 Gross Water losses - Mooi River Irrigation Scheme

8.4.5.1 Overview

Figure 8.4 indicates that the monthly average gross water losses including the return flow, over the period. It is important to note that during the period between November/December to January/February the amount of water losses as a percentage of inflow volume is consistently higher than normal. This may be attributed to the fact that although the demand is lower because of the rainfall during this period the amount of water released into the sub-scheme remains high indicating that there is inconsistency in matching supply to the demand during this period.

The water depth in the canal infrastructure is high and there is potential for overflows because of the aquatic weeds found in the canals. The top section of irrigation canals are more exposed to the elements and general wear and tear (small breakages, chips, etc.) than the lower section resulting in higher leakages when the canal is running close to or at full capacity.

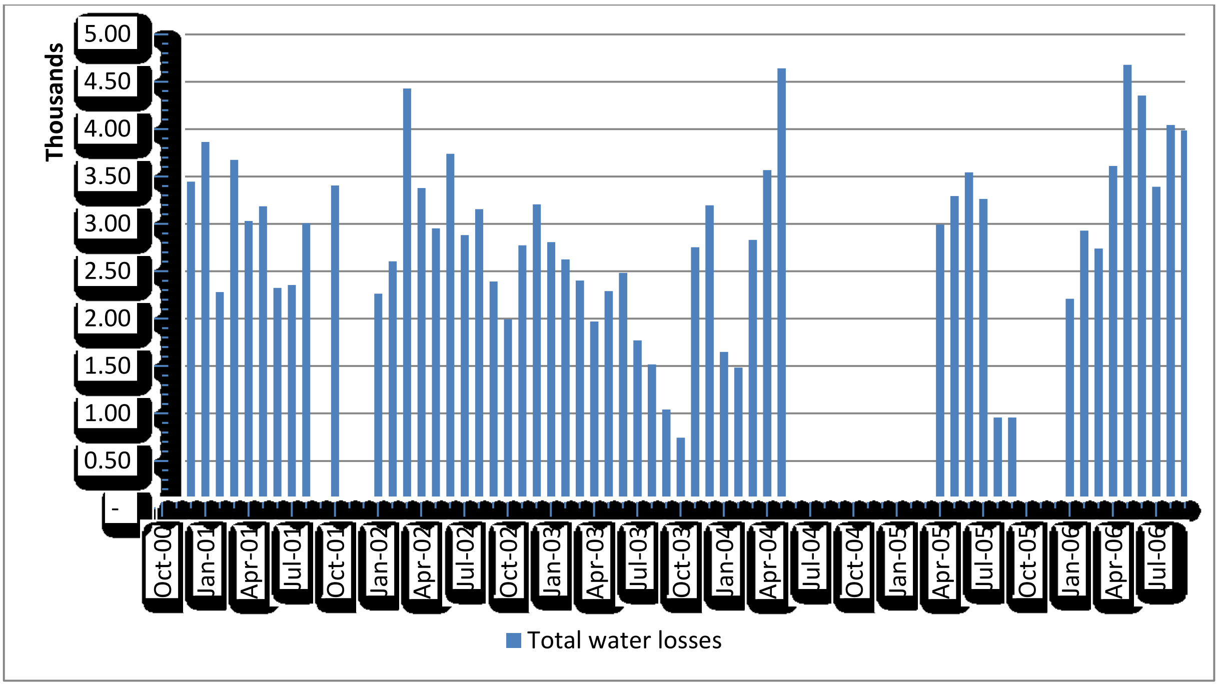

Figure 8:4: Water losses in Mooi River Irrigation Scheme area (million m^3/a)

8.4.5.2 Water losses - Mooi River Government Water Scheme

Based on the above Best Management Practice (BMP) for evaporation losses, and expected seepage losses from lined canal infrastructure, the estimated water losses for the whole Mooi River GWS were 36% of the net inflow over the seven year records. This is equivalent of 30.2 million m^3/a if the canal tail ends are not considered. This is because some of the canal tail ends include delivery to downstream canals within the Mooi River GWS. This is illustrated in **Table 8.1** below.

8.4.6 Unavoidable water losses

The total unavoidable water losses for the scheme was determined to be 6.7 million m^3/a per annum at 8% of the net inflow for the seven years records used to carry out the water balance assessment.

8.4.6.1 Seepage losses

The seepage loss from canals is governed by hydraulic conductivity of the subsoils, canal geometry, hydraulic gradient between the canal and the aquifer underneath, and initial and boundary conditions. Although a portion of the seepage losses is unavoidable due to the type of conveyance infrastructure, there is a portion of the seepage which can be avoided through the maintenance of the conveyance infrastructure.

These losses are due to the constant movement of water through the bottom and sides of the canal system due to small cracks whereas leakage is due to abnormally large cracks in the canal infrastructure which can be reduced through maintenance.

Based on the BMP for lined canal infrastructure, the unavoidable seepage losses was calculated using the seepage rate of 0.03 m^3/d per m^2 of wetted perimeter. This provides expected seepage losses of 7% of the net inflow. This translates into 5.7 million m^3/a over the seven year period of available records.

8.4.6.2 Evaporation losses in canals

The evaporation losses were calculated based on the pan evaporation and the surface area of the canals. This was determined to be approximately 1.2% of the total water released into the irrigation canal system. The total estimated evaporation losses for the Mooi River scheme is 1.02 million m^3/a. This amount is considered as unavoidable water losses due to evaporation from the canal surfaces.

Table 8:1: Summary of water losses in the Mooi River Government Water Scheme (million m^3/a)

<table>
<tr><th>Description</th><th>Unavoidable losses</th><th>BMP for operation & distribution</th><th>Avoidable losses</th><th>Total losses</th><th>% of total losses</th></tr>
<tr><td>Seepages</td><td>5.72</td><td></td><td></td><td>5.72</td><td>18.9%</td></tr>
<tr><td>Evaporation</td><td>1.02</td><td></td><td></td><td>1.02</td><td>3.4%</td></tr>
<tr><td>Filling losses</td><td></td><td rowspan="5">8.31</td><td rowspan="5">15.14</td><td rowspan="5">23.45</td><td rowspan="5">77.7%</td></tr>
<tr><td>Leakages</td><td></td></tr>
<tr><td>Spills</td><td></td></tr>
<tr><td>Operational Losses</td><td></td></tr>
<tr><td>Over delivery to users</td><td></td></tr>
<tr><td>Canal end returns*</td><td></td><td></td><td>53.89</td><td></td><td></td></tr>
</table>

Description	Unavoidable losses	BMP for operation & distribution	Avoidable losses	Total losses	% of total losses
Canal end returns contributing to downstream use within the GWS			53.89		
Total (excl the canal tail-ends which contribute to downstream users within the GWS)	6.72	8.31	15.14	30.19	
% of total losses	22%	28%	50%	100%	
% of total volume released into system	8%	10%	18%	36%	

8.4.7 Avoidable water losses

8.4.7.1 Leaks and spills

The determination of the volume of water that is wasted as a result of leakages is very difficult to calculate and can only really be determined through accurate measurement or undertaking tests such as ponding tests on the irrigation canals. Leaks normally occur in broken sections of the canals and at the top sections of canal bodies and can be attributed to maintenance problems and the general deterioration of the canal infrastructure network due to its age.

An important factor that has a marked effect on leakages is the water depth in a canal system. The top section of irrigation canals are more exposed to the elements and general wear and tear (small breakages, chips, joints between concrete panels, etc.) than the lower section resulting in higher leakages when the canal is running close to or at full capacity.

Given the high volume of algae and water grass in the Mooi River irrigation canals there are likely to be operational spills as the algae reduces the hydraulic capacity of the canal leading to potential overflows in some sections of the canal network.

In the case of the Mooi River Irrigation Scheme, the leaks and spills have been taken as the difference between the unavoidable losses (i.e. evaporation losses and seepages), and the gross water losses.

There are two aspects to the avoidable water losses. Over the seven year period of the records used to assess the extent of water use efficiency, the seepage losses and leakage including some of the operational spills averaged 23.4 million m^3/a or 28.2% of the volume of water diverted into the canals.

8.4.7.2 Aquatic weeds and algae

Aquatic weed and algae growth in irrigation canal systems is fast becoming one of the major operational problems in scheme management, especially on those schemes where water is becoming progressively eutrophic. Du Plessis and Davidson (1996) list the following impacts of excessive aquatic weed growth on irrigation canal systems:

(i) A negative influence on hydraulic capacity and flow speeds in the canals. This decrease in canal capacity occurs particularly when the water demand is at its highest.

(ii) Overestimation of the amount of water supplied, because of the artificially increased water levels that are measured at calibrated weirs.

(iii) Water loss because of the flooding of canals.

(iv) Impediment of floodgate and sluices at dividing structures.

(v) Water logging of long-weirs.

(vi) Structure (slab) failure of concrete-lined irrigation canals due to flooding.

(vii) Aquatic weed fragments block irrigation systems and filters at water purification plants.

(viii) The mechanical removal of the biomass is extremely labour intensive, expensive and mostly ineffective.

It is likely that the high water losses can be attributed to algae growth in the Mooi River irrigation canals (see **Photo 8.1** below) which is reducing the hydraulic capacity of the canal system and therefore more water is required to meet the applications.

Photo 8:1: Algae growth in the Boskop right bank canal

8.4.7.3 Operational losses and canal end returns:

Apart from the seepage and leakage losses described above, there are also other losses on the canal system which can be classified as operational losses due to the way the scheme is operated. Such losses include start-up and shutdown losses, operational wastage due to the lack of quick response to changes in demand, water not used (outflows) due to unexpected drops in demand and losses due to incorrect metering. These losses are estimated to fluctuate between 9% and 17% of the irrigation water losses (Reid, Davidson and Kotze, 1986).

For the Mooi River irrigation scheme, the canal tail ends deliver water to either Klerkskraal or Boskop Dams. This is considered a demand as water is used by downstream irrigators in the Mooi River GWS. The total water at canal tail ends delivering water to downstream canals and dams as well as operational spills at the end of the scheme was estimated to be 53.89 million m^3/a.

However without measurements of the spills at each of the approximately 14 canal tail ends, it was not possible to differentiate between the losses to the scheme due to the operational spills and inflow to the downstream Dams.

8.4.7.4 Total avoidable water losses - Mooi River irrigation scheme

The estimated avoidable water losses for the seven year period from 2000/01 to 2007/08 water years have averaged approximately 23.45 million m^3/a (see **Table 8.1** above). The high avoidable water losses can be attributed to the following management issues:

(i) The excessive growth of nuisance aquatic vegetation (algae and aquatic macrophytes) causes extensive operational problems in irrigation canals, and plays a significant role in increased water loss and wastage.

(ii) The condition of the canal infrastructure and lack of sufficient dry periods to carry out the required maintenance of the irrigation canals.

(iii) The lack of constant flow measurement to determine the deliveries to other canal systems which is resulting in estimating the deliveries and may affect the calculation of the avoidable water losses.

(iv) The lack of continuous flow monitoring to ensure that the WCOs can respond to operational problems quicker than is currently the case.

8.5 Sub-scheme level water balance assessment - Klerkskraal Dam irrigation canals

8.5.1 Klerkskraal right bank canal water losses

Table 8.2 below provides a summary of the water losses determined for the Klerkskraal right bank canal based on the water balance assessment of the sub-scheme.

8.5.1.1 Unavoidable water losses

As indicated in **Table 8.2** below the unavoidable water losses comprises two components, the expected seepage losses based on the geometry and characteristics of the conveyance infrastructure assuming the infrastructure is maintained in accordance with the required scheduled maintenance and the evaporation losses as the conveyance infrastructure is an open channel system.

Seepage losses

Based on the BMP for lined canal infrastructure, the unavoidable seepage losses which cannot be avoided was calculated using the seepage rate of 0.03 m^3/d per m^2 of wetted perimeter. This provides expected seepage losses of 7% of the net inflow. This translates into 0.57 million m^3/a over the seven year period of available records.

Evaporation losses in canals

The evaporation losses were calculated based on the pan evaporation and the surface area of the canals. This was determined to be approximately 1.3% of the total water diverted into the irrigation canal system. The total estimated evaporation losses for the Klerkskraal right bank sub-scheme is 0.16 million m^3/a. This amount is considered as unavoidable water losses due to evaporation from the canal surfaces.

The expected unavoidable water losses in order to deliver the irrigation water application over the period of the analysis was 0.72 million m^3/a or 9% of the average annual water diverted into the Klerkskraal right bank canal.

Table 8:2: Summary of the water losses in the Klerkskraal right bank canal (million m^3/a)

Description	Unavoidable losses	Avoidable losses	Total losses	% of total losses
Seepages	0.56			26%
Evaporation	0.16			7%
Filling losses				0%
Leakages		1.42		66%
Spills				
Operational Losses				
Over delivery to users				0%
Canal end returns contributing to downstream use within the Scheme		3.49		163%
Other				0%
Total (excl the canal tail-ends which contribute to	0.72	1.42	2.14	

Description	Unavoidable losses	Avoidable losses	Total losses	% of total losses
downstream users within the GWS)				
% of total losses	34%	66%	100%	
% of total volume released into system	9%	18%	28%	

8.5.1.2 Avoidable water losses - Klerkskraal right bank

Leaks and spills

In the case of the Klerkskraal right bank canal system, the leaks and spills have been taken as the difference between the unavoidable losses (i.e. evaporation losses and seepages), and the gross water losses.

Over the seven year period of the records used to assess the extent of water use efficiency, the seepage losses and leakage including some of the operational spills averaged 1.42 million m^3/a or 18% of the volume of water released into the right bank canals.

Operational losses and canal end returns

For the Klerkskraal right bank canals, the canal tail ends deliver water to the Boskop Dam as well as back into the Mooi River. This is considered a demand as water is used by downstream irrigators in the same government water scheme. The total water delivered to downstream canals by the canal tail ends of the Klerkskraal right bank amounts to 3.487 million m^3/a.

However one other canal tail end returns the water to the Mooi River, the amount of which is currently not being measured. This may represent operational losses as there is no rationale for spills into the Mooi River from the canal tail end.

However without measurements of the spills at each of the 2 canal tail ends, it was not possible to differentiate between the losses to the scheme due to operational spills and releases into the Boskop Dam for downstream irrigators.

Total avoidable water losses - Klerkskraal right bank canal

The estimated avoidable water losses for the seven year period from 2000/01 to 2007/08 water years have averaged approximately 1.42 million m^3/a (see **Table 8.2** above). The high avoidable water losses can be attributed to the following management issues:

(v) The excessive growth of nuisance aquatic vegetation (algae and aquatic macrophytes) causes extensive operational problems in irrigation canals, and plays a significant role in increased water loss and wastage.

(vi) The condition of the canal infrastructure and lack of sufficient dry periods to carry out the required maintenance of the irrigation canals.

(vii) The lack of constant flow measurement to determine the deliveries to other canal systems (sub-schemes) which is resulting in estimating the deliveries and may affect the calculation of the avoidable water losses.

(viii) The lack of continuous flow monitoring to ensure that the WCOs can respond to operational problems quicker than is currently the case. This is particularly the case for the canal tail end where significant spills into the Mooi River are taking place.

8.5.2 Klerkskraal left bank canal water losses

Table 8.3 below provides a summary of the water losses determined for the Klerkskraal left bank canal based on the water balance assessment of the sub-scheme.

8.5.2.1 Unavoidable water losses

As indicated in **Table 8.3** below the unavoidable water losses comprises two components the expected seepage losses based on the geometry and characteristics of the conveyance infrastructure assuming the infrastructure is maintained in accordance with the required scheduled maintenance and the evaporation losses as the conveyance infrastructure is an open channel system.

