water affairs

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REPUBLIC OF SOUTH AFRICA

DIRECTORATE: WATER USE EFFICIENCY

CONTRACT NO. WP 10276

DEVELOPMENT AND IMPLEMENTATION OF IRRIGATION WATER MANAGEMENT PLANS TO IMPROVE WATER USE EFFICIENCY IN THE AGRICULTURAL SECTOR

BOEGOEBERG WATER USER ASSOCIATION

FINAL REPORT

March 2013

Prepared by

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Contract Title: Development and Implementation of Water Management Plans to improve water use efficiency in the agricultural sector

Report Title Boegoeberg Water User Association - Water Management Plan

Authors Toriso Tlou, Pr. Eng; Francois Joubert

Revision	Date	Report Status
Draft 1	22/03/2012	First draft for comment
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Client: Department of Water Affairs

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EXECUTIVE SUMMARY

The Boegoeberg irrigation scheme was constructed during the Great Depression when in March 1929, the government decided to undertake the Boegoeberg Dam and canal project as part of its drought alleviation scheme. The main aim was to provide work for whites who were suffering as a result of the drought and the financial pressures. Capital for the project was provided by the Department of Labour but the construction thereof fell under the department of Water Affairs (then known as the Department Irrigation). The construction camp for the dam was situated on the farm Seekoebaart and the camp for the workers responsible for the construction of the canals was situated at Sterham (later re-named Groblershoop in honour of Mr Piet Grobler, Minister of Labour).

All the construction work was done with pick and shovel and wheelbarrows with the help of some donkeys. Even the children carried stones for the lining of the canal for a sixpence a day to boost the family's income.

Many of the concrete flumes, sluice gates and measuring structures within the unlined canal of 121 kilometres on the southern bank of the Orange River were already built in the late 1930's. In 1952 the Department of Water Affairs commenced with the lining of the canal.

Irrigation development in the Upper Orange WMA was stimulated by the construction of several dams. Great expansions of irrigation were made possible along the Orange River by the construction of Gariep and Vanderkloof dams in the Upper Orange WMA during the 1970's.

The Boegoeberg Dam is effectively a concrete weir which was initially equipped with 68 sluices designed to allow sediment to pass through the structure. The original capacity of over 40 million m^3 has been reduced through sedimentation to the current capacity of approximately 20 million m^3 and appears to have reached some form of equilibrium. The sediment sluices have recently been closed permanently and the structure is now effectively a concrete weir which supplies water into a canal on the left bank

The canal was extended in the 1970's to be 172 kilometres long. Siphons were built to serve irrigation farmers north of the Orange River from the main canal on the southern bank with the 38 km Gariep canal, the 8 km Rouxville West canal and the 40 km Northern Orange canal. The canal wall height had to be extended at some sections to accommodate the higher flow demand due to these additions.

The Boegoeberg water user association was established in 2003 and is an amalgamation of the Boegoeberg GWS, the Northern Orange IB, the Gariep IB, a portion of the Middle Orange Irrigation Area, and the Karos-Geelkoppan Water Board. The Boegoeberg GWS, Gariep IB and Northern Orange IB were all served by common infrastructure which was operated by the Department of Water Affairs. The total area under irrigation is 9 198 ha. While some farmers pump directly from the rivers the majority are supplied from the canals. The Boegoeberg water user association supplies 306 irrigators. Nine livestock farmers are also supplied with water for domestic and animal use.

Originally designed as a flood irrigation scheme, 90% of the area is still irrigated by flood irrigation and the remaining 10% is irrigated with micro and drip irrigation systems. The 297 canal users are measured using calibrated sluices while some 9 users which abstract directly from the river are not metered. Water shortages are rare and users are billed on a m³/ha/a with the allocation being 15 000 m³/ha/a for users on the Boegoeberg, Northern Orange and Gariep portions and 10 000 m³/ha/a on the Middle Orange portion.

The infrastructure is very old and the entire scheme is in need of rehabilitation. Consequently losses are high. The operating philosophy is that the water user association has created just another channel of the river and water flows through the canals with similar or less losses as would be the case if the water had stayed in the river.

The main crops that are under irrigation include grapes, lucerne and maize and other crops such as cotton, wheat, peas and pecan nuts. The typical crop mix across the Boegoeberg WUA is shown in the table below.

Crop	***Hectares***	***% of irrigated area***
Grapes	*7 358.4*	*80%*
Lucerne & maize	*919.8*	*10%*
Other	*919.8*	*10%*
Total	***9 198.00***	***100%***

<u>Water balance assessment</u>

Using the information obtained from the Water Use Efficiency Accounting Reports (WUEARs), previous studies and consultation with the management of the WUA, a water budget for the Boegoeberg WUA was prepared.

The average water losses have been 32.3% (15.3% unavoidable and 17.0% avoidable) of the quantity released into the canal system. This translated to an average of approximately 100.13 million m^3/a water losses in the Boegoeberg WUA area of operation. In terms of volume, approximately 52.7 million m^3/a are avoidable losses.

<u>Existing water conservation measures</u>

The Boegoeberg WUA has been implementing various measures to improve the management of delivery to the irrigators and to minimise losses. These measures include annual maintenance of the irrigation canals to reduce avoidable water losses, as well as having programs to address problems with midgets and the promotion of laser levelling.

<u>Best Management Practice - water losses</u>

An evaluation of the expected water losses based on the existing canal infrastructure and assuming the infrastructure is sufficiently maintained was conducted for the Boegoeberg WUA canal system. The analysis indicated that the unavoidable water losses due to *evaporation losses and seepage is 47.3 million m^3/a, which translates to 15.3% of the total volume of water diverted into the Boegoeberg WUA canal system.*

A Water Research Commission (WRC) study conducted in 2010 (Report TT 465/10) provided guidelines of the desired range of operational losses that have to be included in order to determine the BMP for operational and distribution efficiency (Reinders 2010). On the basis of the WRC study a BMP for operational and distribution efficiency has been taken as 10% of the inflow into the scheme. This amounts to 31 million m^3/a based on the average inflow into the canals. 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 was set at 25.3% of the total releases into the canal system or 78.4 million m^3/a.

Water management issues

The water budget analysis together with discussions held with the Boegoeberg WUA has helped to identify several key water management issues. There is however insufficient data to clearly determine where and how losses are occurring. Currently there are no records as to how much water spills occur due to operational issues or how much water is returned to the river through the reject structures or at the canal end points.

The most noticeable aspect that was identified during the consultations with the WUA is the sense of awareness of management of the importance of efficient irrigation water management and water conservation. The main water management issues identified include the following;

a) *The Boegoeberg WUA appears to have adequate flow measurement structures in place to conduct a water budget analysis at both scheme and sub-scheme level. The WUA makes regular measurements of flows into the major sections. These include weirs and parshall flumes on the canals, and flumes and rated sluice gates on the laterals to the individual farmers. However, there is no measurement of water returning back to the river through reject structures or canal end points. Without these measurements it is impossible to conduct an accurate water budget.*

b) *It is currently impossible to accurately calculate or measure losses and it is therefore difficult to calculate avoidable losses such as leakage, spills and over delivery to users. Presently it is not possible to conduct water budgets for the various sections on the scheme. If this is undertaken it may highlight sections that require specific attention. The accuracy of the seepage losses remains questionable and it is proposed that ponding tests be done to verify the accuracy of the theoretical calculations.*

c) *WAS is not implemented at all on the scheme. The problem is not so much with the current system in operation but with continuity. Only one or two persons really know how the spreadsheets relate to one another and how calculations are performed within them. The WUA is therefore totally dependent on one or two individuals and should they leave or pass away, nobody else knows how to operate the program. WAS is a standardised program in use on various schemes throughout the country* *with many trained operators handling the system. This reduces the risk of an in-house developed program and temporary personnel could assist with the upkeep of the system should the regular operator(s) leave of fall ill.*

d) *Balancing dams decrease the pressure on the canal system and allows for shorter delivery periods to water users. They also intercept any surplus water in the system and act as backups to supplement supply should shortages arise (canal breaks, etc.). The Boegoeberg WUA only has the benefit of one balancing dam on the scheme which limits the security of water supply during maintenance periods or major canal failures.*

e) *The overall condition of the canal infrastructure is poor. At present maintenance is reactionary and there is no formal maintenance or refurbishment plan.*

Water saving targets

The set targets for the Boegoeberg WUA are illustrated in the table below.

Description	System inflow	Present situation - Losses				Acceptable water losses		Water savings targets	
	(x $10^6 m^3$)	Unavoidable losses (x $10^6 m^3$)	Avoidable losses (x $10^6 m^3$)	Total Losses (x $10^6 m^3$)	% of total volume released	Annual volume (x $10^6 m^3$)	% of total volume released	Annual volume (x $10^6 m^3$)	% of total volume released
Seepages		46.50	0	46.50	15.00%	21.011	15.0%	0	0.00%
Evaporation		0.93	0	0.93	0.30%	0.93	0.30%	0	0.00%
Filling losses									
Leakages									
Spills			52.7	52.7	17.00%	31.0	10.0%	21.7	7.0%
Over delivery									
Canal end returns									
Other		0	0	0	0.00%	0	0.00%	0	0.00%
Total	**310**	**47.3**	**52.7**	**100.13**	**32.3%**	**78.4**	**25.3%**	**21.7**	**7.0%**
% of total volume released into system		**15.3%**	**17.0%**	**32.2%**					

Based on the projected water saving targets, the Boegoeberg WUA can achieve a 3% reduction in water losses in a relative short period (3 years and less).

For the short term which has been taken as 3 years, the total water savings that can be achieved through implementing the flow measurement and monitoring plans is some 9.3 million m^3/a.

For the long term a further 12.4 million m^3/a saving is envisaged by optimising the operations and refurbishment of the canal infrastructure.

The priorities for implementation based on the volume of water savings and the average incremental cost of water saved are as follows:

(i) Identify "obsolete" return structures in order to minimise measurement.

(ii) Devise methods to protect measuring equipment.

(iii) Installing measurement devices to improve management of the water delivery system and undertake water budgets based on measured data.

(iv) Disaggregate losses and conduct water budgets at sub-scheme level.

(v) Revise and improve current maintenance procedures and actions.

(vi) Undertake study to identify suitable locations for additional balancing capacity.

(vii) Incorporate all relevant data in a custom Management Information System.

Conclusions and recommendations

The Water Management Plan forms the backbone of actions that have to be taken in increasing the efficient use of water within the Boegoeberg WUA.

The intention of the Water Management Plan not to burden the WUA and its officials with administrative tasks, but rather to promote a culture of using water as effectively and efficiently as possible. The plan will allow the WUA to improve on current water management practices and to profit from their efforts.

The success of WC/WDM through a WMP will depend on the effective participation of all the participants. A well balanced "carrot and stick" plan will be required based on the principal of a "win win "situation where the benefits of the successes of the water management plan will filter through to the users in one or other form such as less water use charges, more water or the possibility of selling any surplus water etc. In terms of WC/WDM the development of a Water Management Plan is in itself a BMP as it force water users and institutions to start thinking and planning.

The main aim of a water management plan is to conserve water, to improve water supply services to the water users and to enable irrigators to use their water more efficiently in the sort and long term. The goals for the WMP have been set and the WUA believes that the targets and objectives set in the WMP are achievable through proper oversight by the CEO and support from the DWA.

This WMP must be seen as a first generation plan and has to be reviewed and updated on an annual basis.

For the short term which has been taken as 3 years, the total water savings that can be achieved through implementing the flow measurement and monitoring plans is some 6.2 million m3/a. For the long term a further 12 million m3/a saving is envisaged by optimising the operations and refurbishing critical canal sections. The long term target is to reduce the water losses to 25% of the total inflow to 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
GWS	Government Water Scheme
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
WCC	Water Conservation Coordinator
WCD	Water Control Department
WC/WDM	Water Conservation and Water Demand Management
WCO	Water Control Officer
WMA	Water Management Area
WMP	Water Management Plan
WUA	Water User Association
WUEAR	Water Use Efficiency Accounting Report
BWUA	Boegoeberg Water User Association

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 quantities 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 area 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 area 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 requirement:	Quantity of water, exclusive of effective precipitation, that is needed 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
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
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.

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".
Run-off	This is the water produced when irrigation water is applied to fields at rates and in quantities greater than can be infiltrated into the soil profile.
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 Schemes 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 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 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 and the DWA Regional Office, this report provides an overview of the water allocation and use situation of the Boegoeberg WUA and related institutional arrangements for irrigation water management.

1.2 Study Objectives

The primary objective of the study is the development and implementation of an irrigation WMP for Boegoeberg irrigation scheme to improve water use efficiency in the scheme. In order to achieve this objective, the following tasks were undertaken:

- Compilation of a situation assessment of the current water use and irrigation water use practices in the scheme.
- Determination of the irrigation water budget and establishing water use baseline for the irrigation scheme.
- Determination of the irrigation water management issues based on the situation assessment and water budget prepared for the irrigation scheme.
- Identification of opportunities to improve water use efficiency in the scheme.
- Benchmarking of irrigation water use efficiency and setting irrigation water use efficiency targets for the scheme.
- Preparation of an irrigation water management plan for the scheme.
- Capacity building of the WUA to implement the identified opportunities to improve water use efficiency

The development of WMP for the Boegoeberg WUA 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 catchment 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 report

This report has been structured to first provide a perspective of the Boegoeberg Irrigation Scheme as well as the potential for irrigated agriculture in the Orange River catchment. The chapter then 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. This is the focus of **Chapter 1**.

Chapter 2 describes the catchment characteristics of the Orange River catchment in which the Boegoeberg Irrigation Scheme is situated. The chapter describes the history of the Boegoeberg Irrigation Scheme, the scheduled quotas and current land-use practices in the catchment.

Chapter 3 provides an overview of water distribution infrastructure found in the Boegoeberg Irrigation Scheme. The chapter also describes the measurement of flow into and out of the scheme.

Chapter 4 provides a condition assessment of the infrastructure of the Boegoeberg Irrigation Scheme.

Chapter 5 describes the scheme operations and operating procedures. Procedures relating to the ordering and delivery of irrigation water are *inter alia* discussed. The procedures for trading and transfers of water are handled as well as the present water pricing structure.