Seepage losses

Based on the BMP for lined canal infrastructure, the unavoidable seepage losses which cannot be avoided was calculated using the seepage rate of 0.03 m^3/d per m^2 of wetted perimeter. This provides expected seepage losses of 8% of the net inflow. This translates into 0.28 million m^3/a over the seven year period of available records.

Evaporation losses in canals

The evaporation losses were calculated based on the pan evaporation and the surface area of the canals. This was determined to be approximately 1.3% of the total water diverted into the irrigation canal system. The total estimated evaporation losses for the Klerkskraal left bank sub-scheme is 0.16 million m^3/a. This amount is considered as unavoidable water losses due to evaporation from the canal surfaces.

The total expected unavoidable water losses in order to deliver the irrigation water application over the period of the analysis was 0.44 million m^3/a, or 8% of the average annual water diverted into the Klerkskraal left bank canal.

8.5.2.2 Avoidable water losses - Klerkskraal left bank canal

Leaks and spills:

Over the seven year period of the records used to assess the extent of water use efficiency, the seepage losses and leakage including some of the operational spills of the Klerkskraal left bank canal system averaged 0.87 million m^3/a or 16% of the volume of water diverted into the left bank canal system.

Operational losses and canal end returns

For the Klerkskraal left bank canals, the canal tail ends represent operational spills as the water is returned back to the Mooi River at approximately 3 points. The total water delivered to downstream canals by the canal tail ends of the Klerkskraal left bank amounts to 3.28 million m^3/a.

The diversion of more water into the canal than is necessary changes the natural flow regime of the Mooi River which may impact on the aquatic ecosystem of this section of the river.

Table 8:3: Summary of the water losses in the Klerkskraal left bank canal (million m^3/a)

<table>
<tr><th>Description</th><th>Unavoidable losses</th><th>Avoidable losses</th><th>Total losses</th><th>% of total losses</th></tr>
<tr><td>Seepages</td><td>0.28</td><td>-</td><td></td><td>22%</td></tr>
<tr><td>Evaporation</td><td>0.16</td><td></td><td></td><td>12%</td></tr>
<tr><td>Filling losses</td><td></td><td rowspan="3">0.87</td><td></td><td>0%</td></tr>
<tr><td>Leakages</td><td></td><td></td><td>66%</td></tr>
<tr><td>Spills</td><td></td><td></td><td>0%</td></tr>
</table>

Description	Unavoidable losses	Avoidable losses	Total losses	% of total losses
Operational Losses				0%
Over delivery to users				0%
Canal end returns contributing to downstream use within the Scheme		3.28		0%
Total (excl the canal tail-ends which contribute to downstream users within the GWS)	0.44	0.87	1.31	
% of total losses	21%	41%	61%	
% of total volume released into system	8%	16%	24%	

Total avoidable water losses - Klerkskraal left bank canal

The estimated avoidable water losses for the seven year period from 2000/01 to 2007/08 water years have averaged approximately 0.87 million m^3/a (see **Table 8.3** above). The high avoidable water losses can be attributed to the following management issues:

(i) Diversion of more water into the canals than is required to meet the irrigation applications. This increases the risk of high leakages and spills.

(ii) The excessive growth of nuisance aquatic vegetation (algae and aquatic macrophytes) causes extensive operational problems in irrigation canals, and plays a significant role in increased water loss and wastage.

(iii) The condition of the canal infrastructure and lack of sufficient dry periods to carry out the required maintenance of the irrigation canals.

(iv) The lack of sufficient flow measurement to determine the deliveries to other canal systems which is resulting in estimating the deliveries which may affect the calculation of the avoidable water losses.

8.6 Sub-scheme level water balance assessment - Gerhardminnebron irrigation canals

8.6.1 Gerhardminnebron canal water losses

Table 8.4 below provides a summary of the water losses determined for the Gerhardminnebron canal based on the water balance assessment of the sub-scheme.

8.6.1.1 Unavoidable water losses

As indicated in **Table 8.4** below the unavoidable water losses comprises two components the expected seepage losses based on the geometry and characteristics of the conveyance infrastructure assuming the infrastructure is maintained in accordance with the required scheduled maintenance and the evaporation losses as the conveyance infrastructure is an open channel system.

Seepage losses

Based on the BMP for lined canal infrastructure, the unavoidable seepage loss which cannot be avoided was calculated using the seepage rate of 0.01 m^3/d per m^2 of wetted perimeter. This provides expected seepage losses of 5% of the net inflow. This translates into 0.57 million m^3/a over the seven year period of available records.

Evaporation losses in canals

The evaporation losses were calculated based on the pan evaporation and the surface area of the canals. This was determined to be approximately 1.3% of the total water diverted into the irrigation canal system. The total estimated evaporation losses for the Mooi River scheme is 0.21 million m^3/a. This amount is considered as unavoidable water losses due to evaporation from the canal surfaces.

The expected unavoidable water losses which was be required in order to deliver the irrigation water application over the period of the analysis was 0.72 million m^3/a or 5% of the average annual water diverted into the Gerhardminnebron canal.

Table 8:4: Summary of the water losses in the Gerhardminnebron canal (million m³/a)

Description	Unavoidable losses	Avoidable losses	Total losses	% of total losses
Seepages	0.57	-		53%
Evaporation	0.21			19%
Filling losses				0%
Leakages		0.31		28%
Spills				
Operational Losses				
Over delivery to users				
Canal end returns contributing to downstream use within the Scheme		14.46		677%
Other				0%
Total (excl the canal tail-ends which contribute to downstream users within the GWS)	0.78	0.31	1.08	
% of total losses	72%	28%	100%	
% of total volume released into system	5%	2%	7%	

8.6.1.2 Avoidable water losses - Gerhardminnebron eye canal

Leaks and spills

In the case of the Gerhardminnebron canal system, the leaks and spills have been taken as the difference between the unavoidable losses (i.e. evaporation losses and seepages), and the gross water losses.

Over the seven year period of the records used to assess the extent of water use efficiency, the seepage losses and leakage including some of the operational spills averaged 0.31 million m^3/a or 2% of the volume of inflow into the Gerhardminnebron canals.

Operational losses and canal end returns

For the Gerhardminnebron eye canal, the canal tail ends deliver water to the Boskop Dam as well as back into the Mooi River. The total water delivered to downstream canals by the canal tail ends of the Gerhardminnebron eye canal amounts to 14.4 million m^3/a. This high volume is due to the fact that the eye cannot be regulated as much when compared with the other dams in the scheme.

However without measurements of the spills at each of the 3 canal tail ends, it was not possible to differentiate between the losses to the scheme due to operational spills on the Gerhardminnebron canal and releases for downstream users.

Total avoidable water losses - Gerhardminnebron canal

The estimated avoidable water losses for the seven year period from 2000/01 to 2007/08 water years have averaged approximately 0.31 million m^3/a (see **Table 8.4** above). The avoidable water losses are not as significant compared to the other sub-schemes of the Mooi River Government Water Scheme.

8.7 Sub-scheme level water balance assessment - Boskop Dam irrigation canals

8.7.1 Boskop right bank canal water losses

Table 8.5 below provides a summary of the water losses determined for the Boskop right bank canal based on the water balance assessment of the sub-scheme.

8.7.1.1 Unavoidable water losses

As indicated in **Table 8.5** below the unavoidable water losses comprises two components the expected seepage losses based on the geometry and characteristics of the conveyance infrastructure assuming the infrastructure is maintained in accordance with the required scheduled maintenance and the evaporation losses as the conveyance infrastructure is an open channel system.

Seepage losses

Based on the BMP for lined canal infrastructure, the unavoidable seepage losses which cannot be avoided was calculated using the seepage rate of 0.03 m^3/d per m^2 of wetted perimeter. This provides expected seepage losses of 8% of the net inflow, adjusted to take into account the clayey expansive soils of the area. This translates into 2.4 million m^3/a over the seven year period of available records.

Evaporation losses in canals

The evaporation losses were calculated based on the pan evaporation and the surface area of the canals. This was determined to be approximately 1.3% of the total water diverted into the irrigation canal system. The total estimated evaporation losses for the Boskop Right Bank canal scheme is 0.37 million m^3/a. This amount is considered as unavoidable water losses due to evaporation from the canal surfaces.

The expected unavoidable water losses to deliver the irrigation water application over the period of the analysis was 2.78 million m^3/a or 9% of the average annual water released into the Boskop Dam right bank canal.

Table 8:5: Summary of the water losses in the Boskop Dam right bank canal (million m^3/a)

<table>
<tr><th>Description</th><th>Unavoidable losses</th><th>Avoidable losses</th><th>Total losses</th><th>% of total losses</th></tr>
<tr><td>Seepages</td><td>2.408</td><td>-</td><td>2.408</td><td>15%</td></tr>
<tr><td>Evaporation</td><td>0.369</td><td></td><td>0.369</td><td>2%</td></tr>
<tr><td>Filling losses</td><td></td><td></td><td></td><td>0%</td></tr>
<tr><td>Leakages</td><td></td><td rowspan="3">12.766</td><td rowspan="3">12.766</td><td rowspan="3">82%</td></tr>
<tr><td>Spills</td><td></td></tr>
<tr><td>Operational Losses</td><td></td></tr>
</table>

Description	Unavoidable losses	Avoidable losses	Total losses	% of total losses
Over delivery to users				
Canal end returns		48.437		0%
Total	2.778	12.766	15.544	
% of total losses	18%	82%	100%	
% of total volume released into system	9%	42%	52%	

8.7.1.2 Avoidable water losses - Boskop Dam right bank canal

Leaks and spills:

In the case of the Klerkskraal right bank canal system, the leaks and spills have been taken as the difference between the unavoidable losses (i.e. evaporation losses and seepages), and the gross water losses.

Over the seven year period of the records used to assess the extent of water use efficiency, the seepage losses and leakage including some of the operational spills averaged 12.77 million m^3/a or 42% of the annual average volume of water diverted into the Boskop Dam right bank canal. This however excludes the operational spills at the canal tail ends as discussed below.

Operational losses and canal end returns:

For the Boskop Dam right bank canals, any flows at the canal tail ends represent operational spills from a scheme perspective as the water is not available to the scheme. Therefore all canal tail ends of the right bank canal should be included in the water loss assessment. The average volume of operational spills at the canal tail ends amounted to 48.487 million m^3/a. This amount includes delivery to Lakeside dam which is provides additional water to the downstream Lakeside Dam canal.

The above figure however is an estimate as there are no flow measurements currently being taken by the scheme. This may represent operational losses as there is no rationale for diverting more water than is necessary, affecting the flow regime downstream of Lakeside Dam.

Therefore without measurements of the spills at each of the canal tail ends, it was not possible to differentiate between the losses to the scheme due to the canal tail end spills or delivery to users on the Lakeside Dam canal. As a result the canal end returns were not included into the avoidable losses.

Total avoidable water losses - Boskop Dam right bank canal

The estimated avoidable water losses for the seven year period from 2000/01 to 2007/08 water years have averaged approximately 12.77 million m^3/a (see **Table 8.5** above) excluding the operational spills at the canal tail ends. The high avoidable water losses can be attributed to the following management issues:

(i) The excessive growth of nuisance aquatic vegetation (algae and aquatic macrophytes) causes extensive operational problems in irrigation canals, and plays a significant role in increased water loss and wastage.

(ii) The condition of the canal infrastructure where some sections of the concrete panels have been lifted due to the conditions of the soil around the canal.

(iii) The current operating rule which allows for significantly more water than is required may be contributing to high leakage and potentially high spills.

(iv) The lack of sufficient flow measurement to determine the deliveries to other canal systems which is resulting in estimating the deliveries to downstream canal systems may affect the calculation of the avoidable water losses.

(v) The lack of continuous flow monitoring to ensure that the scheme operators can respond to operational problems quicker than is currently the case. There are significant spills at the canal tail ends which can be reduced by managing the flows released into the sub-scheme.

8.7.2 Boskop left bank canal water losses

Table 8.6 below provides a summary of the water losses determined for the Boskop left bank canal based on the water balance assessment of the sub-scheme.

8.7.2.1 Unavoidable water losses

As indicated in **Table 8.6** below the unavoidable water losses comprises two components: the expected seepage losses based on the geometry and characteristics of the conveyance infrastructure assuming the infrastructure is maintained in accordance with the required scheduled maintenance and the evaporation losses as the conveyance infrastructure is an open channel system.

Seepage losses

Based on the BMP for lined canal infrastructure, the unavoidable seepage losses which cannot be avoided was calculated using the seepage rate of 0.03 m^3/d per m^2 of wetted perimeter. This provides expected seepage losses of 5% of the net inflow. This translates into 0.71 million m^3/a over the seven year period of available records.

Evaporation losses in canals

The evaporation losses were calculated based on the pan evaporation and the surface area of the canals. This was determined to be approximately 1.3% of the total water diverted into the irrigation canal system. The total estimated evaporation losses for the Boskop Left bank canal sub-scheme is 0.17 million m^3/a. This amount is considered as unavoidable water losses due to evaporation from the canal surfaces.

The total expected unavoidable water losses which was be required in order to deliver the irrigation water application over the period of the analysis was 0.88 million m^3/a or 6% of the average annual water released into the Boskop Dam left bank canal.

8.7.2.2 Avoidable water losses - Boskop Dam left bank canal

Leaks and spills:

Over the seven year period of the records used to assess the extent of water use efficiency, the leakage including some of the operational spills of the Boskop Dam left bank canal system averaged 2.1 million m^3/a or 15% of the volume of water diverted into the left bank canal system.

Operational losses and canal end returns:

For the Boskop Dam left bank canals, the canal tail ends represent delivery to downstream canals as well as to Lakeside dam. Therefore this was not considered an operational loss but a downstream demand within the Mooi River irrigation scheme.

Table 8:6: Summary of the water losses in the Boskop Dam left bank canal (million m^3/a)

<table>
<tr><th>Description</th><th>Unavoidable losses</th><th>Avoidable losses</th><th>Total losses</th><th>% of total losses</th></tr>
<tr><td>Seepages</td><td>0.71</td><td>-</td><td>0.71</td><td>24%</td></tr>
<tr><td>Evaporation</td><td>0.17</td><td></td><td>0.17</td><td>6%</td></tr>
<tr><td>Filling losses</td><td></td><td></td><td></td><td>0%</td></tr>
<tr><td>Leakages</td><td></td><td rowspan="4">2.07</td><td rowspan="4">2.07</td><td rowspan="4">70%</td></tr>
<tr><td>Spills</td><td></td></tr>
<tr><td>Operational Losses</td><td></td></tr>
<tr><td>Over delivery to users</td><td></td></tr>
<tr><td>Canal end returns</td><td colspan="4">None as it contributed to downstream Scheme use</td></tr>
<tr><td>Other</td><td></td><td></td><td></td><td>0%</td></tr>
<tr><td>Total</td><td>0.88</td><td>2.07</td><td>2.94</td><td>100%</td></tr>
<tr><td>% of total losses</td><td>30%</td><td>70%</td><td>100%</td><td></td></tr>
<tr><td>% of total volume released into system</td><td>6%</td><td>15%</td><td>22%</td><td></td></tr>
</table>

Total avoidable water losses – Boskop left bank canal

The estimated avoidable water losses for the seven year period from 2000/01 to 2007/08 water years have averaged approximately 2.1 million m^3/a (see **Table 8.6** above). The avoidable water losses can be attributed to the following management issues:

(i) Release of more water into the canals than is required to meet the irrigation applications. This increases the risk of high leakages and spills.

(ii) The excessive growth of nuisance aquatic vegetation (algae and aquatic macrophytes) causes extensive operational problems in irrigation canals, and plays a significant role in increased water loss and wastage.