Chapter 6 describes the water balance assessment undertaken for the Boegoeberg WUA. The various losses identified on the scheme are also handled in detail.

Chapter 7 of this report describes the existing water conservation and demand management measures that the irrigation sector is currently undertaking.

Chapter 8 describes the key issues that the Boegoeberg WUA is facing and also includes the goals of the WUA when WCWDM is contemplated.

Chapter 9 provides the Water Management Plan for the Boegoeberg WUA.

Chapter 10 includes the conclusion and recommendations.

2 CATCHMENT CHARACTERISTICS OF ORANGE RIVER CATCHMENT

2.1 Overview

The Boegoeberg WUA is situated within the Lower Orange Catchment Management Area and near the town of Groblershoop, which is about 110km south–east of Upington. The management area of the Boegoeberg Water User Association includes all the properties entitled to use water from the Orange River via the Boegoeberg Dam and the river below the dam. Figure 2.1 presents the locality map of the Boegoeberg Irrigation Scheme.

The Orange River is South Africa's major river. Its length from the Drakensberg in Lesotho to the mouth at the West Coast at Alexander Bay is approximately 2 300 km. Where it rises in the eastern highlands of Lesotho, the river is known as the Senqu River. The Orange River forms the borders between several South African provinces as well as the border between Namibia (southern boundary) and South Africa. The Orange River flows through the semi-desert/desert area along the southern border of Namibia. The estimated annual sediment load is approximately 120 million tons, 6 times more than any other river in South Africa. The Department of Water Affairs divided the Orange River catchment in two water management areas, which are the Upper Orange and the Lower Orange Water Management Areas.

The Lower Orange WMA is the lowest WMA in the Orange/Vaal River Basin and as such is affected by upstream activities, both in terms of the Upper Orange and the Vaal System. The topography of the area is flat with large pans or endoreic areas that do not contribute runoff to the Orange River system.

The Orange River, which forms a green belt in an otherwise arid landscape, also forms the border between South Africa and Namibia over about 550 km to the west of 20 degrees longitude. The Vaal River, the main tributary to the Orange River, has its confluence with the Orange River about 13 km west of Douglas. Other tributaries are the Ongers and Hartebeest Rivers from the south, and the Molopo River and Fish River (Namibia) from the north.

The two major storage dams Gariep and Vanderkloof, which supply all the irrigation, urban, and mining requirements along the Lower Orange River are located in the Upper Orange WMA and are of critical importance to the Lower Orange WMA and shortages in the Upper Orange WMA will directly impact on the Lower Orange WMA

2.1.1 Climate and rainfall distribution

The area comprising the Lower Orange WMA is largely arid and experiences a harsh climate. It has the lowest mean annual rainfall in the country, varying from 400mm in the east to 50 mm per annum on the west coast. Potential evaporation can reach 3 000 mm per annum.

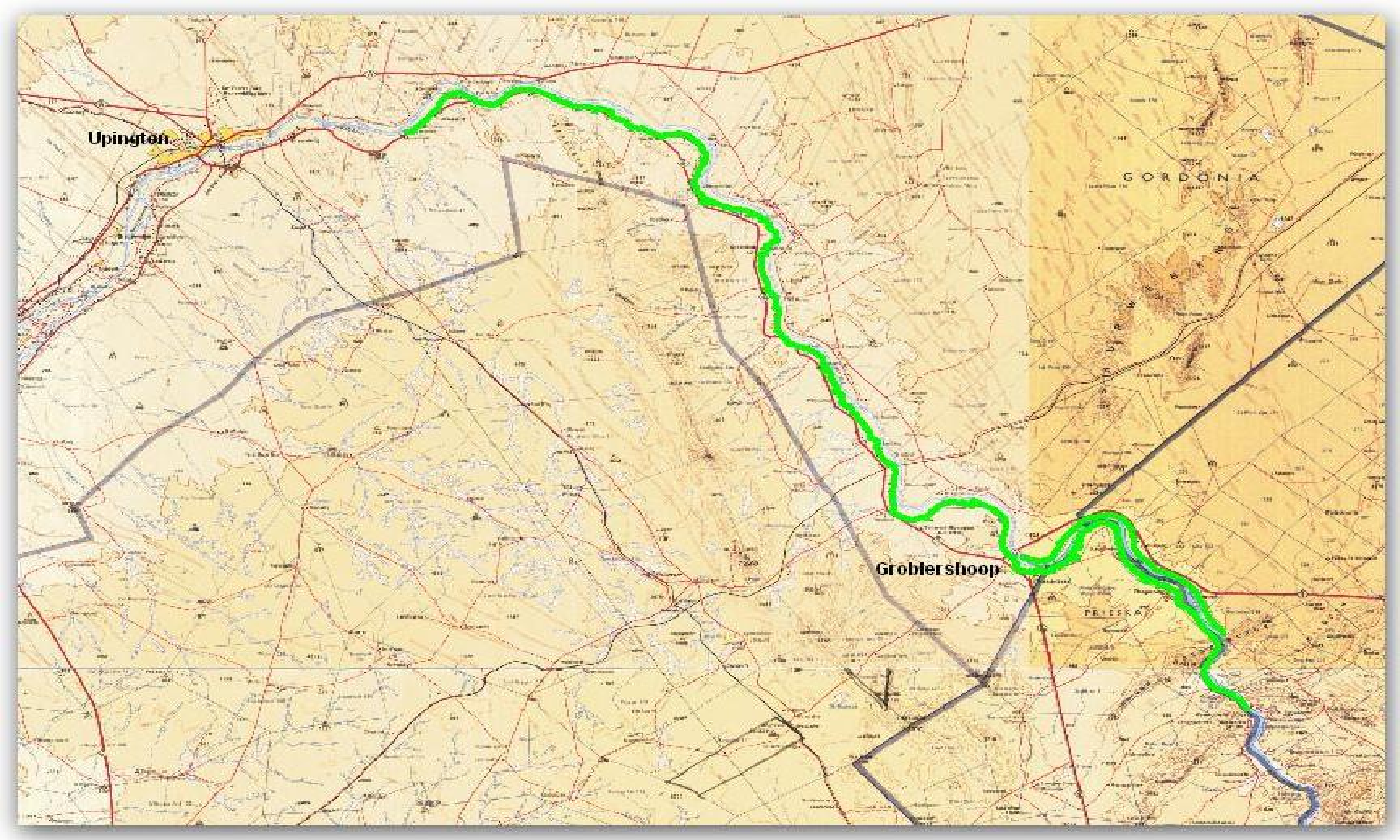


Figure 2-1: Location Map of Boegoeberg Irrigation Scheme

2.1.2 Geology and soils of the catchment

The topography of the Lower Orange WMA is such that it is largely flat, with large pans or endoreic areas that do not contribute significant runoff to the Orange River system. Water users situated outside the reach of the Orange River therefore rely heavily on groundwater supplies. In the western side of the WMA, the rocky and barren Richtersveld Mountains are found while the northern area is covered by Kalahari sands. A complex geology exists south and westwards of the Orange River, with a variety of rich mineral deposits and shallow, rocky soils. The area in and around the Lower Orange WMA is typically characterised by four desert systems, three of which drain into the Orange (UNDP, 2007): the Succulent Karoo, Nama Karoo (receiving mainly summer rainfall and comprising numerous vegetation types) and the Southern Kalahari (consisting of a deep layer of windblown sand with little run-off from rainfall). The Namib Desert system which does not drain into the Orange River Basin, is the driest of the four, forming a narrow strip along the Atlantic coast (GDC, 2009).

2.2 History of the Boegoeberg Irrigation scheme

The Boegoeberg irrigation scheme was constructed during the Great Depression when in March 1929, the government decided to undertake the Boegoeberg Dam and canal project as part of its drought alleviation scheme. The main aim was to provide work for whites who were suffering as a result of the drought and the financial pressures. Capital for the project was provided by the Department of Labour but the construction thereof fell under the department of Water Affairs (then known as the Department Irrigation). The construction camp for the dam was situated on the farm Seekoebaart and the camp for the workers responsible for the construction of the canals was situated at Sterham (later re-named Groblershoop in honour of Mr Piet Grobler, Minister of Labour).

All the construction work was done with pick and shovel and wheelbarrows with the help of some donkeys. Even the children carried stones for the lining of the canal for a sixpence a day to boost the family's income.

Many of the concrete flumes, sluice gates and measuring structures within the unlined canal of 121 kilometres on the southern bank of the Orange River were already built in the late 1930’s. In 1952 the Department of Water Affairs commenced with the lining of the canal.

Irrigation development in the Upper Orange WMA was stimulated by the construction of several dams. Great expansions of irrigation were made possible along the Orange River by the construction of Gariep and Vanderkloof dams in the Upper Orange WMA during the 1970’s.

The canal was extended in the 1970's to be 172 kilometres long. Siphons were built to serve irrigation farmers north of the Orange River from the main canal on the southern bank with the 38 km Gariep canal, the 8 km Rouxville West canal and the 40 km Northern Orange canal. The canal wall height had to be extended at some sections to accommodate the higher flow demand due to these additions.

The Boegoeberg *water user association* was established in 2003 and is an amalgamation of the Boegoeberg GWS, the Northern Orange IB, the Gariep IB, a portion of the Middle Orange Irrigation Area, and the Karos-Geelkoppan Water Board. The Boegoeberg GWS, Gariep IB and Northern Orange IB were all served by common infrastructure which was operated by the Department of Water Affairs. The total area under irrigation is 9 198 ha. The Boegoeberg GWS has been in existence since 1931. The scheme consists of a lined canal on one or both sides of the Orange River which more or less track the river course. While some farmers pump directly from the rivers the majority are supplied from these canals. The Boegoeberg *water user association* supplies 306 irrigators. Nine livestock farmers are also supplied with water for domestic and animal use.

Originally designed as a flood irrigation scheme, 90% of the area is still irrigated by flood irrigation and the remaining 10% is irrigated with micro and drip irrigation systems. The 297 canal users are measured using calibrated sluices while some 9 users which abstract directly from the river are not metered. The main crops grown are grapes, lucerne and maize, with other crops such as cotton, wheat, peas and pecan making up the balance. Water shortages are rare and users are billed on an m^3/ha/a with the allocation being 15 000 m^3/ha/a for users on the Boegoeberg, Northern Orange and Gariep portions and 10 000 m^3/ha/a on the Middle Orange portion.

The infrastructure is very old and the entire scheme is in need of rehabilitation. Consequently losses are high. The operating philosophy is that the *water user association* has created just another channel of the river and water flows through the canals with similar or less losses as would be the case if the water had stayed in the river.

All the irrigation areas (summarised in Table 2-1) have been consolidated to form the Boegoeberg Water User Association. The announcement of the formation of the *water user association* was made on 4 May 2001 as per Government notice No. 369. The Minister of Water Affairs signed final approval in March 2003 and *water user association* took over the maintenance of all infrastructures from the Department of Water Affairs. The ownership of the infrastructure remains vested in the Department of Water Affairs.

Table 2-1: Boegoeberg Water User Association irrigation areas

Site	Area under irrigation (ha)	Annual quota (10^6m³)
Boegoeberg GWS and Gariep IB canals	6 731.8	100.977
Boegoeberg GWS and Gariep IB river extraction	1 310.1	19.652
Northern Orange IB canals	966.1	14.492
Portion of Middle Orange Irrigation Area river extraction	208	2.08
Total	**9 198**	**137.2**

2.3 Water use permits / licenses and contracts

The authorisation for the water use, within the Boegoeberg WUA's area of jurisdiction, lies in the Schedule of Rateable Areas for 9 198 ha, drawn up in terms of section 88 of the 1956 Water Act. This Schedule is included as an Annexure to the Constitution of the Boegoeberg WUA and was declared as Existing Lawful Water Use under section 33 of the National Water Act, 1998.

In terms of the National Water Act (Act 36 of 1998), the irrigation boards were required to be transformed into Water User Associations (WUA). The Boegoeberg Irrigation Board was then transformed into a WUA in 2003. The scheme has a scheduled quota of 15 000 m^3/ha/a for users on the Boegoeberg, Northern Orange and Gariep portions and 10 000 m^3/ha/a on the Middle Orange portion.

2.4 Irrigated areas and types of crops

The typical crop mix across the Boegoeberg WUA is shown in Table 2.2 below. The main crops that are under irrigation include grapes, lucerne and maize, and other crops such as cotton, wheat, peas and pecan nuts.

Table 2-2: Crops irrigated within the area of operation of the Boegoeberg WUA

Crops	Hectares	%
Grapes	7 358.4	80%
Lucerne & maize	919.8	10%
Other	919.8	10%
Totals	**9 198.00**	**100%**

2.5 Historic water use

The four water years (2007/3 to 2010/07) demonstrate a range of water use in the Boegoeberg WUA. Monthly irrigation agriculture has ranged between 13.49 million m^3/month in March 2008 and 4.39 million m^3/month in June 2007, with an average of 10.87 million m^3/month. The total average other requirements for the same period is 0.427 million m^3/month.