(iii) The condition of the canal infrastructure and lack of sufficient dry periods to carry out the required maintenance of the irrigation canals.

(iv) The lack of sufficient flow measurement to determine the deliveries to other canal systems which is resulting in estimating the deliveries which may affect the calculation of the avoidable water losses.

8.8 Sub-scheme level water balance assessment - Lakeside Dam irrigation canals

8.8.1 Lakeside dam canal water losses

Table 8.7 below provides a summary of the water losses determined for the Lakeside dam canal based on the water balance assessment of the sub-scheme.

8.8.1.1 Unavoidable water losses

As indicated in **Table 8.7** below the unavoidable water losses comprises two components the expected seepage losses based on the geometry and characteristics of the conveyance infrastructure assuming the infrastructure is maintained in accordance with the required scheduled maintenance and the evaporation losses as the conveyance infrastructure is an open channel system.

Seepage losses

Based on the BMP for lined canal infrastructure, the unavoidable seepage losses which cannot be avoided was calculated using the seepage rate of 0.03 m^3/d per m^2 of wetted perimeter. This provides expected seepage losses of 9% of the net inflow, adjusted to take into account the clayey expansive soils of the area. This translates into 0.92 million m^3/a over the seven year period of available records.

Evaporation losses in canals

The evaporation losses were calculated based on the pan evaporation and the surface area of the canals. This was determined to be approximately 1.3% of the total water released into the irrigation canal system. The total estimated evaporation losses for the Lakeside canal sub-scheme is 0.12 million m^3/a. This amount is considered as unavoidable water losses due to evaporation from the canal surfaces.

The expected unavoidable water losses which was required in order to deliver the irrigation water application over the period of the analysis was 1.04 million m^3/a or 11% of the average annual water released into the Lakeside Dam canal.

8.8.1.2 Avoidable water losses - Lakeside Dam canal

Leaks and spills

In the case of the Lakeside Dam canal system, the leaks and spills have been taken as the difference between the unavoidable losses (i.e. evaporation losses and seepages), and the gross water losses.

Over the seven year period of the records used to assess the extent of water use efficiency, the seepage losses and leakage including some of the operational spills averaged 4.02 million m^3/a or 41% of the annual average volume of water diverted into the Lakeside Dam canal. This includes the operational spills at the canal tail ends as discussed below.

Operational losses and canal end returns

For the Lakeside Dam canals, any flows at the canal tail ends represent operational spills and therefore a loss from a scheme perspective as the water is not available to the scheme. Therefore all canal tail ends of the Lakeside dam canal were included in the water loss assessment. The average volume of operational spills at the canal tail ends amounted to 8.42 million m^3/a. This was deemed to be partly due to the additional water being diverted into the canal when the dams are spills. It was therefore not included as part of the water losses.

Table 8:7: Summary of the water losses in the Lakeside Dam canal

<table>
<tr><th>Description</th><th>Unavoidable losses</th><th>Avoidable losses</th><th>Total losses</th><th>% of total losses</th></tr>
<tr><td>Seepages</td><td>0.92</td><td>-</td><td></td><td>18%</td></tr>
<tr><td>Evaporation</td><td>0.12</td><td></td><td></td><td>2%</td></tr>
<tr><td>Filling losses</td><td></td><td></td><td></td><td>0%</td></tr>
<tr><td>Leakages</td><td></td><td rowspan="2">4.02</td><td></td><td rowspan="2">79%</td></tr>
<tr><td>Spills</td><td></td><td></td></tr>
</table>

Description	Unavoidable losses	Avoidable losses	Total losses	% of total losses
Operational Losses				
Over delivery to users				
Canal end returns		8.42		
Other				0%
Total	1.04	4.02	5.06	
% of total losses	21%	79%	100%	
% of total volume released into system	11%	41%	52%	

*Operational spills at canal tail-ends amount to 8.42 million m^3/a due to additional water being diverted when dams are spilling.

The above figure is an estimate as there are no flow measurements currently being taken by the scheme. This may represent operational losses as there is no rationale for releasing more water than is necessary into the sub-scheme and thereby affecting the flow regime downstream of Lakeside Dam.

Therefore without measurements of the spills at each of the 2 canal tail ends, it was not possible to determine accurately the operational spills which are water losses to the scheme.

Total avoidable water losses - Lakeside Dam right bank canal

The estimated avoidable water losses for the seven year period from 2000/01 to 2007/08 water years have averaged approximately 4.02 million m^3/a (see **Table 8.7** above) including the estimated operational spills at the canal tail ends. The high avoidable water losses can be attributed to the following management issues:

(i) The volume of water in the balancing dam was not taken into account resulting in the significantly high percentage of water losses.

(ii) The excessive growth of nuisance aquatic vegetation (algae and aquatic macrophytes) causes extensive operational problems in irrigation canals, and plays a significant role in increased water loss and wastage.

(iii) The condition of the canal infrastructure where some sections of the concrete panels have been lifted due to the conditions of the soil around canal.

(iv) The current operating rule which allows for releasing significantly more water than is required including for the expected seepage and evaporation losses may be contributing to high leakage and potentially high spills.

(v) The lack of sufficient flow measurement to determine the spills at canal tail ends, which may affect the calculation of the avoidable water losses.

9 EXISTING WATER MANAGEMENT MEASURES AND PROGRAMMES

9.1 Overview

Chapter 8 indicated that the water losses in the Mooi River Irrigation Scheme for the six sub-schemes are all generally high. This illustrates that there is a need to implement water management measures to improve the water use efficiency of the scheme. However there are existing water management measures and programmes in place which the scheme operators are conducting as part of efficient and effective irrigation water management of the Mooi River Irrigation Scheme.

The Mooi River Irrigation GWS has been implementing measures to improve the management of delivery to the irrigators. These have included the following:

(i) Water order and request measures which ensures that only the water applied for is supplied;

(ii) Flow measurement and preparation of WUEAR reports which provides an indication of the extent of water losses and scheme irrigation water use efficiency levels;

(iii) Carrying out maintenance of the canal system during dry periods to reduce avoidable canal losses.

These existing water management measures are discussed in more detail below.

9.2 Existing Water Management Measures

9.2.1 Flow measurements

The Mooi River GWS has installed flow measurements at all the farm turnouts in order to measure the water delivered to each irrigator in the scheme. The availability of sluices at each farm turnout ensures that each irrigator can only get the scheduled allocation they are entitled for.

There are also flow measurement, namely Parshall Flumes and weirs at some of the critical diversion points to measure how much water is diverted at different points of the irrigation scheme. There are flow measurements at the Gerhardminnebron Eye which provides the flow rate and volume of water diverted into the canal; the flow measurements at the canals at Klerkskraal and Boskop Dams which provides information on the volume of water diverted into these canals.

The existing flow measurement can provide the overall gross water losses of the six sub-schemes of the Mooi River Irrigation Scheme. However this cannot provide the operational losses at canal tail ends as there are no flow measurements. If there are, then the flow measurements are not being read and included in the WUEAR reports.

9.2.2 Water ordering policy

The Mooi River Irrigation Scheme has a water ordering policy which enables only the amount of water applied for plus the estimated water losses to be diverted into the main irrigation canals. The irrigators and other users put their water application for the following week by the Thursday to allow the scheme operators to plan how much water to be released to meet these demands only.

9.2.3 Water Shortage Contingency Plan

The Mooi River Irrigation Scheme has a water contingency plan. The basic objectives of the plan:

(i) Hydrologic forecasting to predict water supply;
(ii) Definition of water allocation procedures to be used during drought periods;
(iii) Identification of alternative or supplemental water supplies.

At the beginning of each water year, information on hydrologic forecasting to predict water availability is provided to water users that will help them decide which crops to irrigate and how many hectares to farm. For example, given a forecast, farmers can choose to irrigate less land or grow crops that require less water.

Defining the water allocation and curtailments to farmers before the drought conditions begin provides irrigators with fairly certain information as to what they can expect in terms of water deliveries and will allow them to plan accordingly.

9.2.4 Flexibility in the Balancing Dam

One of the ways the Mooi River Irrigation Scheme uses to manage and match the supply to the delivery is the use of the Boskop Dam, Lakeside Dam and Klerkskraal Dam as "balancing dams", although they are not strictly balancing dam per se.

Boskop and Klerkskraal Dams play an important role in helping the scheme operator match water deliveries to irrigation water requirements by reducing the time of delivery to downstream irrigators. Together with the farm dams that are in the scheme the reservoirs allow farmers to use their allocations at their convenience, both in terms of time of irrigation and the amount of water used. In addition to increasing water delivery flexibility, the storage reservoirs are used to:

(i) Reduce overall system spills as well as capture spills from upstream users as well as from the Gerhardminnebron eye which is difficult to regulate for the benefit of the irrigation scheme

(ii) Capture storm water runoff from the tributaries where these dams are located, which provides an additional source of supply

Although the Mooi River Irrigation Scheme also has the ability to check or shut down canals and branch canals to avoid spills, there is a lag time of 12 hours for the changes to take place. This is because the system is not automated and the users do not cancel their orders in time. The loss is taken to the account of the farmer who requested the water, although it will be a loss to the scheme.

9.2.5 Operation and maintenance of the canal infrastructure

9.2.5.1 Maintenance of the canal system

The ownership of the canal infrastructure at the Mooi River Irrigation Scheme is with the DWA Infrastructure Branch which is also responsible for the operation and maintenance of the canal infrastructure.

During dry periods, significant maintenance is carried out on the primary canal and secondary canals. The availability of Klerkskraal, Lakeside and Boskop dams provides the flexibility during the dry period to provide some of the irrigators from the dams. It also reduces the amount of water required for filling.

9.2.5.2 Penalties for not taking up the requested water

According to the scheme operating rules, when an irrigator orders a certain volume of water and he/she does not take up their full water application, the scheme operators deduct this from the scheduled quota of the irrigator. The irrigators must provide changes to their irrigation water application by a certain timeframe to enable the scheme operators to adjust the supplies to the scheme.

This procedure provides incentives for irrigators to schedule their irrigation water requirements and minimise the scheme water losses.

9.3 Impact of existing water management measures

The existing water management measures described have helped reduce water losses in the Mooi River Irrigation Scheme. However, the findings of the water balance assessment indicate that the water losses in the GWS are still very high. There is still significant potential to improve irrigation water use efficiency in the Mooi River Irrigation Scheme if specific water loss control and operational measures are put in place.

The water management issues contributing to the high water losses and the management to address these issues with a view to improving irrigation water management in the Mooi River Government Water Scheme are discussed in detailed in the following chapter.

10 WATER MANAGEMENT ISSUES AND GOALS

10.1 Overview the management issues

The water budget analysis discussed in chapter 8 together with discussions held with the Mooi River GWS, has helped to identify several key water management issues. First there are substantial losses taking place in the Mooi River Irrigation Scheme, as illustrated by the water budget. There is insufficient data to clearly determine where and how losses are occurring. Currently there are no records as to how much water spills are due to operational issues at the tail end discharges or due to over-irrigation.

The water balance assessment analysis did reveal, however, that on an annual basis, the Boskop Dam right bank canal has the highest water losses by volume as well as by percentage while the Gerhardminnebron had the lowest level of water losses. Avoidable water losses in the Boskop Dam right bank canal amounted to 12.7 million m^3/a, or 42% of the total water released into the canal system. This does not include the spills at the canal tail ends which would raise the sub-scheme water losses even more. The second highest water losses took place in the Lakeside Dam sub-scheme where the annual average water losses amounted to 6.7 million m^3/a over the seven year period.

In addition to the water balance assessment, some limited discussions were held with the management and other people who are knowledgeable about the Mooi River Irrigation Scheme. This was done to determine the key water management issues the scheme is facing. **Table 10.1** below provides the key issues identified and these are discussed in more detail in the following sections of this chapter.

10.2 Water Measurement and Accounting Systems

10.2.1 Lack of sufficient water measurement

Effective water measurement and accounting is necessary for developing sound water management programmes. There is a lack of sufficient flow measurement in the Mooi River Irrigation Scheme. The ideal water measurement system for Mooi River GWS would have flow measurements at all points in the release, conveyance and delivery system where flow releases takes place (i.e. to branch canals), including farm turnouts and tail ends, drainage and system spill locations (see **Figure 10.1** below).

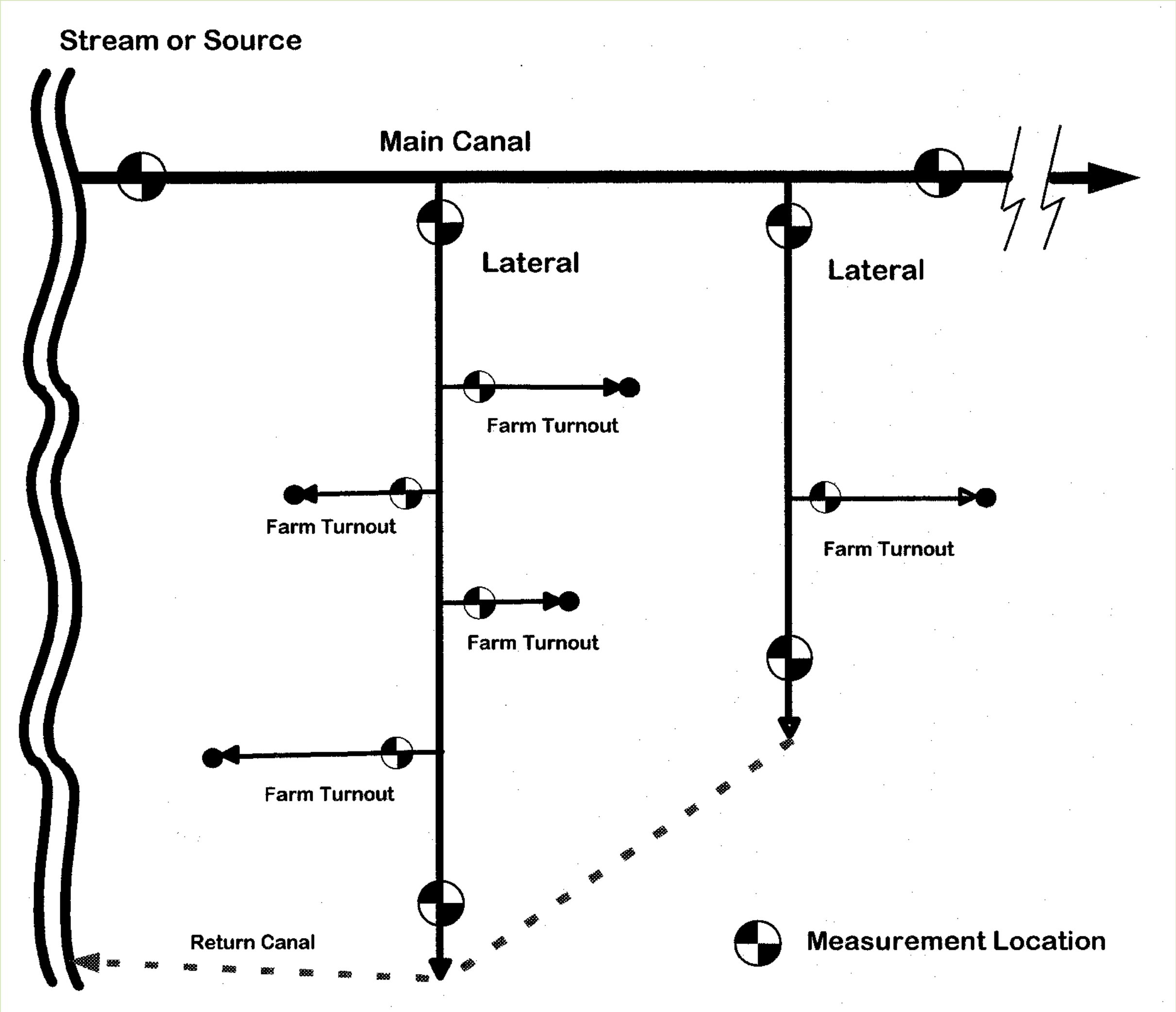

Figure 10:1: Irrigation Scheme with ideal water measurement system

Source: Bureau of Reclamation

Many of the critical points in the Mooi River GWS have flow measurement. There are flow measurement structures at the inlets to the six sub-scheme canals where accurate flow measurement is being taken. There is no accurate measurement at the canal tail ends of the following canals:

(i) Five canal tail ends on the Klerkskraal canal system; three on the left bank and two on the right bank to measure spills back into the Mooi River. Either there are flow measurements structures which are currently not being used or no measurement structures making it difficult to accurately determine the delivery to Boskop Dam as well as determine the conveyance efficiency of the two canals.