Table 2-3: Historic water use levels (million m^3/a) for the Boegoeberg WUA

Month	Irrigation $x10^3$ m^3	Other users($x10^3$ m^3)					Total $x10^3$ m^3
		Domestic & Stock	Industrial	Municipality	State Dept	Total other	
Mar-07	13 062.0	298.6	23.1	87.8	7.9	417.4	13 479.4
Apr-07	6 413.3	297.7	14.7	84.3	6.4	403.1	6 816.4
May-07	8 796.0	268.3	18.9	83.0	6.8	377.0	9 173.0
Jun-07	4 398.0	270.1	19.8	83.8	6.8	380.5	4 778.5
Jul-07	6 832.3	270.8	15.5	89.3	6.1	381.7	7 214.0
Aug-07	12 120.4	298.4	21.2	83.1	7.6	410.3	12 530.7
Sep-07	12 355.7	298.7	7.2	85.3	6.5	397.7	12 753.4
Dec-07	13 296.4	299.8	24.8	79.9	7.5	412.0	13 708.4
Jan-08	15 915.7	300.1	31.0	81.1	6.8	419.0	16 334.7
Feb-08	13 062.0	299.5	43.1	81.3	6.9	430.8	13 492.8
Mar-08	13 441.4	299.8	41.4	80.2	7.1	428.5	13 869.9
Apr-08	12 961.9	299.8	35.8	76.9	5.9	418.4	13 380.3
May-08	5 654.1	299.2	26.3	81.9	6.9	414.3	6 068.4
Jun-08	5 183.3	299.2	24.1	76.6	7.9	407.8	5 591.1
Jul-08	8 010.6	297.1	18.9	80.1	6.8	402.9	8 413.5
Sep-08	11 470.2	298.3	20.6	81.3	8.0	408.2	11 878.4
Nov-08	13 297.4	300.9	73.5	86.4	8.0	468.8	13 766.2
Dec-08	13 297.4	300.1	70.6	84.4	7.9	463.0	13 760.4
Jan-09	13 297.4	301.0	78.0	92.1	6.6	477.7	13 775.1
Feb-09	13 062.0	301.2	88.6	87.1	7.0	483.9	13 545.9
Mar-09	13 495.8	297.7	82.8	82.5	6.8	469.8	13 965.6
May-09	5 754.1	299.4	68.1	84.0	7.1	458.6	6 212.7
Jun-09	5 183.1	298.8	64.6	81.8	3.3	448.5	5 631.6
Jan-10	13 257.4	302.5	30.9	93.2	4.7	431.3	13 688.7
Feb-10	13 062.0	302.4	37.1	87.5	4.9	431.9	13 493.9
Mar-10	12 014.8	303.1	43.0	85.3	4.6	436.0	12 450.8
Apr-10	10 602.4	306.1	29.6	84.6	4.6	424.9	11 027.3
Jul-10	10 386.9	312.6	17.8	81.8	2.8	415.0	10 801.9
Average	**10 868.1**	**297.3**	**38.4**	**85.6**	**6.6**	**427.8**	**11 296.0**

3 INVENTORY OF THE EXISTING WATER INFRASTRUCTURE

3.1 Overview

The Boegoeberg Irrigation Scheme comprises a dam/weir, main irrigation canal infrastructure, primary irrigation conveyance infrastructure which diverts water from the Orange River into the scheme, the canal distribution system which delivers the water ordered to the irrigators at their farm turnouts through a number of sluice gates.

3.2 Boegoeberg Dam

Boegoeberg Dam was constructed by the Department of Irrigation during the economic depression of the 1930's as a measure to relieve unemployment. The dam wall is more of a barrage than a dam with a maximum height of 10.7 m and approximately 622 m long.

The dam wall is effectively a concrete weir which was initially equipped with 68 sluices designed to allow sediment to pass through the structure. The original capacity of over 40 million m^3 has been reduced through sedimentation to the current capacity of approximately 20 million m^3 and appears to have reached some form of equilibrium. The sediment sluices have recently been closed permanently and the structure is now effectively a concrete weir which supplies water into a canal on the left bank.

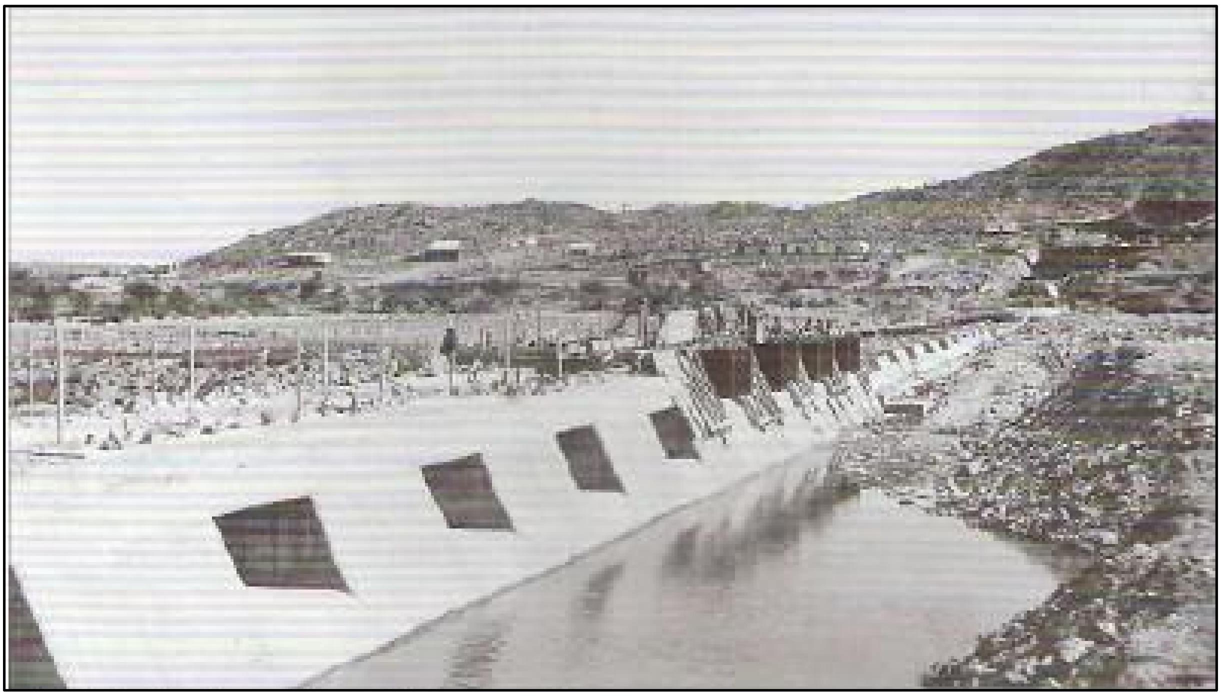


Figure 3-1: Boegoeberg Dam under construction

The left bank canal supplies water to 7 560 ha of irrigation in the Boegoeberg Dam Irrigation Area most of which is used for field crops and a small portion of fodder crops. Technically the area is ideal for certain high value crops such as Pistachios, Lemons, Olives, Figs and Pecans and a new Pistachio development has already been established just upstream of the dam near the town of Prieska.

The Boegoeberg Dam site is one of several sites being considered for a new larger dam along the Lower Orange River to provide additional storage and regulation capacity below Van der Kloof. No decision has yet been made in this regard and the investigations are continuing.

3.3 Irrigation conveyance infrastructure

Figure 3.1 below, illustrates the conveyance and distribution infrastructure of the Boegoeberg WUA. The bulk of the Boegoeberg scheme consists of lined canals on one or both sides of the Orange River which more or less track the river course. It is a long narrow scheme with the longest canal being 182 km from the dam to the end of the canal. Table 3-1 below indicates the different canal sections and their lengths and flow rates.

Table 3-1: Boegoeberg WUA canal sections

Canal section	Length (km)	Maximum flow rate (m^3/s)
Boegoeberg Main canal	174	15.18
Northern Orange canal	40	2.00
Gariep canal	38	2.00
Rouxville West canal (starts below the end of the main canal)	8	0.40
Total	**260**	

3.3.1 Boegoeberg Main Canal

The Boegoeberg main canal is divided in various sections which are described below:

3.3.1.1 Brandboom Groblershoop reach

The canal section has different profiles along the mountainous part with sections having a rock face on one side. The downstream sections are all concrete lined, rectangular or parabolic shaped canals. The canal cross section in this area is approximately 2.4m deep and 4.5m wide.

The portion of the canal having a rock face on the uphill side has a concrete lined floor and the downhill canal wall changes from a stone grouted wall to a vertical concrete precast panel and semi parabolic *in situ* cast wall further downstream.

At some dry water courses, aqueducts are used to cross these sections and some of these structures exceed 60 meters in length.

Figure 3-2: Rock face canal section

3.3.1.2 Grootdrink – upper reach

A balancing dam is situated at the beginning of this section which starts off as a rectangular shaped concrete lined profile and changes to a parabolic shape further downstream close to Grootdrink. There is a portion of the canal that has a rock face on the uphill side with a concrete lined floor. The cross section for this reach is approximately 1.6m deep and 4.2m wide.

3.3.1.3 Grootdrink – lower reach

The canal profile for this section of the canal is parabolic and the cross section is approximately 1.4m deep and 3.8m wide.

3.3.1.4 Karos reach

The canal has a parabolic profile along this reach and the cross section is approximately 1.2m deep and 3.2m wide.

3.3.2 Northern Orange Canal

A parshall flume and measuring station is found before the inlet to the siphon servicing the Northern Orange canal. The siphon crosses the Orange River at a rocky outcrop in the river bed. A trench was constructed through this rocky riverbed and was enclosed in concrete to protect the pipe. The canal has a parabolic shape (which reduces in size along the length of the canal) and is approximately 1.8 meters deep.

Figure 3-3: Siphon inlet to Gariep canal

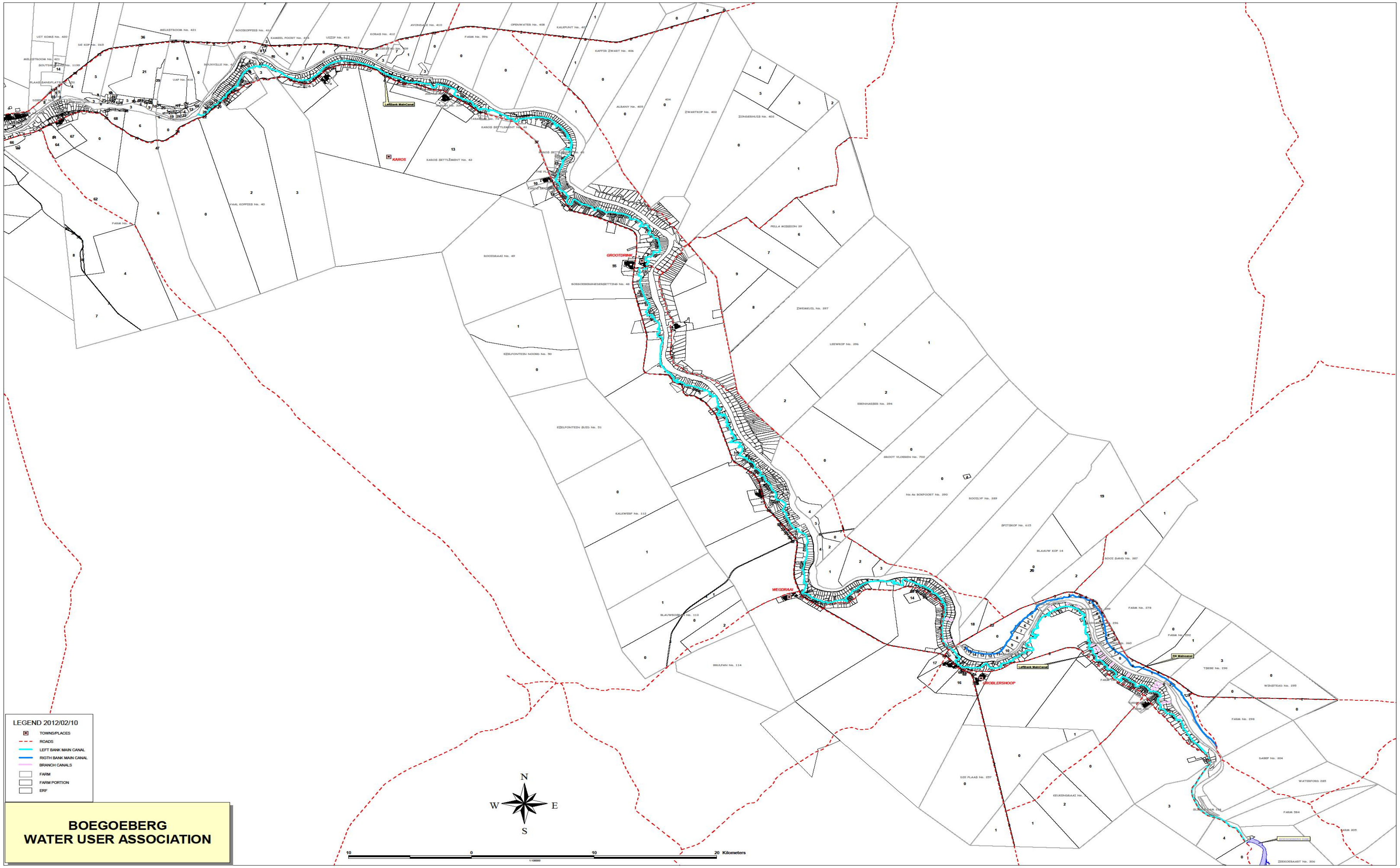
3.3.3 Gariep Canal

A parshall flume and measuring station is provided before the inlet to the siphon servicing the Gariep canal. The canal has a parabolic shape which is concrete lined and the cross section in this reach is approximately 1.1m deep and 3.2m wide.

3.3.4 Rouxville West Canal

A parshall flume and measuring station is provided before the inlet to the siphon servicing the Rouxville West canal. The concrete lined Rouxville West canal is the smallest canal within the scheme and has a parabolic shape. The cross section for this reach is approximately 1.8m deep and 3.0m wide.

Figure 3-4: Boegoeberg Irrigation Scheme Infrastructure



3.4 Irrigation storage and regulation system

The Boegoeberg WUA has one balancing dam to their disposal (Figure 3-5). The balancing dam decreases the pressure on the canal system and allows for shorter delivery periods to water users. It also intercepts any surplus water in the system and act as backup to fill up any shortages.

During weekends the main aim is to get the dam full and the following process is followed. On Friday evenings the Karos is cut back to 1.29 m. Dam sluice stays on the mark and bypass. Gariep is cut to 0.6 m. If the Karos is higher on Saturday morning at 06:00, it is cut to 1.29 m and also adjusted if lower. At 12:00 the process is repeated. The dam sluice is completely lifted at 18:00. Bypass stays the same. Karos is reduced to 0.8 m and Sunday morning at 06:00, and depending whether the dam's level has increased, adjustments can be made, otherwise it is left unchanged.

For example, if the dam is almost full, it can be left unchanged. If it overflows, it can be increased to 1.24m at Karos. The level is checked at 12:00 and kept on 1.24 m if it overflows. At 18:00 the final set is done. The Gariep canal is also cut back at 18:00 to 0.2 m on Saturday evening. No adjustments on Sunday morning depending on the dam level. At 12:00 the Gariep is increased to 0.5 m. At 16:00 it is increased to 0.6 m. On Monday morning it is increased to 0.62 m.

Figure 3-5: Boegoeberg balancing dam

The lack of storage capacity, i.e. balancing dams within the canal system, makes it difficult to manage the water releases since shortfalls cannot be supplemented within a short time frame. The canal system was designed to meet its water demand within a 144 hour week, but with mostly labour intensive flood irrigation taking place in the scheme, the water abstraction is peaking during day time.

3.5 Flow Measurement and telemetry system

3.5.1 Measurement of flow into and out of the Scheme

The total flow of water released into the scheme is measured at Seskanale and also measured at the siphons located at the beginning of the Northern-Orange, Gariep and Rouxville-West sections. These measuring devices are not linked to a telemetry system to provide real-time data and the information is downloaded manually. The diversion and measurement structures and equipment at the Gariep siphon are shown in Figure 3-6 .

Figure 3-6: Diversion to Gariep section

The scheme is subdivided into 18 wards and calibrated readings are taken at the beginning of each ward. Although these flumes were recently calibrated they are not equipped with electronic measuring equipment and the quantity of water flowing into each ward is measured manually.

There are also some 40 reject points located on the canal system which discharge water back to the Orange River. 30 of these points have the necessary infrastructure in place to allow for the measurement of water returned to the river but are not equipped with measuring devices and no return flows are measured.

3.5.2 Measurement at user outlets

The Boegoeberg Water User Association (WUA) measures the weekly volume of water delivered to the water users using calibrated sluice gates and there are 769 sluice gates in the area of operation of the Boegoeberg WUA.

There are 9 river users who abstract water directly from the Orange River and these users are not measured. The rates of abstraction of these pumps are however the control measure and control is achieved through the size of the pump which can only just apply the required volume for a given area.

3.6 Infrastructure summary

A description of the various structures found within the area of operation of the Boegoeberg WUA is provided in Table 3-1.

Table 3-1: Description of infrastructure within the BWUA

Type of structure	Description
Secondary canals / pipelines	Includes small secondary canals and pipelines that convey water from the Main Canal to irrigation properties not adjacent to the canal.
Aqueducts	Elevated canal structures constructed to convey water over dry water courses, supported on tie beams.
Siphons	Underground pipes constructed to convey water underneath dry water courses, preventing damage to the canal structure
Flow measuring structures	Permanent structures constructed to measure the volume of water that passes the measuring point, (parshalls, sharp crested weirs, etc.)
Bulk water sluices	Sluices situated in the waterway, used to control the flow of water downstream of the control point.
Property sluices	Water from off takes that are serving the irrigation properties is controlled by sluices and the volume of water is measured by a parshall.
Reject structures	Water diversion structures that are used to divert excess water back to the river, i.e. water that is more than the maximum flow capacity of the downstream section of the canal.
Vehicle bridges	Bridges that were constructed and which allow direct access for vehicles and equipment over the canal where no alternative route exists.
Foot bridges	Smaller bridges that were constructed to allow access for people and farm workers to either side of the canal without safety risks.

An inventory of the canal infrastructure, summarised by section in presented in

Table 3-2.

Table 3-2: Infrastructure summary

Type of structure	Section				Total
	Main	Northern Orange	Gariep	Rouxville West	
Secondary canals/pipelines (km)	56.9	1.1	4.2	0	62.2
Aqueducts	15	0	0	0	15
Siphons	32	5	20	11	68
Flow measuring structures	18	5	5	2	30
Bulk water sluices	55	3	2	4	64
Property sluices	604	73	82	10	769
Reject structures	18	3	2	3	26
Vehicle bridges	249	33	46	27	355
Foot bridges	165	3	11	9	188

4 INFRASTRUCTURE CONDITION ASSESSMENT

4.1 Overview

The Boegoeberg WUA was very concerned about the high water loss and maintenance to the canal system and Africon was appointed to assist the WUA with a study to *inter alia* identify the causes for water loss and to assess the structural condition of the canal. A full investigation was conducted on the whole canal system during June 2008 while the canal was laid dry for maintenance purposes.

The following section provides the results of the infrastructure condition assessment.

4.2 Canal Condition Evaluation

4.2.1 Boegoeberg Main Canal

With the inspection on the structural condition of the canal and associated hydraulic structures, it was found that the condition of the Main Canal varied from poor to very poor. A portion of the canal has a rock face on the uphill side and a concrete lined floor and the downhill canal wall changes from a rough stone grouted wall to a vertical concrete precast panel and semi parabolic *in situ* cast wall further downstream. The rock face portion is affected by erosion, resulting in soil and finer aggregate being washed away and larger rocks falling into the canal. Other issues identified are;

- Water loss through the rock face walls is high due to fractured characteristics of the exposed rock.
- Erosion at the rock face results in gravel, silt and rock ending up inside the canal which contributes significantly to scouring the canal floor and damaging joints.
- Tunnel action behind canal walls on the downhill side of the canal can be seen in places. This is caused by the washing out of fine fill material behind the walls due to the good downhill drainage provided by the fill material under the service road. If left unchecked, these tunnels can result in the canal walls having insufficient support behind them which can result in the walls “leaning over” causing horizontal cracks.
- Joints in the concrete panels are adequately spaced at approximately 3m with only a bond breaker in between. This is effective in allowing relief for shrinkage in the concrete but not allowing for any expansion of the concrete due to temperature affects. Instances of spalling of concrete at joints can be seen at many slab joints.

- Root action penetrating the canal, due to large trees close the canal was evident in isolated areas and these roots contribute to further damage of existing cracks, open joints and may contribute to spalling of concrete slabs.
- Many joints in the floor and wall panels are not sealed with a membrane and bituminous sealant or require reapplication of a bituminous sealant or replacement of the membrane.
- The thickness of the concrete lining varies but, at places, are only approximately 60mm thick. Shrinkage cracks are opening up, exposed aggregates and hand compaction used during the placing of the concrete, all contributing to the canal concrete lining being more porous and resulting in considerable water loss. Seepage of water through the canal lining is clearly visible in some places.
- The quality of the concrete in places is very poor and big holes have started to open up. Some contributing factors can be poor quality control with the mixes as well as the age of the canal lining. The poor condition of the lining reduces the water tightness of the canal and can also lead to subsequent damage to other slabs upstream or downstream of these points.

4.2.2 Northern Orange Canal

- This concrete lined canal has been repaired in some areas in the past with a thin cement based lining of approximately 15-20mm thickness.
- Shifting sand dunes encroaching at places on the canal increases the scouring of the canal lining and joints, placing more demand on maintenance.
- Canal linings previously repaired with a thin cement based material has debonded in isolated areas and have spalled in places.
- Green plant growth can be found directly behind the canal slabs where neither bituminous sealant nor any membrane sealants were applied over canal lining joints. This is a clear indication of water leaking through the canal lining and joints.
- The unlined drainage and storm water drainage canal in the flood plain adjacent to the canal is waterlogged due to reed growth and cannot fulfil its function as drainage canal.

4.2.3 Gariep Canal

The quality of the concrete is not up to standard at some places. It is suspected that the lack of quality control measurers during construction have contributed to the deterioration of the concrete lining. Seeping cause the back fill material to sag and leads to cracks in the cement slab under the pressure of the water. This reduces the water tightness of the lining significantly. Other issues include:

- Many joints are ”flush” joints with one panel placed up against the next panel. This does not allow for any expansion of the concrete due to temperature affects. Many instances of spalling of concrete can be seen - the effects of spalling various from minor to more severe.
- The raised section on the topping of the canal is not properly segmented in many cases, i.e. not allowing for expansion joints has caused the concrete to crack. It is also suspected that no wet-to-dry bonding liquid was used during the construction to bond the old and new material. This caused the new section to move independently from the old one which results in a crack all along the construction joint. The root action of the grass growing from these cracks contributes to further damage.

4.2.4 Rouxville West Canal

At more than one section it was found that the water level was topping the lining of the canal structure. No obstruction could be found and it seems to be an operational problem. The effects can be seen where some of the concrete slabs started to move in relation to each other. This is caused by either lifting or sagging of the slabs, depending on the movement of the soil that is used as backfill material. With the canal overflowing for extensive periods this movement of the slabs will increase.

5 SCHEME OPERATION AND OPERATING PROCEDURES

5.1 General

The BWUA employs 44 full time employees that oversee the day-to-day management of the scheme. The Board consists of 17 members and the current profile of the membership of the Boegoeberg Water User Association is as follows:

- Commercial farmers - 9 representatives
- Emerging farmers – 1 representative
- Industries – 1 representative
- Municipalities – 2 representatives
- Domestic water users – 1 representative
- Recreational users - 1 representative
- Local communities - 2 representatives

The Board is accountable to the members who elect them and are required to meet with the members at least once a year at an annual general meeting (AGM). The function of this meeting is to report back to the WUA members and for the members to raise issues with the Board. The WUA, particularly the Chairman of the Board, is however at the members' disposal at any time and, therefore, if there are pressing issues that a farmer, or group of farmers wish to discuss, they are not required to wait until the AGM. In addition to the AGM, the Board is required to meet with and report to the local Department of Water Affairs. The purpose of these meetings is to discuss management and operational issues and to ensure the efficient running of the WUA.

According to the National Water Act (Act No. 36 of 1998), an ecological reserve is required to be set aside for the sustainable maintenance of ecosystems along a particular water course. The calculation of the ecological reserve is the function of the DWA, who will then be required to inform the WUA of any changes to their abstraction rights as a result of the reserve.

5.2 Water ordering and delivery procedures

The supply at the main canal is from the canal sluice which constantly remains open and may vary due to the height of the water flowing over the dam wall. The sluice gate is currently hanging on a chain at an opening of about 0.65 m which supplies sufficient water into the canal. The sluice gate can be closed by lifting it hydraulically from the safety clamp and lowering it. If the canal level increases due to higher volumes in the river, a spillway sluice gate can be used at the divert structure of the canal to get rid of excess water. The opposite applies if the canal level decreases, the sluice gate can be turned smaller to increase the canal level.

The canal supplies sufficient water at 1.38 m on the measuring plate at the measuring house located at the start of the canal, which represents 14.83 m^3/s.

Every irrigation farmer submits a request to the scheme administrators before 14:00 every Wednesday for the water requirement of the following week. It is the responsibility of the scheme administrators to add up all the irrigation requests and then compile a distribution sheet for the following.

The total scheme is divided into a number of water wards/sections with a water control officer responsible for each section/ward. The water orders are captured and a distribution sheet is then generated which is used to determine the releases and settings for a number of control points at the start of each section/ward.

The main control is at Seskanale. Seskanale also serves as a sand trap, preventing further sand from entering the channel. Five sluice gates are in operation and are continuously open to prevent the accumulation of sand under normal circumstances. Seskanale is also used to empty the canal for midget shutdowns on weekends and to do maintenance work during winter months. The canal is closed on Fridays at 17:00 to do midget shutdowns by opening the five sluice gates causing the water level to decrease below the retaining wall, preventing the water to flow into the canal. The sluice gates are opened on Saturdays at 12:00 to again allow water to flow into the canal. These sluices are also used to control the level of the main canal by opening and closing it.

The operating philosophy is that the water user association has just created another channel for the river and water flows through the canals with similar or less losses as would be the case if the water had stayed in the river.

5.3 Water trading - Temporary water transfers

There are periods when existing irrigators exhaust their scheduled quota before the water year and may require additional irrigation water. The current practice is that the irrigator sources for additional water from other irrigators who are not using their full water quota and negotiates for a temporary transfer subject to agreeing compensation for the transfers.

- The current rules of the BWUA regarding the temporary transfer of water are as follows:

- No water can be transferred between the left and right bank canals.
- Only when an irrigator has exhausted the allocated water at a specific sluice can water be transferred.
- No water will be transferred down-stream during periods of high demand.
- Irrigation water will only be transferred if the allocated water of that specific sluice has been exhausted.
- Transfer of water between two sluices can only happen if both are in the same immediate vicinity.
- Transfer can only take place if it is requested on the required form.

Permanent transfer of water use entitlements are however problematic and is presently hampering development as water users are not prepared to undertake the huge capital outlay required to establish new fields without a permanent transfer and water use entitlement.

5.4 Water pricing structure

5.4.1 Setting of the irrigation pricing

The BWUA incurs a number of expenses relating to the maintenance and refurbishment of the canal systems and the administration of the scheme. The present cost of water for the various users is provided in Table 5-1.

Table 5-1: Water tariffs (2013)

Water use sector	Tariff
Agricultural water – from Noord Oranje canal (R/ha)	R 1 113.00
Agricultural water – from canals (excluding Noord Oranje) (R/ha)	R 1 521.49
Agricultural water – from river (R/ha)	R 550.08
Agricultural water – from river (Middle Oranje) (R/ha)	R 360.26
Industrial water – from canal (c/m^3)	88.8
Industrial water – from river (c/m^3)	37.4

6 BOEGOEBERG IRRIGATION SCHEME WATER BUDGET

6.1 Introduction

The purpose of a water balance is to summarise the inflows, consumption and outflows from the area of operation of an Irrigation Board/Scheme. During the preparation of the water balance the beneficial and non-beneficial consumptive uses are determined which form the basis for the calculation of performance indications which are necessary in identifying water savings opportunities.

Every water use component in a Scheme/Board is represented in the water balance and the various categories for inflows, consumptive use and outflows are described and discussed below.

6.2 Inflows

The first measurement of water flow takes place at the Boegoeberg Dam where water is released from the dam into the irrigation canal.

6.3 Consumptive use

Consumptive use can be classified as the use that removes the water from the scheme that renders it unavailable for further use. Consumptive use can be classified into two main categories;

Process consumption

Process consumption or productive use is that volume of water that is used to produce the crops and is therefore considered beneficial use.