(ii) Three canal tail ends on the Gerhardminnebron canal to measure spills back to the Mooi River. This includes the delivery into Boskop Dam which makes it difficult to calculate how much water is actually lost in the upper canal system.

(iii) Three canal tail ends on the Boskop Dam right bank canal and three canal tail ends on the Boskop Dam left bank to measure spills back to the Mooi River and Loopspruit including the delivery into Lakeside Dam which makes it difficult to calculate the water losses in the right bank canal.

(i) Two canal tail ends on the Lakeside Dam canal to measure spills back to the Mooi River which makes it difficult to accurately determine the water losses in the canal.

From the WCO's perspective, adequate water measurement will help with:

- Assembling information needed for a detailed water balance to be done which provides the basis to implement measures to reduce water losses;
- Identifying areas where additional efficiency measures can be achieved;
- Implementing a cost recovery system based on deliveries (this is available as each irrigator is measured through the sluices).

10.2.2 Lack of real time monitoring

The Mooi River Irrigation Scheme is a manually operated system with no telemetry infrastructure linked to any of the existing flow measurements within the scheme area to carry out real time or near real time flow monitoring and control of deliveries.

The ideal system for improving irrigation water use efficiency would be to provide data on a real-time basis through the use of automatic and data transmission devices such as the Android Telemetry system used by some irrigation schemes in the country.

The lack of real time information reduces the scheme operators' capacity to respond to changes in demand by water users thereby improving the efficiency of irrigation water management.

10.2.3 Management Goal 1

The objective to address the above irrigation water management issue is to ensure that the following is achieved by the Mooi River GWS:

(i) Continuation of regular measurement of flows into all primary and branch canals, as well as measurement at the tail ends of the canal system.

(ii) Include the measurement of operational spills at the reject points by the end of this water year, in order to enable operational spills to be measured.

(iii) Ensure that all measuring devices in the scheme are in good operating condition and regularly calibrated.

(iv) Continuous flow monitoring to enable intervention measures such as reducing the volume of releases into the primary canals quicker.

10.2.4 Weak Water Accounting System

One of the critical aspects of irrigation water management is the use of a water accounting system which may vary depending on the complexity of the scheme conveyance system. The Mooi River Irrigation Scheme is one of the schemes which were identified to install the Water Administration System (WAS). The WAS has not been fully implemented and therefore does not have the capabilities to track water deliveries but also monitor and control the operation of the scheme to reduce water losses.

The WAS is a water accounting system that was developed as a tool to be used by Irrigation Boards/Schemes to optimise their irrigation water management and minimise management-related distribution losses in irrigation canal systems. The WAS consists of seven modules, integrated into a single programme and these modules can be implemented partially or as a whole.

At present the WAS is only being utilised at scheme level. There will be substantial benefit in utilising the WAS system to undertake Water Use Efficiency Accounting Reporting (WUEAR), at sub-scheme level or at irrigation wards with a view to determining which of the irrigation wards are experiencing significant water losses. This can provide priority areas, where issues need to be addressed in irrigation water management in the Mooi River Irrigation Scheme.

It has been estimated that field measurements indicated water savings of between 10% and 20% on fully implementing the water release module of the WAS program alone. In the case of Mooi River Irrigation Scheme, the WAS programme has been installed for about 10 years but the records indicate that these savings have not been achieved because the WAS programme has not been fully implemented, in particular the water release module.

10.2.5 Management Goal 2

The management objective to address the above issue, is to ensure that all the modules of the WAS programme, particularly the water order and water release modules, are implemented fully and that weekly and monthly reports WUEAR are generated. This can be undertaken within 1 year from the completion of this Water Management Plan (WMP).

Furthermore, the measured data module should be linked to a telemetry system, to enable direct reading of the measured data in the WAS programme. This can be used to undertake automatic reporting on water losses, not only at scheme level, but also at sub-scheme levels.

10.2.6 Irrigation water balance is not conducted in detail

10.2.6.1 Overview

Although there is data available from the different flow measurements in the Mooi River Irrigation Scheme, there are some components that are not being measured, and are currently being estimated or not included in the water balance assessment. These include the following:

(i) Measurement of operational spills at the canal tail ends;

(ii) Measurement of additional water supplied into the Lakeside canal from the Boskop left bank canal (This may be the reason for the high water losses as currently determined);

(iii) Measurement of evaporation using pan evaporation, to determine local evaporation losses, is currently not being conducted. Therefore the losses calculated at present from the water budget are unreliable or inaccurate;

(iv) Measurement of precipitation records is currently not being included in the water budget, which may indirectly result in higher operational spills if irrigators do not take up their full water demands.

10.2.6.2 Irrigation outfalls and operation spills are not included in the irrigation water budget

The irrigation water balance assessment for the Mooi River Irrigation Scheme indicated that the scheme "water losses", comprising seepage losses, evaporative losses, operational spills, was averaging approximately 30.2 million m^3/a (see **Table 8.1** in previous chapter). Furthermore the operational spills at the canal tail ends were not included because it is currently difficult to disaggregate the volume discharged at the canal tail ends which provide additional water to the scheme and what can be deemed scheme losses due to spills at the canal tail end. This is due to a lack of sufficient or no flow measurement structures in the irrigation scheme particularly at the canal tail ends.

10.2.7 Management Goal 3

The goal to address the above issue is to ensure that all the flow measurements in the Mooi River Irrigation Scheme are included in determining water budgets and calculating water losses at scheme as well as sub-scheme level. This will enable the GWS to undertake comprehensive water audits from where priority areas for improving irrigation water management as well as reducing water losses can be identified.

10.3 Operational water management issues

10.3.1 The additional water to meet the water losses of the scheme is not limited to a percentage or volume of water

The scheduled quota for the Mooi River Government Water Scheme (GWS) is 35.25 million m^3/a. It is understood that this is the allocation to be supplied at the sluice gates in the irrigation scheme and does not include the water losses required to ensure the scheduled quota is delivered. The additional water due to conveyance and distribution water losses is borne by the Department of Water Affairs and is considered additional to the scheduled quota.

There is very little incentive for the scheme to save the additional water required to deliver their scheduled quota because there is no limit set of how much additional water should the scheme be allowed in order to deliver it entitlement. This is an aspect that needs to be address in order to improve the scheme irrigation water use efficiency.

10.3.2 Management Goal 4

The objective of addressing the above water management issue is to limit the unavoidable water losses due to seepage and evaporation and establish over a period the percentage of the unavoidable water losses to the volume of water diverted into the irrigation canal system. The BMP for irrigation water management as determined in chapter 7 can be used as a basis for determining the additional water required. Any water used above the agreed amount should then be to the account of the Mooi River Irrigation Scheme.

This can be used to set the limit of additional water required to deliver the scheduled allocation of the Mooi River Irrigation Scheme.

10.4 Infrastructure related management issues

10.4.1 General

In order to properly develop the Mooi River Irrigation Scheme water management plan, it was essential that an assessment of the overall condition of the conveyance, distribution and control infrastructure to identify potential issues was carried out. As indicated in Chapter 4, a high level condition assessment together with discussions with the Mooi River GWS was undertaken. These included the operation and maintenance system, the conveyance and distribution system. No assessment of the on-farm delivery systems was conducted. The main issues that were identified are discussed in the following sections.

10.4.2 Hydraulic capacity of the canals is affected by aquatic weeds and algae growth

One of the major issues that were identified in the Mooi River Irrigation Scheme is the growth of aquatic weed and algae in the canals. This has had a serious impact on the condition of the canals and the hydraulic capacity of the canal systems. The algae proliferation during the summer in particular is as a result of several factors including high levels of nitrogen (N) and phosphorous (P) from untreated domestic wastewater and agricultural runoff, long daylight duration, high temperature, low flow velocity, and long watercourse retention time.

The current canal slope is fixed and cannot be changed. Current operation of the canal is demand-based, meaning that the flow in the canal is directly related to the water delivery requirements downstream. Water is only delivered based upon demand and the rate of delivery is based on the rate of downstream water use. Hence, canal flow must be matched to water use and canal flow cannot be increased without an increase in downstream use. Based on the irrigation demands for the 6 years of records, the demand is not anticipated to increase significantly in the near future; therefore canal flow will not be able to be increased.

The algae growth and aquatic weeds in the canal systems is likely to exacerbate. This will affect the water use efficiency of the scheme unless the aquatic weeds and algae are completely removed. Currently the algae are removed using hand rakes and this is not addressing the problem.

Effective management of aquatic weeds in the canal will result in the ability of the canal to convey water at design flows. Further, improvements in water quality (i.e., less algae present to clog farmer’s drip emitters and filters) are anticipated to increase the demand for water delivery. An increase in demand will require an increase in flow. An increase in flow may result in less algae establishment and proliferation.

10.4.3 Management Goal 5

The management objective to address the above issues, is to develop and implement an effective management of the aquatic weeds and algae proliferation as well as refurbishment programme to reduce irrigation canal losses.

10.5 Lack of sufficient maintenance of the existing canal infrastructure

10.5.1 Condition of canal infrastructure

Although there are no measurements to determine the actual leakage in the Mooi River canal systems, the assessment carried out in the previous chapter have highlighted that there are high water losses due to leakage in canals particularly on joints. This is the case with the Boskop Dam right bank canal which is in a poor condition and is currently being refurbished by the DWA.

It is therefore important to undertake a detailed condition assessment of the canal conveyance infrastructure during the dry periods to determine the sections that require refurbishment.

10.5.2 Limited resources available to undertake maintenance

Due to the limited resources both financial and management, the Mooi River Irrigation Scheme cannot undertake all the maintenance requirements needed during the dry periods. As a result there is a significant backlog in the maintenance of the canal infrastructure as well as the canal siphons.

Furthermore there are sections of the canals where complete renewal of these sections is required.

The lack of maintenance of the canals may be resulting in a rapid deterioration of the canal infrastructure. This may therefore be one of the major reasons contributing to the high irrigation water leakages in the Mooi River Irrigation Scheme.

10.5.3 Management Goal 6

The management objective to address the above issue is to undertake a detailed condition assessment and develop a canal infrastructure management plan for the maintenance of the canal based on the critical canal system during the dry periods and on-going maintenance of the infrastructure.

10.6 Institutional Water Management Issues

10.6.1 Lack of incentive in current irrigation water pricing structure

One of the ways to encourage efficient water use is to base the scheme's pricing and billing procedures at least in part, on the quantity of water delivered. This is not the case in the agricultural sector where the water pricing for the sector is based on the area irrigated or fixed charge per area of irrigated land regardless of the quantity of water used which is a major disincentive to efficient water use.

Because irrigators are charged for their scheduled quota regardless of the volume of water they use, this can lead to excessive water use as irrigators are likely to order up to their allocation even if they do not necessarily require the water.

The Mooi River GWS could benefit from implementing an incentive based water pricing structure to encourage efficient water use by increasing the unit price of water as deliveries increase. With incentive based pricing, a base price per unit of water is charged for all water deliveries up to a certain amount to cover the operating costs. Water use in excess of the amount is then charged at a higher unit price.

10.6.2 Management Goal 7

The objective to address the issue of a lack of incentive based water pricing structure is to review the current pricing structure of the Mooi River Irrigation Scheme and take into account the scheme operating costs in developing an incentive based pricing structure for the scheme.

10.7 Summary of the water management issues

Table 10.1 below presents a summary of the water management issues as discussed above. In order to improve water use efficiency in the Mooi River GWS these management issues need to be addressed as discussed in the following chapter.

Table 10:1: Mooi River Irrigation Scheme: Identified water management issues

Item No.	Water Management Issue	Issue description	Comments
1	Water measurement & Accounting system	***Water measurement*** - There are insufficient flow measurement at critical control points of the irrigation scheme. This includes deliveries to Boskop and Lakeside Dams and the canal tail ends. This creates problems in determining water balances for the scheme and the sub-schemes with a view to identifying potential areas to improve water use efficiency.	Install and implement flow measurements at all canal tail-ends.
		Real time monitoring: There is no real time monitoring in place to provide the flexibility of adjusting water deliveries in time as water demands change	Review and determine the business case of automation and telemetry system
		Water Accounting System - The current water accounting system does not provide sufficient information for monitoring and control of water deliveries. The WAS modules for release, which would improve the management of the irrigation water and improve irrigation water use efficiency is currently not implemented.	Implement the release modules of the WAS programme once the flow measurements are installed.
2	Operational water management	***Conveyance and distribution operating procedures*** - The canals are generally run full. This has the effect that when the demands changes there is potential for	Run the canals based on demands plus the calculated compensation

Item No.	Water Management Issue	Issue description	Comments
	issues	operational spills contributing to the high water losses.	water losses.
		Additional water to meet losses not fixed- The cost of the additional water to supply the scheduled allocation is borne by the DWA. Therefore the irrigation scheme does not have the incentive to ensure the water losses are kept to a minimum.	
3	Infrastructure related water management issues	***Aquatic weeds and algae growth in canal systems*** - The scheme has a serious problem of aquatic weeds and algae growth in the canals. This is reducing the hydraulic capacity of the canals meaning more water than is necessary is being released into the Scheme. This is contributing to the high water losses of the scheme.	Develop and implement a programme to eradicate aquatic weeds and algae
		Condition of the canal infrastructure - The condition of the canal infrastructure particularly at the joints of the concrete panels appears to indicate cracks as grass is growing in these joints. The losses indicate that more maintenance of the infrastructure is required. A complete renewal of sections of the Boskop right bank canal is required (this is currently being carried out).	Implement a condition assessment and refurbishment programme of sections of the canals which are not in good condition.

Item No.	Water Management Issue	Issue description	Comments
4	Institutional Water Management Issues	***Lack of incentive based pricing structure -*** Irrigators are paying for water based on fixed costs per irrigated area regardless of the amount of water being used (i) Current pricing is area based (per ha); (ii) Irrigators are losing on the benefits of their full water use entitlements; (iii) Area based assessment charges encourage water waste and produce inequitable water costs between efficient and inefficient users.	Financial incentives are necessary to encourage efficient water use

11 IDENTIFICATION AND EVALUATION OF WATER MANAGEMENT MEASURES FOR MOOI RIVER GWS

11.1 Identification and evaluation of water management measures

There are numerous water management measures that can be implemented to address the water management issues and achieve a wide range of the goals identified in the previous section. However, only a few of the measures have the capacity to accomplish the goals to improve irrigation water use efficiency in the Mooi River Irrigation Scheme.

The priority water management measures to improve irrigation water use efficiency on the Mooi River Irrigation Scheme include the following:

(1) Water measurements of the flow rates, duration and volume of flows at all the critical points which include the inflow and outflow at the balancing dams, the branch canals, as well as the canal tail ends, etc.