Non-process consumption

Non-process consumption or non-productive use occurs when water is consumed (depleted), but not by the irrigation of crops. Non-process consumption can further be subdivided in two types of uses, namely;

- Beneficial use, such as water that is used by indigenous riverine vegetation, and
- Non-beneficial use, such as evaporation or deep percolation that cannot be retrieved for productive use.

The supply to individual water users is measured (or rather administered) through the different sluice gates. The monthly data on releases at the individual sluices and parshalls were aggregated to provide records of consumptive use by the irrigators.

Records of weekly deliveries to other water users especially in the industrial sector were included in the consumptive use.

6.4 Outflows

As the name suggests, outflow is water flowing out of the system or area of operation of the scheme and can be classified as ether committed or non-committed outflow. Committed outflow is that part of the outflow that is committed to other uses or users. Uncommitted outflow is outflow that is available for other or downstream use. Uncommitted outflow can occur as a result of a lack of storage or operational measures. There are numerous reject points on the Boegoeberg scheme that discharges water back to the river but none of these points are measured, making it impossible to determine the outflows.

6.5 Overall scheme water balance

Currently there is no accurate data available on the exact volume of water loss on the canal system. An estimated figure of 20% is used by the BWAU in submitting their monthly water loss reports to DWA. According to the "Guidelines for the design of canals & related structures" document as drafted by the Department of Water Affairs, the suggested combined seepage and evaporation losses for concrete lined canals is approximately 1,9 ℓ/s per 1000 m^2 of wetted lining. The wetted perimeter of the canal will vary on the flow conditions throughout the different seasons as the water level rises and drops. For practical reasons in these calculations, it was assumed that the canal will flow at full capacity with about 150mm free board in all cases. When determining the wetted perimeter of the canal system based on the assumptions as above, a total area of 1 443 500 m^2 was calculated.

Seepage & evaporation losses = [1 443 500 / 1000] x 1,9
= 2 742 ℓ/s
= 2,74 m^3/s

These combined seepage and evaporation losses of 2,74 m^3/s for the Boegoeberg canal system accumulates to approximately 18% of the maximum flow capacity of the Main Canal.

The actual water releases for the period 1 July 2007 to 30 June 2008 are shown in Table 6-1.

Table 6-1: Actual releases

Month	Total volume released (m^3)
Jul-07	17 946 646
Aug-07	31 537 602

Month	Total volume released (m^3)
Sep-07	31 016 266
Oct-07	31 849 516
Nov-07	30 520 840
Dec-07	30 465 864
Jan-08	30 691 176
Feb-08	26 804 960
Mar-08	29 362 876
Apr-08	16 563 590
May-08	17 971 604
Jun-08	15 636 376
Total	**310 367 316**

6.6 Losses

6.6.1 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 headwork 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 evaporation 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.

The outflows consist of all the ways that water is consumed within the scheme. This includes the canal seepage, operational spills, evaporation from the canals, percolation and delivery to the irrigators and other users.

6.6.2 Conveyance losses

Conveyance losses within a canal system can be defined as the difference between the water released at the canal inlets and the water delivered to the farm boundary. Conveyance losses are made up of unavoidable and avoidable losses.

Unavoidable losses

Unavoidable losses take place on a continual basis and the bulk of unavoidable losses are made up of seepage losses and evaporation losses.

Avoidable losses

Avoidable losses include items such as leakages and spills and include operational losses and wastages resulting from inter alia, inefficient management of the system and other factors such as algae growth, etc.

6.6.2.1 Evaporation losses

The evaporation loss, expressed as a percentage of total inflow, is usually very low and has been estimated at approximately 0.3% of total inflow volume (Reid, Davidson and Kotze :1986).

For the Boegoeberg WUA the estimated value of the evaporation loss as a percentage of the total inflow into the scheme was calculated as 931 000 m^3 per annum.

6.6.2.2 Seepage losses:

Seepage losses from concrete lined, half lined and earth canals are normally expressed in l/s per 1 000 m^2 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 perimeter and this could result in an unavoidable loss rate of up to 15%. The depth of the ambient water table also has an effect on seepage losses. In an area where generally high water table levels are found, canal seepage decreases to roughly 5% of the input volume (Streutker, 1981 and Muller, 1984).

Other factors that have an effect on seepage losses are *inter alia*, Soil characteristics, water depth in the canal, flow speed, soil capillary tension, quantity of sediment, etc.

Given the overall poor condition and age of the canal infrastructure the seepage loss on the Boegoeberg Irrigation Scheme as a percentage of the total input volume was the estimated to be 15 %. This translates to a volume of 46.5 million m^3 per annum.

6.6.2.3 Operational wastage:

Apart from the two losses described above there are also other losses on the canal system which can be classified as avoidable losses. Such losses include start-up and shut-down losses, water not used (outflows) due to unexpected drops in demand and losses due to incorrect measuring. These losses are estimated to fluctuate between 9% and 17% (Reid, Davidson and Kotze, 1986).

6.6.2.4 Leaks and Spills:

Leaks normally occur on broken sections of the canals and on the top sections of the canal body and can be as a result of maintenance problems and the general deterioration of the canal network due to its age. The determination of the volume of water that is lost as a result of leakages and spills is very difficult to calculate and can only really be determined through accurate measuring. 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, etc.) than the lower section resulting in higher leakages when the canal is running close to or at full capacity.

The distribution network of the Boegoeberg WUA is old and in some sections very poor. The average operational losses and leakages for the WUA were estimated at 17 % of the inflow.

6.6.2.5 Aquatic weeds

Water grass and algae growth in irrigation canal systems are fast becoming one of the major operational headaches 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 quantity 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 (sluice) working at dividing structures.

(v) Water logging of long-weirs occurs.

(vi) Aquatic weed fragments occlude irrigation systems and filters at water purification plants.

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

A comprehensive study regarding aquatic weeds was undertaken by Modjadji Vegetation CC and their final report *“Compliance audit on the management of aquatic weeds in South African waterways”* was released in November 2007 (DWA/RSA/01-0707). This report will not try to repeat the findings of the Modjadji Vegetation CC investigation but specific detail will be discussed where necessary

The total outflow from the canal system was calculated using the formula below.

Total outflow = (Volume released – Registered water use) / Volume released

= (310,367,316 – 121,472,000) / 310,367,316

= 60,9%

Of the total volume released into the canal system, 29% can be classified as committed outflow for downstream users. Although there is no accurate information available on the volume of water that is diverted back to the river at various reject structures, the percentage of operational losses and leakages in the canal system was estimated at approximately 17%.

Table 6-2 provides a summary of the various losses on the canal distribution network of the Boegoeberg WUA. It is important to note that a further breakdown of the losses was not possible.

Table 6-2: Boegoeberg WUA - Breakdown of water losses

<table>
<tr><th rowspan="3">Description</th><th rowspan="3">System inflow (x $10^6 m^3$)</th><th colspan="4">Present situation - Losses</th></tr>
<tr><th>Unavoidable Losses</th><th>Avoidable Losses</th><th>Total Losses</th><th rowspan="2">% of total volume released</th></tr>
<tr><th>(x $10^6 m^3$)</th><th>(x $10^6 m^3$)</th><th>(x $10^6 m^3$)</th></tr>
<tr><td>Seepages</td><td rowspan="8"></td><td>46.5</td><td></td><td>46.5</td><td>15.0%</td></tr>
<tr><td>Evaporation</td><td>0.9</td><td></td><td>0.9</td><td>0.3%</td></tr>
<tr><td>Filling losses</td><td rowspan="6">0</td><td rowspan="6">52.7</td><td rowspan="6">52.7</td><td rowspan="6">17.0%</td></tr>
<tr><td>Leakages</td></tr>
<tr><td>Spills</td></tr>
<tr><td>Over delivery</td></tr>
<tr><td>Canal end returns</td></tr>
<tr><td>Other</td></tr>
<tr><td>Total</td><td>310.4</td><td>47.4</td><td>52.7</td><td>100</td><td>32.3%</td></tr>
<tr><td>% of total volume released into system</td><td></td><td>15.3%</td><td>17.0%</td><td>32.3%</td><td></td></tr>
</table>

From the data presented Table 6-2 it is evident that the total losses on the scheme amount to 32.3%. Of the total losses occurring on the scheme 47.4 million m^3 can be classified as unavoidable losses.

6.6.3 Avoidable water losses

Based on the above assessment and disaggregation of the gross water losses, the average estimated avoidable water losses have been 52.7 million m^3. This quantity can be attributed to a number of factors.

- *Measuring errors*: With the current method of manual reading of the depth of flows by the WCOs, there is a likelihood of measurement errors due to human error. The implementation of telemetry systems may reduce the avoidable losses.

- *Scheduling of deliveries.* Although there is weekly scheduling of deliveries and water is delivered only when needed, it is a very complicated process of trying to match the deliveries with the water applications. This happens particularly when the irrigators change their requests and there may be a time lag in adjusting the volume required not only at the sluice but through the canal system.
- *Over delivery*: There is potential for significant “water losses” to take place if the sluice settings to individual users and direct abstractions from the river are not monitored on a continuous basis to ensure that they are indeed correct.
- *Leakage in the canal structure*: 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/or deterioration of the canal network.

7 EXISTING WATER MANAGEMENT MEASURES AND PROGRAMMES

7.1 Overview

The Boegoeberg WUA has been implementing various measures to improve the management of delivery to the irrigators. These measures include annual maintenance of the irrigation canals to reduce avoidable water losses, as well as having programs to address problems with midgets. These existing water management measures are discussed in more detail below.

7.2 Canal condition assessment

Boegoeberg WUA appointed Aurecon to undertake an investigation into the condition of the canal system downstream of Boegoeberg Dam. The project entailed a survey of the canal system and focussed on three aspects of the canal system. Firstly the hydraulic components of the system were investigated, secondly a visual inspection and structural investigation of the canal was undertaken to determine the short and long term rehabilitation requirements of the canal and thirdly, an economical investigation was done to evaluate the different rehabilitation scenarios. The Boegoeberg WUA funded the study.

7.3 Midget control

While other schemes are fighting a battle against algae and water grass, the battle in the Boegoeberg WUA is against a small enemy, midgets. They may be small in size, but the problems that these insects can cause in the operation of the scheme are huge. This problem is addressed by lowering the water level in the canal in order to expose the eggs and dry them out. This process is locally referred to as “muggie afsitte”.

The purpose of midget shutdowns is twofold, firstly to control midges in the canal and secondly to repair defects. These shutdowns are determined annually and included on the local water timetable.

Different reject structures are used and are determined by the level of the balancing dam. The main canal can be closed at Boegoeberg Dam or Seskanale. The hydraulic canal sluice is lowered at Boegoeberg Dam and five sluices are closed until no water is overflowing into the canal at Seskanale. 10 reject structures are used between Boegoeberg Dam and the balancing dam namely: Luisdraai, Sandpunt, Stofkraal, Brandboom, Skerpioenpunt, Kamp 6, Groblershoop, Rooilyf, Wegdraai and Saalskop. The location where work needs to be done and the level of the balancing dam determines how many reject structures will be used to get rid of the water. The local water control officer in conjunction with personnel will decide which reject structures to use.

The same procedure is followed to get rid of water through reject structures from the balancing dam to Dagbreek. Die following structures are used: Grootdrink, Olyn, Potgieterdam, Mouton, Karosdam, Driesluis, Blousloot and Willem. From Dagbreek to Rouxville there is a siphon beneath the river where the water can be cut off at Dagbreek to Rouxville-Wes. Otherwise, the water can be rejected at the division of Rouxville-Wes.

7.4 Operation and maintenance of the canal infrastructure

Although the ownership of the canal infrastructure at the Boegoeberg WUA is with the Department of Water Affairs (DWA) there is an agreement that the WUA is responsible for the operation and maintenance of the canal infrastructure.

The Boegoeberg WUA has an annual O&M budget which amounts to some R12.784 million per year. This is financed from the scheme charges as shown in Table 5-1.

Continuous maintenance and repair work to the structures and canals have to be done. For this purpose there is currently a maintenance division that is tasked with construction and maintenance. To explain, the following:

- Replacement of canal sections due to the changing ground formations,
- Relining of existing canals which no longer meet the set requirements due to erosion,
- Replacement of structures that no longer provide water accurately due to erosion and wear,
- Maintenance of storm water structures that protects the canal system from flood water.

During the scheduled dry weeks, which occur more or less four times a year, canal sections are maintained and repaired where necessary.

All refurbishment and maintenance is financed by the WUA who operates within the available budget as financed by the water users. No subsidy is received from DWA.

7.5 Promotion of laser levelling

Originally designed as a flood irrigation scheme, 90% of the area is still irrigated by flood irrigation and the remaining 10% being irrigated with micro and drip irrigation. The active promotion of laser levelling of flood irrigation areas is resulting in an increase in laser levelling with 30% of the flood irrigated area already laser levelled.

This procedure, which takes place when an old vineyard is replaced, significantly improves the efficiency of flood irrigation by eliminating uneven distribution, ponding and related water-logging and over-irrigation.

8 WATER MANAGEMENT ISSUES AND GOALS

8.1 Overview the management issues

The water budget analysis discussed in the previous chapter together with discussions held with the Boegoeberg WUA, has helped to identify several key water management issues. There is however insufficient data to clearly determine where and how losses are occurring. Currently there are no records as to how much water losses occur due to operational issues or how much water is returned to the river through the reject structures or at the canal end points.

The most noticeable aspect that was noticed during the consultations with the WUA is the sense of awareness of the management of the importance of efficient irrigation water management and conservation, and the interest shown to learn as much as possible. Table 8.1 below provides the key issues identified and these are discussed in more detail in the following sections of this chapter.