(2) Preparation of more detailed water balance assessments for the Mooi River irrigation scheme, as well as the sub-schemes which include the Klerkskraal canal and its branches and the Boskop canal and the main branch canals; Lakeside dam canal as well as Gerhardminnebron canal.

(3) Implementation of all modules of the WAS programme to enable irrigation monitoring and control of water use to reduce operational losses such as canal tail ends spills to be carried out as well as undertake water balance assessment at scheme as well as sub-scheme level.

(4) Installation of telemetry infrastructure to enable real time monitoring of irrigation water in the long term.

(5) Developing an incentive based water pricing structure to improve irrigation water use efficiency and reduce significant fluctuations in demand.

(6) Maintenance and refurbishment of the existing delivery canals as well as the siphons, in order to reduce leakage losses, improve flow rates and increase head at diversion points.

11.2 Best Management Practices for irrigation water management in Mooi River Government Water Scheme

11.2.1 Overview

In order to evaluate the candidate water management measures it was important to first of all determine the water loss target by incorporating not only the unavoidable water losses but also determining the attainable level of water losses based on the Best Management Practices (BMP) that can be achieved in the Mooi River Irrigation that takes account of the technical and managerial capacity of the Government Water Scheme. This is discussed in the following sections.

11.2.2 Gross water losses

The water losses in the Mooi River Irrigation Scheme are considered to be very high at 36% of the total system input volume of water released from the Klerkskraal Dam, Gerhardminnebron eye, Lakeside dam and Boskop Dam. The total water losses were determined to be 30.2 million m^3/a based on the seven years of available records. It has been estimated that the unavoidable water losses due to evaporation losses and seepage due to the age and condition of the infrastructure is 6.7 million m^3/a, which translates into 8% of the total volume of water diverted into the Mooi River canal system.

In order to determine the potential water that can be saved from the two sub-schemes, the unavoidable water losses as well as the BMP for operational and distribution efficiency were determined

11.2.3 Unavoidable water losses

Based on the evaluation of the unavoidable water losses for the Mooi River Irrigation Scheme, the water delivery Best Management Practice (BMP) should be based on the allowable water losses of approximately 8% of the total inflow into the irrigation canal.

There should be a policy established by the Mooi River GWS to use this as a basis for improving irrigation water management and to use this as the water saving target in the long term.

11.2.4 Best Management Practice for operational and distribution efficiency

Besides the seepage and evaporation losses which are unavoidable because of the type of conveyance infrastructure which are open channels and are liable to leak because of the hydraulic conductivity of the concrete lining, there are operational losses which are unlikely to be recovered at a scheme level due to a number of factors. These factors include the following:

(i) Canal filling – The Mooi River GWS allows for a minimum of 2 weeks scheduled dry period to allow for the maintenance of the canal infrastructure and repairs necessary at measuring structuring, etc. During this period the canal is emptied to allow for the maintenance to be carried out. A significant volume of water is then required to fill the canals before they can deliver the irrigation applications to the users in the scheme. Filling is also required after weekends. This canal filling is included as part of the operational losses which cannot be recovered through any major intervention measures.

(ii) Operational performance losses – The existing sluices and Parshall flumes have in inherent error that needs to be included in the operational performance of the scheme even after improving the calibration of the flow measurements. These metering errors have to be taken into account when determining the Best Management Practice (BMP) for in the Mooi River Irrigation Scheme distribution efficiency

(iii) Untimely deliveries of water that cannot be used as a result of cancellations which will take a minimum of 12 hours to make adjustments to the releases. These losses can result in either operational spills at the canal tail ends representing a loss to the scheme or excess water which is delivered to downstream storages or canals within the scheme.

A Water Research Commission (WRC, TT466/10) which was conducted in 2010, has provided guidelines of the desired range of operational losses due to metering errors, canal filling losses after each dry period that have to be included in order to determine the BMP for operational and distribution efficiency (WRC 2010). This is additional to the unavoidable losses determined in the previous sections. This desired range is expressed as a percentage of inflow into the irrigation scheme. The desired range for operational losses (i.e. metering errors, canal fillings, etc.) is 10% of the inflow into the irrigation scheme.

Therefore on the basis of the WRC study a BMP for operational and distribution efficiency has been taken as 10% of the inflow into the Mooi River irrigation canal systems. This has been used in setting the water savings and the target water losses of each of the two canal systems.

11.2.5 Target water losses in the Mooi River Irrigation Scheme

The unavoidable water losses in the Mooi River irrigation scheme were determined to range between 6% for the Boskop left bank canal and 11% for the Lakeside canal with the average unavoidable losses for the Mooi River scheme being 8% of the total releases into the irrigation canals. This water is additional to the irrigation water use required at the farm edge.

Furthermore there are operational performance inefficiencies in operating the Mooi River scheme including trying to match the delivery to the irrigation applications as mentioned in the previous section. Based on the WRC study the attainable range of operational losses which are not likely to the recovered through water management intervention measures is 10% of the total releases into the Mooi River canal systems. **Table 11.1** below provides the water loss target for the Mooi River canal system.

As illustrated in **Table 11.1** below, the expected average water losses taking into account the unavoidable water losses and the expected inefficiencies in the distribution of irrigation water due to problems of matching supply and delivery as well as metering errors and canal filling losses will be 18% of the total releases into the Mooi River canal system.

Therefore based on the 6 year average and taking into account the unavoidable water losses and expected operational inefficiencies, the expected water losses were determined 15.06 million m^3/a. When compared with the total losses of 30.19 million m^3/a for the same period, there is still potential to implement water saving measures to reduce the current water losses from 36% to the target water losses of 18% of the total releases into the Mooi River canal system.

Table 11:1: Target water losses in the Mooi canal system (million m^3/a)

<table>
<tr><th>Description</th><th>Unavoidable losses</th><th>BMP Distribution Efficiency</th><th>Acceptable water losses</th><th>Target water savings</th><th>Total losses</th></tr>
<tr><td>Seepages</td><td>5.72</td><td></td><td>5.72</td><td></td><td>5.72</td></tr>
<tr><td>Evaporation</td><td>1.02</td><td></td><td>1.02</td><td></td><td>1.02</td></tr>
<tr><td>Filling losses</td><td></td><td rowspan="4">8.31</td><td rowspan="4">8.31</td><td rowspan="4">15.13</td><td rowspan="4">23.45</td></tr>
<tr><td>Over delivery to users</td><td></td></tr>
<tr><td>Leakages</td><td></td></tr>
<tr><td>Spills</td><td></td></tr>
</table>

Description	Unavoidable losses	BMP Distribution Efficiency	Acceptable water losses	Target water savings	Total losses
Operational Losses					
Canal end returns					
Other					-
Total	6.74	8.31	15.06	15.13	30.19
% of total volume released into system	8%	10%	18%	18%	36%
% of total losses	22%	28%	50%	50%	100%
Total releases					83.14

11.3 Water Measurement and Water Accounting Systems

11.3.1 Task 1: Water measurement

11.3.1.1 Install water measurement devices at critical points of the canal system

A scheme's measurement should be capable of recording the volume of water diverted into the irrigation canal, lost due to operational spills, water delivered to individual water users including other canals, and amount of water lost from the scheme due to spills at canal tail ends. In order to achieve this, the Mooi River Irrigation Scheme requires additional water measurements. This includes the installation of flow measurement devices at 16 canal tail ends and critical points in the irrigation scheme as follows:

(i) Installation of flow measurement devices on the irrigation canals delivering excess water into the Boskop Dam and Lakeside Dam.

(ii) Installation of flow measurement device on the canal tail ends of the following canals

a. Klerkskraal left bank and right bank canals;
b. Boskop right and left bank canal tail ends;
c. Boskop flow into the Lakeside canal;

d. Lakeside Dam canal tail end.

These devices will be permanently installed to monitor deliveries and operational spills into the particular canal systems.

Given the size of the irrigation scheme it is not envisaged in the short term to install a remote control system to send the information from the flow measurements to scheme headquarters. For the short term it is recommended that the flow measurements are taken on a daily/weekly basis by the water control aids who can send the information by cellular phone to the Water Control Officer for use in the accounting system. This information will allow the GWS to track water usage, identify where changes in deliveries are needed within a 24 hour period, and identify where losses are occurring and allow the scheme to manage irrigation water use efficiently.

11.3.1.2 Initial Capital Costs and O&M Costs

Table 11.1 below indicates that initial capital costs and related operation and maintenance costs. The estimated initial capital investment is the cost of the installation of water measurement devices. This has been estimated to be R1.5 million. The O&M costs to maintain the water measurements in good working condition by conduction calibration of the devices is estimated at R150 000 per year

As indicated further in **Table 11.1** below, the expected water savings due to the installation of water measurement devices in order for the scheme operators to the operate the system more efficiently. This has been estimated to be 3.28 million m^3/a allowing for an 80% success rate.

The rand value water savings from installation of water measurement devices is expected to be R0.12 million per year based on the water use charge of R0.0965 per m^3 for canal irrigators.

Table 11:2: Summary of the costs and potential savings - Installation of flow measurement devices

Item	Description	Water Savings Million m^3/a	Cost Savings R per year	Sub-Total	Total
Installation of flow measurements	Install flow measurements at critical points				
Installation period					12 months
Productive period					20 years
Initial Capital Investment Costs	Water measurement devices (Parshall Flumes; Long crested weir, etc)			1 515 000.00	
Annual O&M Expenses	Calibration of devices, taking of readings			150 000.00	
Water Savings					
Estimated reduction in water losses due to installation of measurement devices	Water Savings	3.28	115 619.51		
Average Incremental Cost (AIC)					0.09

The water saved can either be sold to the domestic water users namely the Potchefstroom Municipality or used to expand irrigation agriculture. The demands for water in the town of Potchefstroom and the surrounding communities have increased significantly. Therefore any water savings that the Mooi River Irrigation Scheme makes can be sold to the domestic consumers at a much higher unit cost than for irrigators. This amount can be used to offset the capital investment required to install the water measurement devices.

11.3.2 Task 2: Implementation of WAS – Release Module

The importance of relevant and opportune information in decision making cannot be overemphasized. Managing irrigation systems is no exception to the rule. On the contrary, information is vital since daily decisions with regard to water deliveries and other aspects may affect the well-being of many farmers. Traditionally, managers of irrigation systems have tried to cope with this problem through the compilation of field information that was manually processed.

Unfortunately, the number of users in a Mooi River irrigation system runs in the order of hundreds and manual processing of information becomes a lengthy and costly exercise. As a consequence, relevant information is often not available on time or is incomplete and many *ad hoc* decisions have to be made.

11.3.2.1 Review the current use of WAS

As mentioned earlier, the Mooi River Scheme does not have a comprehensive water accounting system to not only track water deliveries but also determine the areas of improving irrigation water management. The scheme is not using the full WAS programme to manage and reduce water losses

The system includes the following seven modules:

Administration module

This module provides the details of all water users on an irrigation scheme. Information managed by this module includes addresses, notes, cut-off list, list of rateable areas, scheduled areas, household and livestock pipes installed on canals, industrial water quotas, crops and areas planted and crop yields.

Water request module

This module captures all the weekly and monthly water requested by each farmer in the scheme. It also includes any additional water requests or any cancellations of water orders.

Water release module

This module takes information from the water request module and calculates the volume of water to be diverted from the water supply sources into the main canal and all its branches allowing for lag times and any water losses and accruals to supply the request for the week.

A schematic layout of the total canal network or river system, is captured with detail such as the cross sectional properties, positioning of sluices or pumps, canal or river slope, structures and canal or river capacities. Discharges are converted to the corresponding measuring plate readings where needed, so that the sluice gates can be set to deliver the volume of water requested.

The Mooi River GWS is currently not utilising the water release module.

Measured data module

This module provides the field data that is measured from the rates and volume of water delivered to each user and the rate and volume of water diverted into the scheme, as well as the rate and flow at different points in the canal system. This data is very useful in conducting water balance assessment not only at scheme level but also at sub-scheme level.

Other modules

The above three modules are the key modules in accounting for water use in an irrigation scheme. However there are other modules which include the following:

(i) *Water accounts module*- this module administers all water accounts for an irrigation scheme or water management office. The water accounts module is a full debit system, from which monthly reports can be printed, including invoices on pre-printed stationery, reconciliation reports, age analysis and audit trail reports.

(ii) *Crop water use module* is used to calculate the water usage per crop between two specified dates for all the planted crops on a scheme, based on the planting date, the area planted and the crop water use curve.

(iii) *Reporting Module* – includes an extensive range of water and financial reports. Water balance sheets, distributions sheets, WUEAR and various other operator defined reports can be generated.

Therefore, the Mooi River Government Water Scheme (GWS) needs to review their water accounting system and incorporate the use of the WAS release modules in undertaking its water accounting.

11.3.3 Initial Capital Expenditure and O&M Costs

The Mooi River GWS has the WAS programme installed at their offices. However, in order to ensure that all WAS modules are operational, will require the training of the water control personnel. The programme should also be set up to enable the water balance assessments at sub-scheme levels to be carried out (i.e. for each of the six canals in the irrigation scheme).

The estimated operation and maintenance costs for operating the WAS programme includes an annual fee of R24 000 to obtain the latest updates of the programme and maintenance of the programme.

The estimated water savings has been included together with the installation of water measurements discussed in section 10.2 above. As mentioned above, it is estimated that 3.28 million m^3/a, could be saved, by undertaking the installation of water measurement devices and implementation of a water accounting system such as the WAS programme.

The capital investment required to carry out these two tasks is minimal, compared to the significant benefit in reducing water losses in the Mooi River Irrigation Scheme. This should be considered priority by the GWS.

11.4 Conveyance infrastructure water management measures

11.4.1 General

The conveyance infrastructure rehabilitation programme is to carry out the refurbishment of the infrastructure in the conveyance system that was found to be causing significant leaks and seepage. The discussion with Mooi River GWS indicated that the major problem currently, is the Boskop right bank canal. This is discussed in the following section.

11.4.2 Task 3: Management of aquatic weeds and algae

11.4.2.1 Chemical aquatic weed management

Considering the losses caused by aquatic weeds, their management is of utmost importance to improve the availability of water from the source to its end users. This does not only improve availability but also the conveyance efficiency. Irrigation and drainage systems provide favourable conditions for the growth of aquatic weeds which interfere with the delivery systems of irrigation water, maintenance of canals, drains, etc. These systems often get choked with the weeds and cause environmental pollution. This is the case in the Mooi River Government Water Scheme.

Mechanical removal has been used in the Mooi River Irrigation Scheme with very little effect. It has also been found that in peak summer months the biomass cannot be removed efficiently.

Therefore the recently recommended chemical process of removing aquatic weeds is proposed based on the successful pilot projects conducted at Hartbeespoort and Roodeplaat canals. This water-soluble aldehyde, which comes in liquid form and has Acrolein as its active ingredient, can be used in operational systems without interrupting irrigation water deliveries, and is characterised by superior effectiveness and quick dissipation without any residue.

Acrolein has been found effective in controlling submerged aquatic weeds and algae. It is used on a large scale in many countries in flowing canals and drainage ditches for quick control of aquatic vegetation. Being volatile, it evaporates from treated water within a short time of its application. It is effective at concentrations varying from 4 -15 ppmv. Acrolein has a pungent and foul smell. It is a non-selective, contact herbicide for control of submerged weeds. Canals require regular treatment as the Acrolein is not translocated to the root systems of the plants but merely chemically mows the plants off at bed level. It also kills snails and mosquitoes.

The herbicides may be introduced over a time period of 30 min to 4 hrs at 3 m^3/s. Dosages are to be adjusted with water temperature, weed intensity and speed of water flow in the system.

Acrolein is injected in water directly from the cylinder through an injecting system. It is toxic to fish. It is irritating to eyes and generally toxic to humans but can be applied without any problem when proper application equipment is used.

Research and extensive field use during a period of 10 years with Acrolein showed that this chemical is not toxic to irrigated crops at concentrations required to control submerged aquatic weeds (Timmons et.al., 1969, USDA 1963).

11.4.2.2 Initial Capital Costs and O&M Costs

The initial capital expenditure for the treatment of the aquatic weeds and algae with Acrolein is estimated to be R750 000. This is illustrated in **Table 11.2** below.

The removal or management of the aquatic weeds and algae growth in the irrigation canals has the potential to save approximately 4.1 million m^3/a, while the average incremental cost of implementing the measure is only R0.08 per m^3 or R633.30 per ha per annum. This would be very prohibitive if the cost is to be borne by the irrigators. Hence the need for the DWA to cover the initial costs of the managing the aquatic weeds as this problem is external to the irrigation water management of Mooi River.

Based on the above capital cost estimates and the estimated water savings, this measure is considered to be justifiable for implementation by the DWA as well as the Mooi River GWS. The capital investment required to carry out this, is minimal compared to the significant benefit in reducing water losses in the Mooi River Irrigation Scheme. This should be considered a priority by the irrigation scheme.

Table 11:3: Summary of the costs and potential savings - Chemical management of aquatic weeds and algae

Item	Description	Water Savings Million m^3/a	Cost Savings R per year	Sub-Total	Total
Chemical treatment of aquatic weeds	Inject Acrolein to manage aquatic weeds and algae				
Installation period					Annually
Productive period					20 years
Initial Capital Investment Costs	Procurement of contractors			1 250 000.00	
	Chemical injection of Acrolein				
				-	1 250 000.00
Annual O&M Expenses	Maintenance of aquatic weeds			250 000.00	
Water Losses					
Estimated reduction in water losses due to removal of aquatic weeds	Water loss reduction	4.10	391 356.21		
Average Incremental Cost (AIC)					0.08

11.4.3 Conveyance infrastructure refurbishment and canal relining

There were a number of sections of the conveyance infrastructure of the Mooi River canal system which will require relining as well as replacement of the concrete panels. This was identified on the Lakeside Dam canal as well as sections of the Mooi canal or the lower Boskop right bank canal. A condition assessment of the canal system should be conducted and the results of the assessment used to develop a canal refurbishment and renewal programme for the Mooi River Irrigation Scheme. It is understood that canal condition assessment was conducted. However the findings of the assessment are not known.

Given the high water losses, due to structural failure of concrete lined irrigation canals due to flooding because of the aquatic weeds and algal growth, there is significant scope for refurbishment of the existing canal infrastructure, in order to reduce the current water losses. This will provide the GWS with the baseline to ensure efficient utilisation of the assets.

The lining and relining of canals requires significant capital investment which the DWA will need to provide, since they own the assets. The DWA has already taken the initiative to implement the refurbishment of sections of the Boskop right bank canal. This should be extended to other canal sections once a detailed condition assessment has been conducted.

The conditions of the transfer of the refurbishment, when the GWS is transformed into a WUA, should be carefully monitored to ensure that rehabilitation of the infrastructure is undertaken.

The refurbishment of the canal infrastructure is likely to save approximately 7.71 million m^3/a (see **Table 11.4** below). However this will come at a significant cost. The total cost estimate for relining of the canal sections with concrete and sealing of the wetted perimeter was determined to be R38.5 million while the operation and maintenance costs to maintain the infrastructure in good condition from thereon was calculated as R0.525 million per year.

A condition assessment of the canal system will need to be conducted and the results of the assessment should be used to develop a canal refurbishment and renewal programme for the Mooi River Irrigation Scheme

Table 11:4: Summary of capital investment requirement & benefits - Rehabilitation of the canal infrastructure

Item	Description	Water Savings Million m^3/a	Cost Savings R per year	Sub-Total	Total
Refurbishment of canals	Refurbishment of canals				
Installation period					One year
Productive period					20 years
Initial Capital Investment Costs	Design of new canals & specifications			3 500 000.00	
	Procurement of contractors				
	Installation of canal sections			35 000 000.00	38 500 000.00
Annual O&M Expenses	Flashing, resealing of canal sections, unblocking siphons,			525 000.00	
Water Losses					
Leakage Reduction	Leakage reduction	7.71	386 906.78		
Average Incremental Cost (AIC)					0.15

11.5 Task 4: Incentive based water pricing

11.5.1 General

To achieve an incentive for efficient water use, the price of irrigation water must be directly related to the volume delivered unlike the current situation where it is based on the scheduled quota.

In order to encourage irrigators to use water efficiently, it is recommended that an incentive based water pricing structure for Mooi River Irrigation Scheme is considered, based on the optimal crop water requirements of the main crop which is maize. The implementation of incentive water pricing in irrigation agriculture, requires that comprehensive regulatory and operational criteria to be met before considering the economic criteria for incentive based pricing of irrigation water.

11.5.2 Regulatory aspects for incentive pricing

An orderly system of distributing water is already in place in the Mooi River Irrigation Scheme, based on the regulatory framework for distributing water among the farmers. The rules and procedures defining the water ordering and water releases are in place. These include responsibilities of the GWS and those of the irrigators, priorities in case of shortage or excess supplies; penalties for breach of rules, and so on. Based on this, there is immediate scope for improving water distribution through pricing. Furthermore, there are already flow measurement devices (i.e. sluice gates and Parshall flumes), for measurement of the quantity delivered.

From a regulatory perspective, the water pricing strategy can be used in determining an incentive pricing structure with two or three levels of pricing, to encourage efficient use of irrigation.

11.5.3 Operational aspects for incentive pricing

Measurement and charging at the farm level will require substantial investment in equipment, and an associated administrative bureaucracy, to collect and collate data on farm-level deliveries, and undertake the billing process.

The Mooi River Irrigation Scheme already has the operational systems in place such as weekly ordering, as well as the sluice gates (however not very accurate) to measure each irrigator's use. Furthermore, the scheme has the administrative system to carry out billing based on actual use, rather than on a scheduled basis.

With the above operational aspects in place, the direct link between service and payment are achieved, and the efficiency incentive that pricing is designed to produce, can be met.

11.5.4 Economic aspects for incentive pricing

The current pricing, based on the scheduled quota does not provide the economic incentives for improving water use efficiency at farm level, as irrigators feel that they are entitled to the full use of their scheduled quota, even when they can achieve higher levels of production with less water.

If the charging system is to have an impact on consumption, then the system of payment must be such as to induce the desired economic response. In the case of Mooi River, the benefit of incentive pricing means irrigators can expect to pay less for their irrigation compared to the current scheduled quota which provides an economic incentive to the irrigators.

Because the Mooi River GWS needs to undertake fixed operation and maintenance activities, the incentive based pricing should consider the potential effects on revenue generated through water sales. However any savings made from reduction in water use at field edge, can be sold to other users such as the domestic sector whose demand is growing. This will provide supplemental revenue that could be used to develop more improvements to the scheme.

The potential savings are on the on-farm water use efficiency. The estimate is that there is likely to be savings of between 15% - 20% of the current irrigation water use of 12.1 million m^3/a (i.e. 1.81 million m^3/a).

12 MOOI RIVER GOVERNMENT WATER SCHEME WATER MANAGEMENT PLAN

12.1 General

12.1.1 Legal provision for developing and implementing a WMP

The development and implementation of a Business Plan is a legal requirement to be undertaken by a GWS in terms of section 21 of Schedule 4 of the National Water Act (Act 36 of 1998). The constitution of a GWS - referred to schedule 5 for model constitution - outlines the principle functions to be performed by the GWS and will include the following:

(i) Prevent water from any water resource being wasted;
(ii) Exercise general supervision over water resources;
(iii) Regulate the flow of water course;
(iv) Investigate and record quantities of water;
(v) Supervise and regulate the distribution and use of water from a water resource.

The Business Plan for a GWS will thus incorporate a Management Plan setting out standards and Best Management Practices. Another key clause in the National Water Act is Section 29(1), which reads as follows:

"*A responsible authority may attach conditions to every general authorisation or licence -*

b) relating to water management by:

(i) specifying management practices and general requirements for any water use, including water conservation measures;

(ii) requiring the monitoring and analysis of and reporting on every water use and imposing a duty to measure and record aspect of water use, specifying measuring and recording devices to be used;

(iii) requiring the preparation and approval of and adherence to, a water management plan."

In light of the above legal requirements, the Mooi River GWS has developed a WMP in terms of the provisions of the act to enable it to manage the irrigation water in the scheme effectively and efficiently.

12.2 Establishment of water saving targets for Mooi River Irrigation Scheme

12.2.1 Introduction

The implementation of a Water Management Plan for the Mooi River Irrigation Scheme to reduce water losses will imply reducing the water diverted per unit of the land area irrigated in the scheme. As is expected this will not affect the yields of the wheat, maize and potatoes that are being irrigated in the scheme area. Therefore reducing the water diverted per unit of land area would mean an increase in productivity per unit of water which would be a clear indication of progress towards greater efficiency for the Mooi River Irrigation Scheme assuming the scheduled quota of 7 700 m^3/ha/a remains constant.

In the Mooi River Irrigation Scheme, the trend line indicates that there has been no improvement in the diversion per unit of irrigated areas from 2000 to 2008 water years for the Mooi River Scheme (see **Figure 12.1** below). The constant diversions per unit of irrigated land are a clear indication that there is no improvement in irrigation water use efficiency during the period when the records were available.

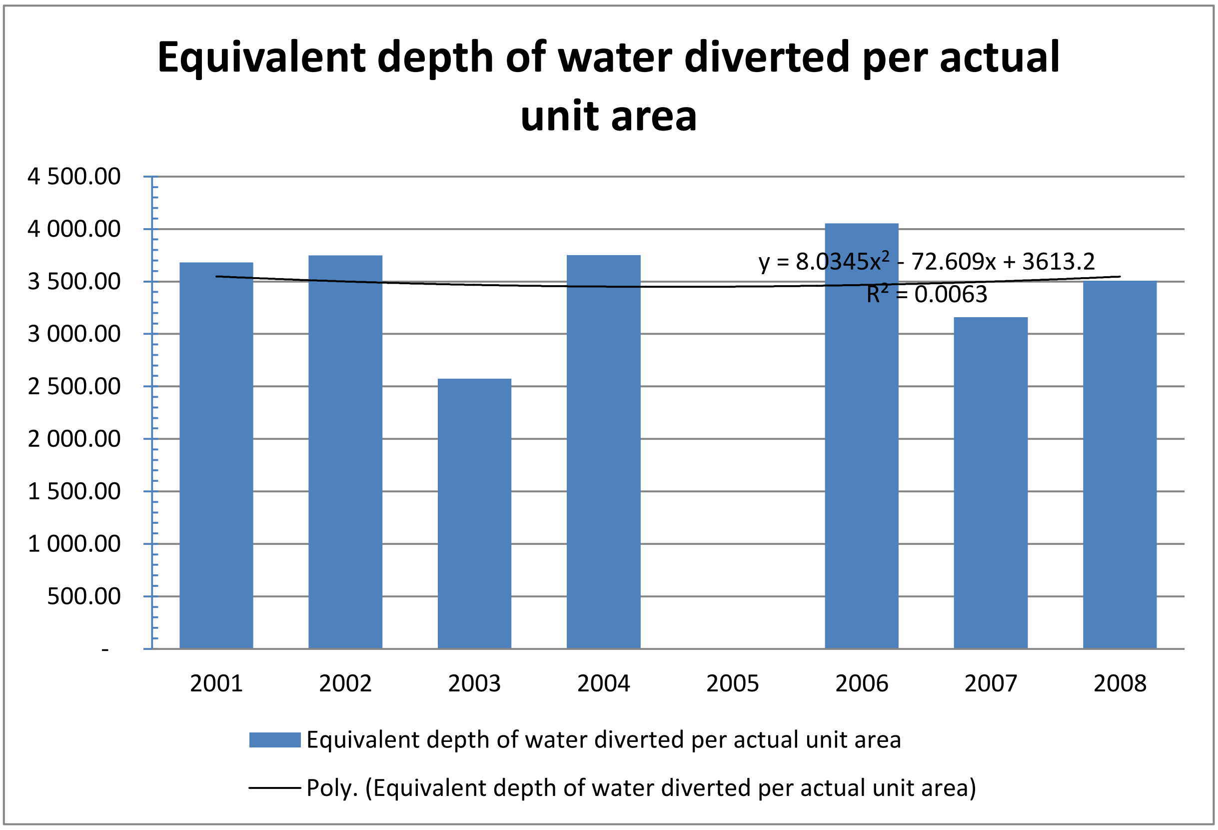

Figure 12:1: Trend line of increasing irrigation water released expressed as an equivalent depth of water released per actual unit area irrigated in the Mooi River Scheme

In the case of the Boskop right bank canal system the trend line indicates a slight decrease in the diversion per unit of irrigated areas from 2000 to 2008 water years (see **Figure 12.2** below). Hardly much has changed in irrigation water use efficiency over the last 2 years of records.

Any improvements for example in on-farm water use efficiency maybe likely to be offset with the increase in water losses. This conclusion has however only been reached with very limited data as no other historical data was available and will need to be verified in time.

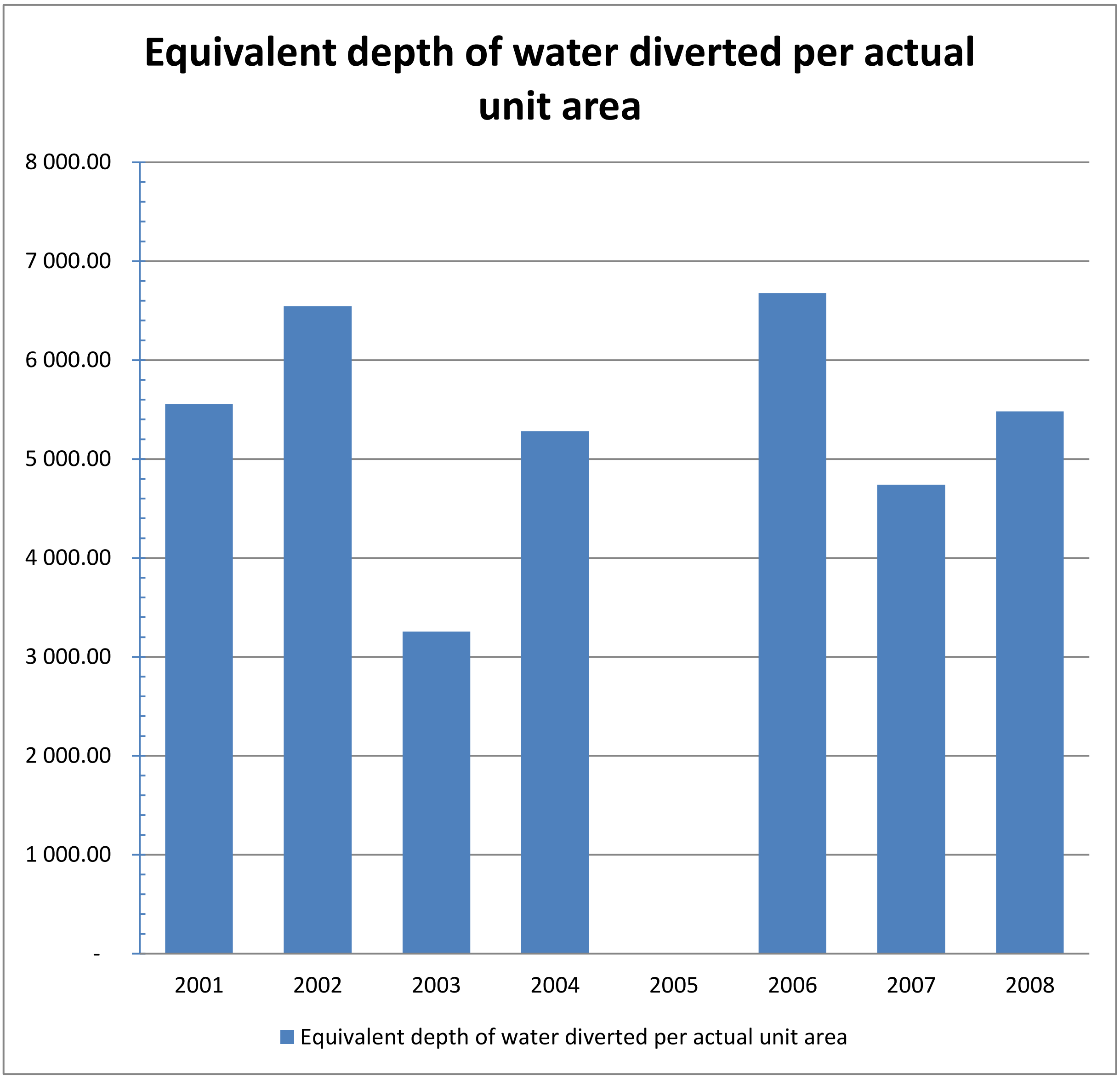

Figure 12:2: Trend line of slightly decreasing irrigation water released expressed as an equivalent depth of water released per actual unit area irrigated for the Boskop Right Bank

In the case of the Lakeside canal system the trend line indicates an increase in the release per unit of irrigated areas from 2000 to 2008 water years (see **Figure 12.3** below). This may be due to the increase in the release from the Lakeside Dam to supply irrigators in the sub-scheme area. The increase may be due to the deteriorating condition of the canal infrastructure and/or the increase in the algae growth in the canal which affects the hydraulic capacity of the canals. The other issue could be increase in the operational spills at the canal tail ends. This can be addressed by continuous monitoring to reduce the operational spills.