8.2 Flow measurement data and assessments

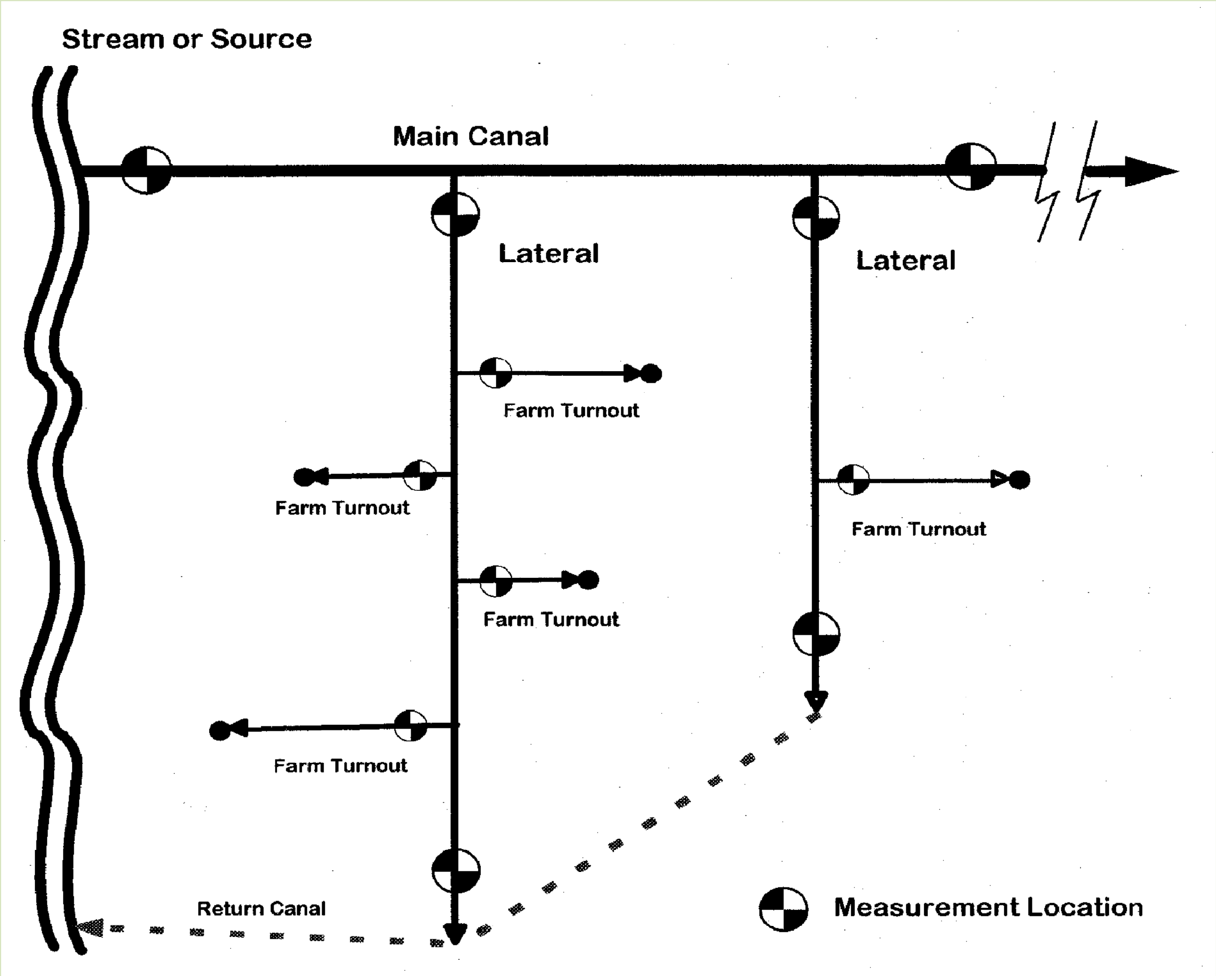
8.2.1 Adequacy of flow data

Good information is fundamental to making decisions on managing irrigation water at any irrigation scheme. Figure 8-1 below provides the extent of flow measurement that is ideal for conducting an irrigation scheme water budget. The availability of flow measurements helps inform both the water user and the WUA about the quantity, timing, and location of water use and therefore enables the WUA to conduct a water budget not only at scheme level but also for sub-schemes within the irrigation scheme.

As illustrated in the figure it would be ideal to have flow measurements at the inlet to the primary canals as well as at the canal ends and reject points. This would assist in determining the water losses in each section of the canal system, as well as the operational spills and major leaks if there are any.

The Boegoeberg WUA does have adequate flow measurement structures in place to conduct a water budget analysis at both scheme and sub-scheme level. The WUA makes regular measurements of flows into the major sections. These include weirs and parshall flumes on the canals, and flumes and rated sluice gates on the laterals to the individual farmers.

However, there is no measurement of water returning back to the river through reject structures or canal end points. Without these measurements it is impossible to conduct a detailed water budget.



Source: Bureau of Reclamation

Figure 8-1: Irrigation Scheme with ideal water measurement system

There is measurement taking place within the scheme linked to a telemetry system where water is released from Boegoeberg Dam into the main canal and there are also other measurements (not telemetric) taken where water is diverted into sub sections of the scheme. WAS is not utilised on the scheme and the flow measurements are only available in spreadsheet format.

Most of the reject points have measurement structures in place but they are not equipped with measuring devices. Not all of the reject structures are used on a continuous basis and are only used when the system is drained for maintenance.

Management Goal 1

The objective to address the above irrigation water management issue is to ensure that the following is achieved by the Boegoeberg WUA:

(i) Identification of reject structures that are rarely used.

(ii) Assess condition of measuring structures at reject points that are regularly used.

(iii) Calibrate those structures that are used on a regular basis.

(iv) Prepare a budget to equip the identified reject structures with measuring devices within one year.

(v) Undertake the installation of measuring equipment on the identified reject structures and current measuring points on a "ward basis" and progress downstream on the main canal.

8.2.2 Irrigation water budget is not conducted in detail

It is currently impossible to calculate or measure any losses and it is therefore impossible to calculate avoidable losses such as leakage, spills and over delivery to users. Currently it is not possible to conduct water budgets for the various sections on the scheme. If this is undertaken it may highlight sections that require specific attention. The accuracy of the seepage losses remains questionable and it is proposed that ponding tests be done to verify the accuracy of the theoretical calculations.

Management Goal 2

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

8.3 Operational water management issues

8.3.1 WAS not implemented

The Water Administration System (WAS) was developed by Dr. Nico Benade (with funding mainly from the WRC) as a tool to be used by Irrigation Boards/Schemes to optimize their irrigation water management and minimize management-related distribution losses in irrigation canal systems. WAS consists of seven modules integrated into a single program and these modules can be implemented partially or as a whole.

The seven modules are the:

(i) Administration module

(ii) Water order module

(iii) Water accounts module

(iv) Water release module

(v) Measured data module

(vi) Crop water use module, and

(vii) Report module

The Water Release module for example links with the water administration and order modules and can be used to:

- Minimize distribution losses on canal networks
- Calculate water releases for the main canal(s) and all their branches allowing for lag times and water losses such as seepage and evaporation; and
- Determine operational procedures for a dam with varying downstream inflows and outflows in a river allowing for lag times and water losses such as seepage, evaporation and transpiration.

However, WAS is not implemented at all on the scheme. The problem is not so much with the current system in operation on the scheme but with continuity. Only one or two persons really know how the spreadsheets relate to one another and how calculations are performed within them. The WUA is therefore totally dependent on one or two individuals and should they leave or pass away, nobody else knows how to operate the program. WAS is a standardised program in use on various schemes throughout the country with many trained operators handling the system. This reduces the risk of an in-house developed program and temporary personnel could assist with the upkeep of the system should the regular operator(s) leave of fall ill.

The whole WAS system does not have to be implemented at once and a phased approach is normally followed. This lessens the burden on the WUA and allows time to get all the necessary information and data in place before a module is implemented.

Management Goal 3

The management objective to address the above issue, is to undertake a feasibility study for the phased implementation of the WAS program.

8.3.2 Available datasets not integrated into a Management Information System

The Boegoeberg WUA has commissioned various studies in the past and has gathered and generated their own detailed datasets, ranging from individual sluice detail to water user address information. All these datasets are in standalone databases of spreadsheets and very little thereof are spatially linked. Having all this data in one integrated Management Information System will be a huge benefit and should enable quicker and better informed decision making.

8.3.3 Management Goal 4

The development of a spatially linked Management Information System that contains all the relevant and available datasets.

8.4 Infrastructure related issues

In order to properly develop the water management plan, it was essential that an assessment of the overall condition of the facilities to identify potential issues was carried out. As indicated in Chapter 4, a detailed condition assessment was undertaken by the Boegoeberg WUA. This included the operation and maintenance system as well as the conveyance and distribution system. No detailed assessment of the on-farm delivery systems was however conducted.

8.4.1 Limited scheme balancing capacity

Balancing dams decrease the pressure on the canal system and allows for shorter delivery periods to water users. They also intercept any surplus water in the system and act as backups to supplement supply should shortages arise (canal breaks, etc.). The Boegoeberg WUA only has the benefit of one balancing dam on the scheme.

Management Goal 5

The Boegoeberg WUA has a limited balancing system in place which limits the security of water supply during maintenance periods or major canal failures. The goal is to investigate the possibility of constructing additional storage capacity which will assist in operating the system as effectively as possible. (An additional dam at Leerkrans was investigated but no further actions were taken).

8.4.2 Canal maintenance

During the condition assessment of the existing canal infrastructure various defects were identified which reflects on the present procedures undertaken by the WUA when maintenance is conducted. When maintenance is conducted on the canal joints for example it was noted that the joints were plastered, therefore providing no room for expansion or contraction. This means that the seal is only performing for a short while before it cracks and starts to leak again. The present modus operandi when maintenance and repairs are undertaken should be investigated and improved where possible.

At present maintenance is reactionary and there is no formal maintenance plan.

Management Goal 6

Revision of the current actions taken when canals are maintained and/or repaired should be investigated and improved where possible and a formal maintenance plan should be developed within one year in order to avoid a catastrophic canal break.

8.4.3 Ownership of irrigation infrastructure

The Water User Association has two main elements that dictate their operations – water and infrastructure. The ownership of irrigation infrastructure can prove to be one of the main barriers to improvement in irrigation efficiency if it is not well managed. More specifically, it is the management of the infrastructure, more than the ownership of the irrigation infrastructure that can create problems with the ensuring the quality of the infrastructure is maintained.

In the Boegoeberg WUA, the Department of Water Affairs (DWA) still owns the irrigation infrastructure including the main and branch canals. However, the WUA operates the irrigation infrastructure as an agent of the DWA and undertakes the normal maintenance of the irrigation infrastructure.

Problems will most likely arise when the major infrastructure needs replacement/total refurbishment. It is unlikely that the WUA has the financial capacity to undertake the refurbishment of the assets which are owned by government. It is also difficult to borrow against the assets as they are owned by government. Therefore the responsibility for replacement of major assets lies with government, whose priorities may be different to those of the WUA.

Management Goal 7

The broad objective to address this issue around ownership of the irrigation infrastructure is to ensure that the levels of responsibility between the DWA and the WUA are further refined than the existing agreement. This is assuming that the DWA does not want to transfer the infrastructure to the WUA in the short to medium term.

8.5 Institutional Water Management Issues

8.5.1 Updating and implementation of the Water Management Plan

The CEO of the Boegoeberg WUA will amongst others be responsible for the annual updating and implementation of the Water Management Plan (WMP) for the scheme. The roles and responsibilities of the CEO for the updating and implementation of the WMP will be the following:

- Take flow measurements and conduct a detailed water balance assessment on a monthly basis at scheme and sub-scheme level

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

Management Goal 8

Implementation, monitoring, reviewing and updating of the WMP by the CEO and reporting by him/her on the status of water losses, water saving targets, goals and objectives.Water Conservation Coordinator.

Table 8-1: Boegoeberg Irrigation Scheme: Identified water management issues

Item No.	Issue description	Comments
1	No flow measurements at reject points are taking place and no water budget can be compiled.	Identification of operational reject points and the installation of measuring equipment.
2	Irrigation water budget cannot be conducted in detail. Data from the monitoring system and other measurements is used for monitoring purposes only and it is impossible to disaggregate the losses.	Break down losses.
3	WAS is not utilised on scheme.	Investigate the use of WAS.
4	Available datasets not integrated into a Management Information System. Having all this data in one integrated system will be a huge benefit and should enable quicker and better informed decision making.	Develop and implement a Management Information System.
5	Limited scheme balancing capacity.	Constructing additional storage capacity which will assist in operating the system as effectively as possible.
6	Maintenance plan and procedures	The maintenance plan should be formalised. Revision of the current actions taken when canals are maintained should be investigated and improved where

Item No.	Issue description	Comments
		possible.
7	Ownership of irrigation infrastructure	Responsibility between the DWA and the BWUA should be further refined.
8	Updating and implementation of the Water Management Plan	Implementation, monitoring, reviewing and updating of the WMP is responsibility of the Scheme Manager as well as scheduled reporting by him/her on the status of water losses, water saving targets, goals and objectives.

9 BOEGOEBERG WATER MANAGEMENT PLAN

A comprehensive Water Management Plan for the Boegoeberg WUA is included in Annexure B and this section will only address the pertinent matters included in the plan.

9.1 Setting of water savings targets

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 Boegoeberg WUA.

A Water Research Commission (WRC) study (Report TT465/10) 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 (Reinders 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 scheme. This amounts to 31 million m^3/a based on the average inflow into the canals. This together with the unavoidable losses has been used in setting the water saving and water loss targets.

The unavoidable water losses in the Boegoeberg WUA were determined to be 15.3% of the total releases into the canal system. This water is additional to the irrigation water use required at the farm edge.

As illustrated in Table 9-1 below, the acceptable 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 is 25.3% of the total releases into the canal system.

Table 9-1: Target water losses in the Boegoeberg WUA

Description	System inflow (x $10^6 m^3$)	Present situation - Losses				Acceptable water losses		Water savings targets	
		Unavoidable losses (x $10^6 m^3$)	Avoidable losses (x $10^6 m^3$)	Total Losses (x $10^6 m^3$)	% of total volume released	Annual volume (x $10^6 m^3$)	% of total volume released	Annual volume (x $10^6 m^3$)	% of total volume released
Seepages		46.50	0	46.50	15.00%	21.011	15.0%	0	0.00%
Evaporation		0.93	0	0.93	0.30%	0.93	0.30%	0	0.00%
Filling losses, Leakages, Spills, Over delivery, Canal end returns			52.7	52.7	17.00%	31.0	10.0%	21.7	7.0%
Other		0	0	0	0.00%	0	0.00%	0	0.00%
Total	**310**	**47.3**	**52.7**	**100%**	**32.3%**	**78.4**	**25.3%**	**21.7**	**7.0%**
% of total volume released into system		**15.3%**	**17.0%**	**32.2%**					

Based on the projected water saving targets, the Boegoeberg WUA can achieve a 3% reduction in water losses in a relative short period (3 years and less).