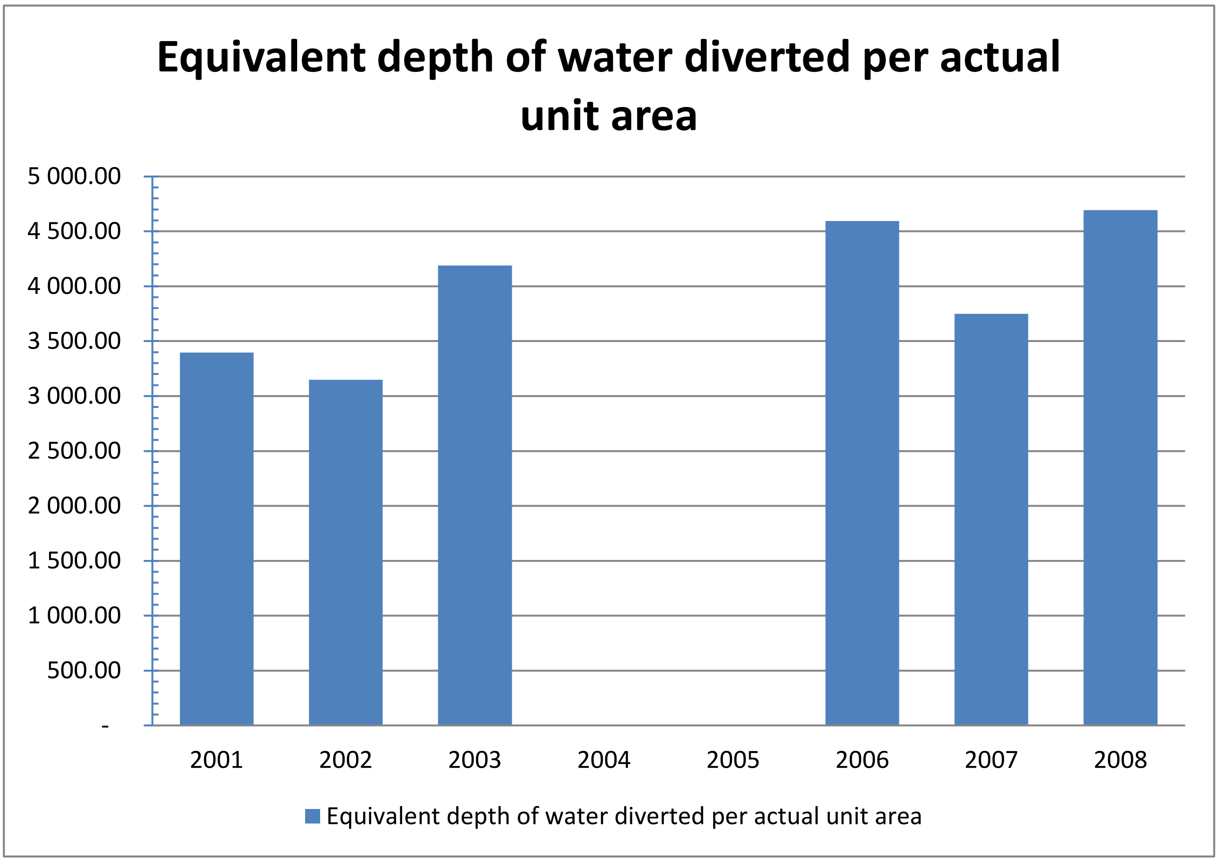

Figure 12:3: Trend line of slightly decreasing irrigation water released expressed as an equivalent depth of water released per actual unit area irrigated for the Lakeside canals

Therefore in setting water saving targets for the Mooi River Irrigation Scheme, the use of the equivalent depth per unit area irrigated as a performance indicator is proposed. Any decrease per unit of actual irrigated area will indicate progress being made by the scheme towards greater irrigation water use efficiency. This performance indicator can be used at scheme as well as at sub-scheme level in the Mooi River Irrigation Scheme. Currently this measure is not being used when the irrigation schemes submit their WUEAR reports.

12.2.2 Recommended water saving targets

Because there has not been a decline in the trend line of the releases per unit area irrigated over the observed period, it would appear there is significant scope in implementing the irrigation management intervention measures discussed in the previous chapter. The water saving targets recommended for the Mooi River Irrigation Scheme is provided in **Table 12.1** below. Based on the projected water saving targets, the Mooi River Irrigation Scheme can achieve a 19% reduction in irrigation water losses relative to 2012 levels, by the end 2022 based on the components provided in **Table 12.1** below.

12.2.2.1 Short term water saving targets

For the short term which has been taken as 3 years, the total water savings from implementing the flow measurements; recalibration of Parshall Flumes and flow monitoring to reduce operational spills at canal tail ends below the scheme of 3.28 million m^3/a can be achieved, while the management of algae and water grass will potentially save 4.1 million m^3/a in the next two years. This is the water savings that have been targeted to be saved over a period of 3 years for the Mooi River Irrigation scheme until 2015.

12.2.2.2 Long term water saving targets

For the long term a further 7.71 million m^3/a, is envisaged to be saved by refurbishment of the canal infrastructure while another 1.09 million m^3/a could potentially be saved through implementing incentive based pricing. This will require amendments to the current water pricing strategy which is currently being reviewed. It is unlikely that these water savings can be realised in the next three years. They are considered for the medium to long term in this water management plan. Therefore because of the complexities in implementing incentive based pricing and the timeline, it is recommended that this measure be implemented last.

The long term target is however to reduce the water losses to approximately 18% of the total diversion. The annual water savings targets are discussed together with the action plans for implementation of the identified measures.

Table 12:1: Projected water saving targets for the Mooi River Irrigation Scheme

Irrigation Component	Intervention	Estimated water savings	Percentage of irrigation diversion	Time frame for implementation
Conveyance Infrastructure	Refurbishment & resealing	7.71	9%	5 to 8 years
Distribution infrastructure	Flow measurement & monitoring	3.28	4%	2 years
	Recalibration of Parshall Flumes			
Operational	Canal tail ends /	4.10	5%	
	Control of aquatic weeds			2 years
Sub-Total Scheme target		15.10	18%	
On Farm irrigation	Incentive pricing	1.09	1%	3 to 5 years
	Irrigation systems			

12.3 Priority list of potential measures for implementation

12.3.1 General

The evaluation of the potential measures for implementation in the Mooi River Irrigation Scheme area, to improve water use efficiency and reduce water losses, indicates that all four measures are economically justified for implementation based on the unit cost of water saved.

The priority for implementation based on the amount of water savings and the average incremental cost of water saved is as follows:

(i) *Flow measurement and monitoring at near real time* - This measure has the second most benefit with estimated water savings of 3.28 million m^3/a, at an average incremental cost of R0.09 per m^3. It is however easier to implement and should be considered a priority as all other measures are dependent on availability of sufficient water measurements in the Mooi River Irrigation Scheme.

(ii) *Chemical management of aquatic weeds and algae growth in canals* - This measure has the most benefit with estimated water savings of 4.1 million m^3/a, at an average incremental cost of R0.08 per m^3. It should be carried out at the same time as the first intervention measure.

(iii) *Water Accounting System* - This measure is aligned to the first measure and will provide the system necessary to identify areas where irrigation water management can be improved. The changes in operation of the canals and canal tail ends can result in significant water savings if no water is allowed at the canal tail ends at the end of the scheme.

(iv) *Refurbishment of the canal infrastructure* - This measure is likely to be very expensive but will benefit the scheme in the long term with the estimated water savings of 7.71 million m^3/a. Because of the high capital investment requirements, the average incremental cost to implement this water management measure is likely to be very high.

(v) *Incentive based water pricing structure*- This measure has the most benefit with estimated water savings of 1.09 million m^3/a. The average incremental cost to implement this water management measure is likely to be very low as this will be done at national level.

The above first three measures indicate that the avoidable beneficial and non-beneficial water losses that will be saved will amount to 15.1 million m^3/a out of a total of 30.2 million m^3/a of the estimated avoidable water losses.

12.4 Action Plan for implementation

12.4.1 Target 1: Conduct flow measurement at all critical measurement points in the scheme

Table 12.2 below provides the plan of activities required in order to ensure all flow measurements are taken by the Mooi River GWS and detailed water balance assessments are conducted on a quarterly basis and a management report presented to DWA on the status of water losses, water saving targets as well as the actions taken to reduce water losses.

As discussed in the previous chapters, the Mooi River irrigation scheme has most of the measurement structures to enable the GWS to take flow measurements at all critical points albeit by manually reading the flow levels and converting these levels to flow rates. The manual reading is because the existing flow recorders at the measurement points are not operational.

The updating and calibration of the existing Parshall flumes should also be conducted to enable accurate flow measurements to be taken.

Table 12:2: Mooi River Irrigation Scheme: Water Management Measures and action plan

Priority	Goal	Action Plan	Timeline	Responsible Authority
1	To measure all critical points in the Mooi River irrigation scheme	(i) Measure the main canal tail ends on a continuous basis	June 2013	Mooi River GWS
		(ii) Measure the inflow and outflow at the downstream dams	June 2013	
		(iii) Calibrate the measurement structures as required	June 2013	
2	Undertake detailed water balance assessments of the scheme	(i) Split the Mooi River scheme into the sub-schemes and prepare water balance assessment and WUEAR reporting to DWA	June 2013	Mooi River GWS
		(ii) For the Boskop and Klerkskraal canals system split the scheme into the left bank and right bank canals	June 2013	
		(iii) Monitor releases into the canal when the Dams are spilling	June 2013	
		(iv) Prepare detailed water balance assessment for the sub-schemes and split the losses to reflect operational losses from canal tail ends	June 2013	
		(v) Set water saving targets to reduce operational losses at canal tail ends	June 2013	

Priority	Goal	Action Plan	Timeline	Responsible Authority
3	To enable real or near real time flow monitoring	(i) Detailed design of the flow measurement and remote telemetry units (RTU) required for flow measurement (ii) Install new telemetry system infrastructure including software to ensure compatibility with WAS (iii) Calibrate the flow measurements such as flumes and sluices to improve the accuracy in flow measurement (iv) Prioritise areas of significant water losses	Oct 2013 Feb. 2014 May 2014 June 2014	Mooi River GWS
4	To fully implement the WAS programme	(i) Review current use of WAS programme modules (ii) Implement the WAS release module (iii) Set up WAS programme to carry out water balances at scheme and sub-scheme level	Oct. 2012 June. 2013 June. 2013	Mooi River GWS
5	Reduce algae	(i) Identify the types and species composition of aquatic weeds and algae	March 2012	Mooi River

Priority	Goal	Action Plan	Timeline	Responsible Authority
	growth in canals	(ii) Prepare a tender for supply of Acrolein or similar approved	June 2013	GWS
		(iii) Apply Acrolein to manage aquatic weeds and algae	Oct 2013	
		(iv) Assess the effect of chemical removal of algae	June 2014	
6	To conduct the refurbishment of the canals	(i) Classify the condition of all canal segments based on the condition of the canals. In cooperation with scheme personnel, conduct field reconnaissance to obtain attribute data and rate the condition of segments.	Aug 2013	Mooi River GWS/DWA Infrastructure
		(ii) Prepare a motivation to DWA Management for refurbishment of the poor sections of the canals requiring total reconstruction as well as relining.	Oct 2013	Mooi River GWS/DWA Infrastructure
		(iii) Prepare tender documents & specifications; Procure SP & undertake total construction of canal sections and relining of the canals with bitumen emulsion.	Nov 2013	DWA Infrastructure
		(iv) Assess water savings made from total construction of sections of the Mooi River canal and relining of canal sections.	Oct 2014	Mooi River GWS/DWA Infrastructure

Priority	Goal	Action Plan	Timeline	Responsible Authority
7	To implement incentive pricing structure for the WMA	(i) Review current irrigation water pricing strategy and update administration systems (ii) Provide inputs in updating the DWA water pricing strategy (iii) Engage with irrigators on incentive pricing structure (iv) Install accurate flow measurement & implement water billing based on incentive pricing rate (v) Update the operating rules of Klerkskraal, Boskop and Lakeside Dams to supply irrigators based on incentive pricing rate	June 2013 July 2013 August 2013 March 2014 June 2014	DWA / Mooi River GWS

12.4.2 Target 2: Conduct detailed water balance assessment at sub-scheme level

In order for the Mooi River GWS to benefit from taking the flow measurements, detailed water balances should be prepared to incorporate actual flow measurements than is currently the case where the GWS has relied on estimates, particularly of the water losses.

As a first step, four water balance assessments, one for the Klerkskraal, Boskop, Lakeside and the other for the Gerhardminnebron sub-schemes should be conducted to include the measurements at the canal tail ends.

Water diverted into the canals when the Dams are spilling must be measured on a daily basis.

12.4.3 Target 3: Management of aquatic weeds and algae

One of the most critical water management measures that need to be implemented is the removal and control of the aquatic weeds and algae growth in the Mooi River irrigation canals. The following actions are needed to implement a programme to control aquatic weeds and algae growth in the canals:

(i) Identify the types and species composition of aquatic weeds and algae growing in the canals as well as the source of the problem. This should include determining the physical and chemical characteristics of water and sediment in the canal system.

(ii) Conduct a critical evaluation of the benefits and problems encountered with on-going management activities to provide a useful baseline for development of a management plan that enhances cost effectiveness and efficacy of aquatic vegetation management in canals.

(iii) Prepare a management plan to implement aquatic weed and algae removal and control based on chemical process using herbicides such as Acrolein. Prepare a tender document to acquire the chemical and resources to apply the chemical.

(iv) Invite tenders and implement an aquatic weed and algae removal and control programme for Mooi River Irrigation Scheme.

(v) Conduct a post project evaluation of the impact of the programme on reducing water losses and improving irrigation water management

12.4.4 Priority 4: Implementation of WAS programme

The benefits of installing sufficient water measurement cannot be fully realised without the implementation of the WAS programme, which needs to be linked with the data and records from the flow measurement system. The following actions are required to implement a water accounting system for the Mooi River Irrigation Scheme:

(i) Review and evaluate the existing water accounting system being used by the scheme operators and identify where the gaps are;
(ii) Determine how the water release and water use modules should be linked to the flow measurement system;
(iii) Implement the WAS programme.

The WAS programme can then use the information and flow records to match the water releases and the water requested, to minimise operational spills, as well as to reduce any current flows at the tail ends. The flow at the tail ends is considered as a loss, although it may have a beneficial use downstream. The downstream demands can however be supplied by direct flows in the Mooi River and/or releases from Klerkskraal Dam and Boskop Dam.

12.4.5 Target 5: Installation of the telemetry system for real time flow and level monitoring

Telemetry basically refers to accessing the data and controlling the system by remote means. With a telemetry setup, the Mooi River GWS can program the system to run automatically and let the scheme operators know the status of a canal system at any time. The GWS can access the system at any time and find out the status of the canal system. If something goes wrong with the system, it can be set up to alarm the scheme operators.

A number of activities and tasks for implementation of installation of telemetry infrastructure is presented in **Table 12.2** above.

As illustrated in the Table, the first priority action plans focuses on designing the telemetry infrastructure and network in the scheme. It is important that the telemetry system first focuses on installing the infrastructure at the two primary canals of Mooi River GWS where the inflow into the Scheme takes place, the main branch canals, the balancing dams as well as the canal tail ends.

With the installation of telemetry system the Mooi River GWS will be in a position to conduct the real time flow measurements at all critical points of the Mooi River irrigation scheme, including the spills at the canal tail ends as well as the flow into the different branch canals. This will assist the scheme in determining where any critical changes to the expected flows such as at canal tail ends can be done thereby allowing the scheme operators to react to any operational losses or even theft of irrigation water.

12.4.6 Priority 6: Updating and implementation of the Water Management Plan

The Scheme Manager will be responsible for amongst others the implementation and updating of the Water Management Plan (WMP) for the scheme.

The roles and responsibilities of the applicable Scheme Manager for the updating and implementation of the WMP will be the following:

(i) Take flow measurements and conduct a detailed water balance assessment on a monthly basis at scheme and sub-scheme level
(ii) Compile Water Use Efficiency Accounting Reports and submit it on a monthly basis to the DWA Regional Office
(iii) Do recommendations on observations regarding water conservation issues and report to the Chief Executive: SAAFWUA and DWA on ways to address the identified issues
(iv) Develop activities that build on and complement other WC/WDM initiatives taking place at other water schemes
(v) Present water conservation information and training to irrigators and inform other scheme managers about success stories undertaken by the scheme
(vi) Maintenance and modernisation of the irrigation infrastructure
(vii) Liaise with DWA and other scheme managers to ensure consistent, efficient and effective deployment of water conservation messages, resources and services throughout the scheme
(viii) Monitor the plan and schedule for implementing water conservation program components
(ix) Report quarterly to DWA on the implementation status of the WMP, i.e. actions taken to reduce water losses and achievements towards achieving water saving targets, goals and objectives
(x) Annually review and update the WMP with a water conservation program for the scheme with goals, objectives, improved water saving targets, action steps, measures, and timelines taking into consideration the latest measured data and the measures that have already been implemented.

12.4.7 Priority 7: Implement incentive pricing

This requires a review and updating of any regulatory and operational criteria required to enable the Mooi River GWS to implement incentive based pricing. The action plans and time frame including the following:

(i) Review and update the regulatory aspects of incentive based water pricing structure by proving inputs into the updating of the water pricing strategy.

(ii) Evaluate the average actual water use by irrigators as a percentage of their scheduled allocation. This can be done through a questionnaire and reviewing the historical records of irrigation demands.

(iii) Determine the fixed operation and maintenance costs of the Mooi River Irrigation Scheme and assess the revenue requirements for sustainable operation of the scheme.

(iv) Establish the base price of irrigation water per unit of water based on the revenue requirements of the scheme to meet the O&M costs.

(v) Determine the marginal costs per unit of water in excess of the base price and design one or more pricing levels above the base price.

(vi) Establish that the operational and accounting aspects of water pricing are in place.

(vii) Implement the incentive based water pricing structure for Mooi River Government Water Scheme.

Besides the reduction in water use and potential additional revenue that Mooi River Irrigation Scheme may benefit from implementing incentive based pricing, the reduction in on-farm irrigation will help the scheme to:

(i) Reduce erosion;
(ii) Improve the crop yield and quality;
(iii) Reduce fertiliser leaching; and
(iv) Reduce drainage problems and downstream water quality problems

As the DWA's water pricing strategy is currently under review and update, where amendments may be required to encourage incentive based pricing in the strategy, this should be considered.

12.5 Funding of the Mooi River Irrigation Scheme WMP

12.5.1 General

All of the Water Conservation and Demand Management measures involve an initial capital investment requirement including the replacement costs over the useful life of the infrastructure. This is followed by on-going operations and maintenance which is required to ensure the installed infrastructure assets can provide the required performance for its intended use.

It has been proven in the analysis of the identified water use efficiency measures that implementation of these measures provides the most viable option at present to improving irrigation water use efficiency and reduce water losses in the Mooi River Irrigation Scheme. However this will come at a cost to the water users. The additional cost for implementing these measures was done using the least cost planning approach where the average incremental costs (AIC) of each intervention measure were determined.

However the financing of the candidate measures should take into account the beneficiaries from water savings made during the implementation of the above identified measures. This is discussed in the following section.

12.5.2 Financing by water users of the Mooi River GWS

The benefits in implementing monitoring of the flows to irrigators will directly benefit the Mooi River irrigators and ensure that irrigation water is managed effectively to enable the scheme operators to provide the water to irrigators when required and on time. Therefore based on the fact that the beneficiaries are the irrigators in the Mooi River Irrigation Scheme, the financing of the following aspects should be borne by the irrigators on the Mooi River GWS;

(i) Providing additional flow measurement and monitoring system

(ii) Providing the full operation of the WAS programme to enable water accounting to be conducted as well as to fulfil the legal requirements in terms of the Act to provide annual reporting to the DWA on the irrigation water management for the scheme.

12.5.3 Financing by the DWA

The canal infrastructure in the Mooi River Irrigation Scheme is owned by the Department of Water Affairs (DWA) as the Mooi River is a GWS. The irrigation scheme is therefore to operated and annual maintenance of the infrastructure carried out by the DWA.

The impact of the aquatic weeds and algae on the condition of some of the infrastructure may have deteriorated to the extent that it requires refurbishment, the cost of which is prohibitive to be carried out by the irrigators through increase in water tariffs. Furthermore this problem is external to the operation of the scheme as the reasons for aquatic weeds may be due to upstream management. This problem is considered a water management area problem and requires the DWA to provide the financing necessary to reduce the water losses due to the aquatic weeds and algae growth in canals resulting in deterioration of the canal system.

It is therefore recommended that the DWA provide the funding necessary to reduce water losses by the following:

(i) Implementation of a programme to remove and control the aquatic weeds and algae growth in canal systems.

(ii) Refurbishment of the sections of irrigation canals which are in a bad condition as identified through a ponding test.

(iii) Implementation of the incentive based pricing by Mooi River GWS

13 CONCLUSIONS AND RECOMMENDATIONS

13.1 Conclusions

The following can be concluded from the assessment of the water supply/requirements conducted for the Mooi River Irrigation Scheme area and can be summarised as follows:

- The Mooi River Irrigation Scheme is situated in the Upper Vaal Water Management Area in the Dr Kenneth Kaunda District Municipality. The scheme has an enlisted area of 4 578.1 ha at an allocation of 7 700 ha/a, which includes canal as well as river irrigators. The total water allocation from the Mooi River is 35.25 million m^3/a.
- The main crops that are under irrigation include maize which is the main crop, vegetables, as well as irrigation of pasture.
- The Mooi River Irrigation Scheme receives its raw water supplies from the storage dams in the Mooi River namely Klerkskraal dam, Boskop Dam and Lakeside Dam where the irrigation canals carry the water within the scheme. The source of supply is the dolomitic aquifers of the area, such as the Gerhardminnebron Eye. The Klerkskraal Dam has a total storage capacity of 7.9 million m^3 while the storage capacity of Boskop Dam is 20.84 million m^3/a. Water is released to supply Mooi River Irrigation Scheme, from the four sources to meet the demands of the irrigators in each sub-scheme based on the weekly orders.
- The Mooi River Irrigation Scheme has a total length of approximately 210 km of irrigation canal which supplies the irrigators as well as Tlokwe Local Municipality. There are six main flow measurement structures measuring the releases into the six main canals. The canals distribute irrigation and domestic water to sluice gates and Parshall flumes.
- Although no detailed condition assessment could be undertaken on the Mooi River Irrigation Scheme, a preliminary assessment and discussion with scheme operators indicated that the Boskop right bank canal was in a very poor condition because of the expansive clayey soils. It was determined that there were significant problems of aquatic weeds and algae growth in the canals affecting the hydraulic performance and condition of the canal system.
- In order to ensure that the irrigators receive their scheduled quota as and when required, the Mooi River GWS operates the irrigation scheme based on “delivery on request” where each water user (irrigator) must submit a written request on a weekly

basis and the water is delivered to the abstraction points along the canal systems. These procedures formerly documented.

- Irrigation water use in Mooi River has ranged from 7.16 million m^3/a in 2003/04 up to 16.26 million m^3/a in 2002/03, with a seven year average of 12.10 million m^3/a. The domestic water use for Potchefstroom however has shown a steady increase in water consumption, increasing from 4.6 million m^3/a in 2003/04 up to 7.18 million m^3/a, in 2007/08.
- The average total water diverted within the Mooi River Irrigation Scheme during the same seven year period, was 83.01 million m^3/a, with the range being 53.35 million m^3/a in 2002/03 up to 101.65 million m^3/a in 2000/01.
- An irrigation water balance assessment conducted for Mooi River Irrigation Scheme indicated that the water losses averaged 36% of the total water diverted, with the Boskop Dam right bank canal system having the highest water losses at 42% of sub-scheme inflow and Lakeside dam canal having water losses of 69% of the sub-scheme inflow. The total gross water losses amounted to 30.2 million m^3/a, for the whole scheme. This was considered to be very high.
- The total water losses were disaggregated to determine the unavoidable and avoidable water losses with a view to establishing the irrigation water delivery BMP for Mooi River Irrigation Scheme. The total unavoidable water losses comprising evaporation losses and seepage due to the age and condition of the infrastructure was determined to be 6.7 million m^3/a or 8% of the total water diverted.
- Based on the unavoidable water losses, there was significant potential to reduce irrigation water losses and improve irrigation efficiency in the Mooi River Irrigation Scheme.
- However an assessment of the operational inefficiencies due to over delivery, metering errors, etc. means that approximately 10% of the total releases will unlikely be able to be saved. This translates to 8.31 million m^3/a, which cannot be saved.
- The water losses that can be saved was 15.1 million m^3/a out of an average total water loss of 30.19 million m^3/a for the Mooi River GWS. This was considered to be operational wastage, leakage and spills which could potentially be saved. This does not include the spills at the canal tail ends within the scheme.
- The irrigation water balance assessment together with discussions with Mooi River GWS operators highlighted that there were number of management issues which included the following:
  (i) Although there are flow measurements, there are not sufficient water measurements at some of the critical points to measure and monitor flows

such as at the canal tail ends as well as measurement of water delivered to other canals. If these measurements were available, the accurate measurements are not being included in the WUEAR reports.

(ii) Not all the modules of the WAS programme which was installed are being utilised. The release module is currently not being used. Together with the compatibility issues of the telemetry system only the administration module is being utilised.

(iii) There were no detailed irrigation water budgets being conducted at both scheme and sub-scheme levels as the flow measurements at the canal endpoints and tail water ends as well as at each diversion where flow measurements are being taken was not being included. There was a need to address this in order to clearly determine where and how much water can be considered as water losses.

(iv) The condition of the canal infrastructure was in a poor state in some areas resulting in significant water leakages. This is due to the aquatic weeds and algae growth in the canal system.

(v) The operational management of the Scheme will require evaluation in terms of the practice of diverting Dam spills into the canal. Diversions into the canal, in excess of the scheduled amount, must be in accordance with the operating rules of the Dams, such as the Boskop Dam. This diversion into the canals during spills will require to be monitored on a daily basis.

- Based on the above water management issues, a number of measures were identified to address the issues with the main management goal being to reduce the high water losses and improve irrigation water use efficiency in Mooi River. These measures were evaluated and prioritised based on the water savings and the average incremental cost (AIC) of implementing the measures.

13.2 Recommendations

13.2.1 Mooi River Water Management Plan

A water management plan for the Mooi River Irrigation Scheme was developed to address the water losses taking place in the scheme and to improve irrigation water management of the scheme. The identified measures for implementation to reduce the water losses from the current 36% to 18% of the total inflow into the irrigation scheme include the following:

(i) *Installation of water measurement* - This measure has the second most benefit with estimated water savings 3.28 million m^3/a, at an average incremental cost of R0.09

per m^3. It is however easy to implement and should be considered a priority as all other measures are dependent on availability of sufficient water measurements in the Mooi River Irrigation Scheme.

(ii) *Operational spills and Chemical management of aquatic weeds and algae growth in canals* - This measure has the most benefit with estimated water savings of 4.1 million m^3/a, at an average incremental cost of R0.08 per m^3. It should be carried out at the same time as the first intervention measure.

(iii) *Water Accounting System* - This measure is aligned to the first measure and will provide the system necessary to identify areas where irrigation water management can be improved. The changes in operation of the canals and canal tail ends can result in water savings for the scheme if no water is allowed at the canal tail ends.

(iv) *Refurbishment of the canal infrastructure* - This measure is likely to be very expensive but will benefit the scheme in the long term with the estimated water savings of 7.71 million m^3/a. Because of the high capital investment requirements, the average incremental cost to implement this water management measure is likely to be very high

(v) *Incentive based water pricing structure*- This measure has the least benefit with estimated water savings of 1.09 million m^3/a. The average incremental cost to implement this water management measure is likely to be very low as this will be done at national level.

13.2.2 Financing options for the WMP

All of the Water Conservation and Demand Management measures involve an initial capital investment requirement including the replacement costs over the useful life of the infrastructure. However the financing of the candidate measures should take into account the beneficiaries from water savings made during the implementation of the above identified measures.

Two sources of funding were identified and is recommended based on the beneficiaries of the intervention measures. The recommendation is that

(i) Mooi River GWS (irrigators) should look at financing the measures which will benefit and improve the operation and monitoring of irrigation water in the scheme. These measures will also allow Mooi River to fulfil it legal requirements in terms of the National Water Act on reporting and efficient management of irrigation water. These include updating the flow measurements, refurbishing the telemetry system and to fully implement the WAS programme.

(ii) The DWA owns the infrastructure in Mooi River Irrigation Scheme. The refurbishment of the canal infrastructure including management of the aquatic weeds and algae requires significant funding which cannot be met from the maintenance budget of Mooi River. As the water savings from the refurbishment of canals will benefit downstream consumers, the financing of the refurbishment of the infrastructure should be undertaken by the DWA. This also includes the implementation of incentive based pricing which will improve the on-farm irrigation efficiency while the savings will benefit downstream users unless Mooi River can use the water to expand their agriculture.

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