9.1.1 Short term water saving targets

For the short term which has been taken as 3 years, the total water savings that can be achieved through implementing the flow measurement and monitoring plans is some 9.3 million m^3/a.

9.1.2 Long term water saving targets

For the long term a further 12.4 million m^3/a saving is envisaged by optimising the operations and refurbishment of the canal infrastructure. The long term target is to reduce the water losses to approximately 25% of the total diversion.

9.2 Implementation Plan

An evaluation of the potential measures for implementation in the Boegoeberg WUA area in order to improve water use efficiency and reduce water losses indicates that all the measures are economically justified for implementation based on the unit cost of water saved (Annexure A).

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

(i) *Identify "obsolete" return structures in order to minimise measurement.*

(ii) *Devise methods to protect measuring equipment.*

(iii) *Installing measurement devices to improve management of the water delivery system and undertake water budgets based on measured data.*

(iv) *Disaggregate losses and conduct water budgets at sub-scheme level.*

(v) *Revise and improve current maintenance procedures and actions.*

(vi) *Undertake study to identify suitable locations for additional balancing capacity.*

(vii) *Incorporate all relevant data in a custom Management Information System.*

The action plan for implementation is presented in Table 9-2.

Table 9-2: Boegoeberg WUA Action Plan

Priority	Goal	Action Plan	Timeline	Responsible Authority
1	Measurement and identification of losses	(i) Identify “obsolete” return structures in order to minimise measurement points. (ii) Devise methods to protect measuring equipment. (iii) Installing measurement devices to improve management of the water delivery system and undertake water budgets based on measured data. (iv) Undertake sub-scheme water budgets. (i) Prioritise areas/sections with significant water losses.	Apr ’13 – Mar ’14 Apr ’13 – Mar ‘14 Apr ’13 – Mar ‘15 Apr ’13 – Mar ‘15 Apr ’13 – Mar ‘14	Boegoeberg WUA
2	Increase operational efficiency	(i) Investigate the implementation of WAS. (ii) Measurement of direct abstractions from the river. (iii) Re-evaluate possibility of balancing dam at Leerkrans. (iv) Incorporate data in a custom Water Management Information System.	Apr ’13 – Mar ‘14 Apr ’13 – Mar ‘15 Apr ’13 – Mar ‘14 Apr ’13 – Mar ‘14	Boegoeberg WUA
3	Reduce losses in irrigation canal infrastructure	(i) Revise and improve current maintenance procedures.	Apr ’13 – Aug ‘14	DWA / Boegoeberg WUA

10 CONCLUSIONS AND RECOMMENDATIONS

The Water Management Plan forms the backbone of actions that have to be taken in increasing the efficient use of water within the Boegoeberg WUA.

The intention of the Water Management Plan not to burden the WUA and its officials with administrative tasks, but rather to promote a culture of using water as effectively and efficiently as possible. The plan will allow the WUA to improve on current water management practices and to profit from their efforts.

The success of WC/WDM through a WMP will depend on the effective participation of all the participants. A well balanced “carrot and stick” plan will be required based on the principal of a “win win “situation where the benefits of the successes of the water management plan will filter through to the users in one or other form such as less water use charges, more water or the possibility of selling any surplus water etc. In terms of WC/WDM the development of a Water Management Plan is in itself a BMP as it force water users and institutions to start thinking and planning.

The main aim of a water management plan is to conserve water, to improve water supply services to the water users and to enable irrigators to use their water more efficiently in the sort and long term. The goals for the WMP have been set and the WUA believes that the targets and objectives set in the WMP are achievable through proper oversight by the CEO and support from the DWA.

This WMP must be seen as a first generation plan and has to be reviewed and updated on an annual basis.

For the short term which has been taken as 3 years, the total water savings that can be achieved through implementing the flow measurement and monitoring plans is some 9.3 million m^3/a. For the long term a further 12.4 million m^3/a saving is envisaged by optimising the operations and refurbishing critical canal sections. The long term target is to reduce the water losses to 25% of the total diversion.

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ANNEXURE A

COST ANALYSIS

Item	**Description**	**Total**
MEASURE RETURN FLOWS		
Measuring equipment	Installing measuring equipment (preferably telemetry) at 10 of the identified reject points.	
Installation period		24 Months
Productive period		20 Years
Initial Capital Investment Costs	Software	R 150 000
	Telemetry infrastructure	R 700 000
	Total	**R 850 000**
Annual O&M Expenses		R 50 000
Reduction in losses	Million m^3/a	9.3
Cost per m^3 (3 years)		**R 0.04**

ANNEXURE B

WATER MANAGEMENT PLAN : BOEGOEBERG WATER USER ASSOCIATION

SUMMARISED WATER MANAGEMENT PLAN FOR THE BOEGOEBERG WATER USER ASSOCIATION

APRIL 2013 TO MARCH 2014

MARCH 2013

Submitted by:

Boegoeberg Water User Association

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8850

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1 BACKGROUND

The Boegoeberg irrigation scheme was constructed during the Great Depression when in March 1929, the government decided to undertake the Boegoeberg Dam and canal project as part of its drought alleviation scheme. The main aim was to provide work for whites who were suffering as a result of the drought and the financial pressures. Capital for the project was provided by the Department of Labour but the construction thereof fell under the department of Water Affairs (then known as the Department Irrigation). The construction camp for the dam was situated on the farm Seekoebaart and the camp for the workers responsible for the construction of the canals was situated at Sterham (later re-named Groblershoop in honour of Mr Piet Grobler, Minister of Labour).

All the construction work was done with pick and shovel and wheelbarrows with the help of some donkeys. Even the children carried stones for the lining of the canal for a sixpence a day to boost the family's income.

Many of the concrete flumes, sluice gates and measuring structures within the unlined canal of 121 kilometres on the southern bank of the Orange River were already built in the late 1930’s. In 1952 the Department of Water Affairs commenced with the lining of the canal.

Irrigation development in the Upper Orange WMA was stimulated by the construction of several dams. Great expansions of irrigation were made possible along the Orange River by the construction of Gariep and Vanderkloof dams in the Upper Orange WMA during the 1970’s.

The Boegoeberg Dam is effectively a concrete weir which was initially equipped with 68 sluices designed to allow sediment to pass through the structure. The original capacity of over 40 million m^3 has been reduced through sedimentation to the current capacity of approximately 20 million m^3 and appears to have reached some form of equilibrium. The sediment sluices have recently been closed permanently and the structure is now effectively a concrete weir which supplies water into a canal on the left bank

The canal was extended in the 1970’s to be 172 kilometres long. Siphons were built to serve irrigation farmers north of the Orange River from the main canal on the southern bank with the 38 km Gariep canal, the 8 km Rouxville West canal and the 40 km Northern Orange canal. The canal wall height had to be extended at some sections to accommodate the higher flow demand due to these additions.

The Boegoeberg water user association was established in 2003 and is an amalgamation of the Boegoeberg GWS, the Northern Orange IB, the Gariep IB, a portion of the Middle Orange Irrigation Area, and the Karos-Geelkoppan Water Board. The Boegoeberg GWS, Gariep IB and Northern Orange IB were all served by common infrastructure which was operated by the Department of Water Affairs. The total area under irrigation is 9 198 ha. While some farmers pump directly from the rivers the majority are supplied from the canals. The Boegoeberg water user association supplies 306 irrigators. Nine livestock farmers are also supplied with water for domestic and animal use.

Originally designed as a flood irrigation scheme, 90% of the area is still irrigated by flood irrigation and the remaining 10% is irrigated with micro and drip irrigation systems. The 297 canal users are measured using calibrated sluices while some 9 users which abstract directly from the river are not metered. Water shortages are rare and users are billed on a m^3/ha/a with the allocation being 15 000 m^3/ha/a for users on the Boegoeberg, Northern Orange and Gariep portions and 10 000 m^3/ha/a on the Middle Orange portion.

The infrastructure is very old and the entire scheme is in need of rehabilitation. Consequently losses are high. The operating philosophy is that the water user association has created just another channel of the river and water flows through the canals with similar or less losses as would be the case if the water had stayed in the river.

A summary of the infrastructure is provided in Table 1-1.

Table 1-1: Summary of infrastructure

Type of structure	Section				Total
	Main	Northern Orange	Gariep	Rouxville West	
Secondary canals/pipelines (km)	56.9	1.1	4.2	0	62.2
Aqueducts	15	0	0	0	15
Siphons	32	5	20	11	68
Flow measuring structures	18	5	5	2	30
Bulk water sluices	55	3	2	4	64
Property sluices	604	73	82	10	769
Reject structures	18	3	2	3	26
Vehicle bridges	249	33	46	27	355
Foot bridges	165	3	11	9	188

The main crops that are under irrigation include grapes, lucerne and maize and other crops such as cotton, wheat, peas and pecan nuts. The typical crop mix across the Boegoeberg WUA is shown in Table 1-2.

Table 1-2: Crops irrigated within the area of operation of the Boegoeberg WUA

Crops	Hectares	%
Grapes	7 358.4	80%
Lucerne & maize	919.8	10%
Other	919.8	10%
Totals	**9 198.00**	**100%**

2 LEGAL PROVISION FOR DEVELOPING AND IMPLEMENTING THE BOEGOEBERG WUA WATER MANAGEMENT PLAN

The development and implementation of a Business Plan is a legal requirement to be undertaken by a WUA in terms of section 21 of Schedule 4 of the National Water Act (Act 36 of 1998). The constitution of a WUA - referred to schedule 5 for model constitution - outlines the principle functions to be performed by the WUA 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 the Boegoeberg WUA 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 Boegoeberg WUA has developed a WMP in terms of the provisions of the NWA to enable it to manage the irrigation water in the scheme effectively and efficiently.

3 BOEGOEBERG WUA WATER BUDGET

3.1 Introduction

The purpose of a water balance is to summarise the inflows, consumption and outflows from the area of operation of the WUA. During the preparation of the water balance the beneficial and non-beneficial consumptive uses are determined which form the basis for the calculation of performance indications which are necessary in identifying water savings opportunities.

Every water use component in a Scheme/Board is represented in the water balance and the various categories for inflows, consumptive use and outflows are described and discussed below.

3.2 Inflows

The first measurement of water flow takes place at the Seskanale where water is released into the irrigation canals.

3.3 Consumptive use

Consumptive use can be classified as the use that removes the water from the scheme that renders it unavailable for further use. Consumptive use can be classified into two main categories;

Process consumption

Process consumption or productive use is that volume of water that is used to produce the crops and is therefore considered beneficial use.

Non-process consumption

Non-process consumption or non-productive use occurs when water is consumed (depleted), but not by the irrigation of crops. Non-process consumption can further be subdivided in two types of uses, namely;

- Beneficial use, such as water that is used by indigenous riverine vegetation, and
- Non-beneficial use, such as evaporation or deep percolation that cannot be retrieved for productive use.

The supply to individual water users is measured (or rather administered) through the different sluice gates. The monthly data on releases at the individual sluices and parshalls were aggregated to provide records of consumptive use by the irrigators.

Records of weekly deliveries to other water users especially in the industrial sector were included in the consumptive use.

3.4 Outflows

As the name suggests, outflow is water flowing out of the system or area of operation of the scheme and can be classified as either committed or non-committed outflow. Committed outflow is that part of the outflow that is committed to other uses or users. Committed outflow is outflow that is available for other or downstream use. Uncommitted outflow can occur as a result of a lack of storage or operational measures. There are numerous reject points on the Boegoeberg scheme that discharges water back to the river but none of these points are measured, making it impossible to determine the outflows.

3.5 Overall scheme water balance

Currently there is no accurate data available on the exact volume of water loss on the canal system. An estimated figure of 20% is used by the BWAU in submitting their monthly water loss reports to DWA. According to the "Guidelines for the design of canals & related structures" document as drafted by the Department of Water Affairs, the suggested combined seepage and evaporation losses for concrete lined canals is approximately 1,9 ℓ/s per 1000 m² of wetted lining. The wetted perimeter of the canal will vary on the flow conditions throughout the different seasons as the water level rises and drops. For practical reasons in these calculations, it was assumed that the canal will flow at full capacity with about 150mm free board in all cases. When determining the wetted perimeter of the canal system based on the assumptions as above, a total area of 1 443 500 m² was calculated.

Seepage & evaporation losses = [1 443 500 / 1000] x 1,9

= 2 742 ℓ/s

= 2,74 m³/s

These combined seepage and evaporation losses of 2,74 m³/s for the Boegoeberg canal system accumulates to approximately 15.3% of the maximum flow capacity of the Main Canal.

The actual water releases for the period 1 July 2007 to 30 June 2008 are shown in Table 3-1.

Table 3-1: Actual releases

Month	Total volume released (m^3)
Jul-07	17 946 646
Aug-07	31 537 602
Sep-07	31 016 266
Oct-07	31 849 516
Nov-07	30 520 840
Dec-07	30 465 864

Month	Total volume released (m^3)
Jan-08	30 691 176
Feb-08	26 804 960
Mar-08	29 362 876
Apr-08	16 563 590
May-08	17 971 604
Jun-08	15 636 376
Total	**310 367 316**

3.6 Losses

3.6.1 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 headwork 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 evaporation 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.

The outflows consist of all the ways that water is consumed within the scheme. This includes the canal seepage, operational spills, evaporation from the canals, percolation and delivery to the irrigators and other users.

3.6.2 Conveyance losses

Conveyance losses within a canal system can be defined as the difference between the water released at the canal inlets and the water delivered to the farm boundary. Conveyance losses are made up of unavoidable and avoidable losses.

Unavoidable losses

Unavoidable losses take place on a continual basis and the bulk of unavoidable losses are made up of seepage and evaporation losses.

Avoidable losses

Avoidable losses include items such as leakages and spills and include operational losses and wastages resulting from inter alia, inefficient management of the system and other factors such as algae growth, etc.

3.6.2.1 Evaporation losses

The evaporation loss, expressed as a percentage of total inflow, is usually very low and has been estimated at approximately 0.3% of total inflow volume (Reid, Davidson and Kotze :1986).

For the Boegoeberg WUA the estimated value of the evaporation loss as a percentage of the total inflow into the scheme was calculated as 931 000 m^3 per annum.

3.6.2.2 Seepage losses:

Seepage losses from concrete lined, half lined and earth canals are normally expressed in l/s per 1 000 m^2 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 perimeter and this could result in an unavoidable loss rate of up to 15%. The depth of the ambient water table also has an effect on seepage losses. In an area where generally high water table levels are found, canal seepage decreases to roughly 5% of the input volume (Streutker, 1981 and Muller, 1984).

Other factors that have an effect on seepage losses are *inter alia*, Soil characteristics, water depth in the canal, flow speed, soil capillary tension, quantity of sediment, etc.

Given the overall poor condition and age of the canal infrastructure the seepage loss on the Boegoeberg Irrigation Scheme as a percentage of the total input volume was the estimated to be 15 %. This translates to a volume of 46.5 million m^3 per annum.

3.6.2.3 Operational wastage:

Apart from the two losses described above there are also other losses on the canal system which can be classified as avoidable losses. Such losses include start-up and shut-down losses, water not used (outflows) due to unexpected drops in demand and losses due to incorrect measuring. These losses are estimated to fluctuate between 9% and 17% (Reid, Davidson and Kotze, 1986).

3.6.2.4 Leaks and Spills:

Leaks normally occur on broken sections of the canals and on the top sections of the canal body and can be as a result of maintenance problems and the general deterioration of the canal network due to its age. The determination of the volume of water that is lost as a result of leakages and spills is very difficult to calculate and can only really be determined through accurate measuring. 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, etc.) than the lower section resulting in higher leakages when the canal is running close to or at full capacity.

The distribution network of the Boegoeberg WUA is old and in some sections very poor. The average operational losses and leakages for the WUA were estimated at 17 % of the inflow.

3.6.2.5 Aquatic weeds

Water grass and algae growth in irrigation canal systems are fast becoming one of the major operational headaches 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 quantity 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 (sluice) working at dividing structures.

(v) Water logging of long-weirs occurs.

(vi) Aquatic weed fragments occlude irrigation systems and filters at water purification plants.

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

A comprehensive study regarding aquatic weeds was undertaken by Modjadji Vegetation CC and their final report *"Compliance audit on the management of aquatic weeds in South African waterways"* was released in November 2007 (DWA/RSA/01-0707). This report will not try to repeat the findings of the Modjadji Vegetation CC investigation but specific detail will be discussed where necessary. The total outflow from the canal system was calculated using the formula below.

Total outflow = (Volume released – Registered water use) / Volume released

= (310,367,316 – 121,472,000) / 310,367,316

= 60,9%

Of the total volume released into the canal system, 29% can be classified as committed outflow for downstream users. Although there is no accurate information available on the volume of water that is diverted back to the river at various reject structures, the percentage of operational losses and leakages in the canal system was estimated at approximately 17%.

Table 3-2 provides a summary of the various losses on the canal distribution network of the Boegoeberg WUA. It is important to note that a further breakdown of the losses was not possible.

Table 3-2: Boegoeberg WUA - Breakdown of water losses

<table>
<tr><th rowspan="3">Description</th><th rowspan="3">System inflow
(x $10^6 m^3$)</th><th colspan="4">Present situation - Losses</th></tr>
<tr><th>Unavoidable Losses</th><th>Avoidable Losses</th><th>Total Losses</th><th rowspan="2">% of total volume released</th></tr>
<tr><th>(x $10^6 m^3$)</th><th>(x $10^6 m^3$)</th><th>(x $10^6 m^3$)</th></tr>
<tr><td>Seepages</td><td rowspan="8"></td><td>46.5</td><td></td><td>46.5</td><td>15.0%</td></tr>
<tr><td>Evaporation</td><td>0.9</td><td></td><td>0.9</td><td>0.3%</td></tr>
<tr><td>Filling losses</td><td rowspan="6">0</td><td rowspan="6">52.7</td><td rowspan="6">52.7</td><td rowspan="6">17.0%</td></tr>
<tr><td>Leakages</td></tr>
<tr><td>Spills</td></tr>
<tr><td>Over delivery</td></tr>
<tr><td>Canal end returns</td></tr>
<tr><td>Other</td></tr>
<tr><td>**Total**</td><td>**310.4**</td><td>**47.4**</td><td>**52.7**</td><td>**100**</td><td>**32.3%**</td></tr>
<tr><td>**% of total volume released into system**</td><td></td><td>**15.3%**</td><td>**17.0%**</td><td>**32.3%**</td><td></td></tr>
</table>

From the data presented Table 6-2 it is evident that the total losses on the scheme amount to 32.3%. Of the total losses occurring on the scheme 47.4 million m^3 can be classified as unavoidable losses.

3.6.3 Avoidable water losses

Based on the above assessment and disaggregation of the gross water losses, the average estimated avoidable water losses have been 52.7 million m^3. This quantity can be attributed to a number of factors.

- *Measuring errors*: With the current method of manual reading of the depth of flows by the WCOs, there is a likelihood of measurement errors due to human error. The implementation of telemetry systems may reduce the avoidable losses.
- *Scheduling of deliveries.* Although there is weekly scheduling of deliveries and water is delivered only when needed, it is a very complicated process of trying to match the deliveries with the water applications. This happens particularly when the irrigators change their requests and there may be a time lag in adjusting the volume required not only at the sluice but through the canal system.

- *Over delivery*: There is potential for significant "water losses" to take place if the sluice settings to individual users and direct abstractions from the river are not monitored on a continuous basis to ensure that they are indeed correct.
- *Leakage in the canal structure*: 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/or deterioration of the canal network.

4 WATER MANAGEMENT ISSUES AND GOALS

4.1 Overview the management issues

The water budget analysis discussed in the previous chapter together with discussions held with the Boegoeberg WUA, has helped to identify several key water management issues. There is however insufficient data to clearly determine where and how losses are occurring. Currently there are no records as to how much water losses occur due to operational issues or how much water is returned to the river through the reject structures or at the canal end points.

The most noticeable aspect that was noticed during the consultations with the WUA is the sense of awareness of the management of the importance of efficient irrigation water management and conservation, and the interest shown to learn as much as possible. Table 8.1 below provides the key issues identified and these are discussed in more detail in the following sections of this chapter.

4.2 Flow measurement data and assessments

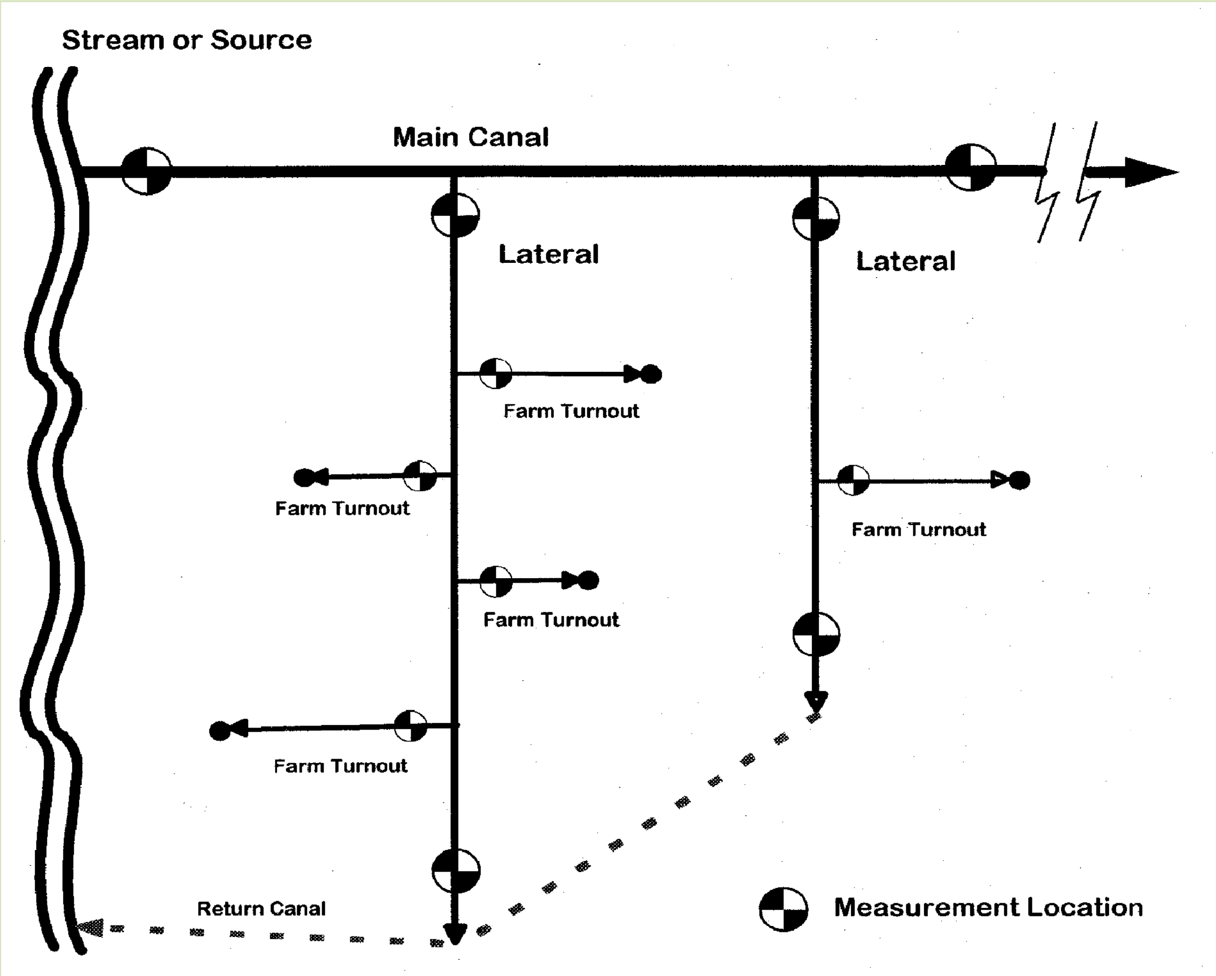
4.2.1 Adequacy of flow data

Good information is fundamental to making decisions on managing irrigation water at any irrigation scheme. Table 4-1 below provides the extent of flow measurement that is ideal for conducting an irrigation scheme water budget. The availability of flow measurements helps inform both the water user and the WUA about the quantity, timing, and location of water use and therefore enables the WUA to conduct a water budget not only at scheme level but also for sub-schemes within the irrigation scheme.

As illustrated in the figure it would be ideal to have flow measurements at the inlet to the primary canals as well as at the canal ends and reject points. This would assist in determining the water losses in each section of the canal system, as well as the operational spills and major leaks if there are any.

The Boegoeberg WUA does have adequate flow measurement structures in place to conduct a water budget analysis at both scheme and sub-scheme level. The WUA makes regular measurements of flows into the major sections. These include weirs and parshall flumes on the canals, and flumes and rated sluice gates on the laterals to the individual farmers.

However, there is no measurement of water returning back to the river through reject structures or canal end points. Without these measurements it is impossible to conduct a detailed water budget.



Source: Bureau of Reclamation

Figure 4-1: Irrigation Scheme with ideal water measurement system

There is measurement taking place within the scheme linked to a telemetry system where water is released from Boegoeberg Dam into the main canal and there are also other measurements (not telemetric) taken where water is diverted into sub sections of the scheme. WAS is not utilised on the scheme and the flow measurements are only available in spreadsheet format.

Most of the reject points have measurement structures in place but they are not equipped with measuring devices. Not all of the reject structures are used on a continuous basis and are only used when the system is drained for maintenance.

Management Goal 1

The objective to address the above irrigation water management issue is to ensure that the following is achieved by the Boegoeberg WUA:

(i) Identification of reject structures that are rarely used.

(ii) Assess condition of measuring structures at reject points that are regularly used.

(iii) Calibrate those structures that are used on a regular basis.

(iv) Prepare a budget to equip the identified reject structures with measuring devices within one year.

(v) Undertake the installation of measuring equipment on the identified reject structures and current measuring points on a "ward basis" and progress downstream on the main canal.

4.2.2 Irrigation water budget is not conducted in detail

It is currently impossible to calculate or measure any losses and it is therefore impossible to calculate avoidable losses such as leakage, spills and over delivery to users. Currently it is not possible to conduct water budgets for the various sections on the scheme. If this is undertaken it may highlight sections that require specific attention. The accuracy of the seepage losses remains questionable and it is proposed that ponding tests be done to verify the accuracy of the theoretical calculations.

Management Goal 2

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

4.3 Operational water management issues

4.3.1 WAS not implemented

The Water Administration System (WAS) was developed by Dr. Nico Benade (with funding mainly from the WRC) as a tool to be used by Irrigation Boards/Schemes to optimize their irrigation water management and minimize management-related distribution losses in irrigation canal systems. WAS consists of seven modules integrated into a single program and these modules can be implemented partially or as a whole.

The seven modules are the:

(i) Administration module

(ii) Water order module

(iii) Water accounts module

(iv) Water release module

(v) Measured data module

(vi) Crop water use module, and

(vii) Report module

The Water Release module for example links with the water administration and order modules and can be used to:

- Minimize distribution losses on canal networks
- Calculate water releases for the main canal(s) and all their branches allowing for lag times and water losses such as seepage and evaporation; and
- Determine operational procedures for a dam with varying downstream inflows and outflows in a river allowing for lag times and water losses such as seepage, evaporation and transpiration.

However, WAS is not implemented at all on the scheme. The problem is not so much with the current system in operation on the scheme but with continuity. Only one or two persons really know how the spreadsheets relate to one another and how calculations are performed within them. The WUA is therefore totally dependent on one or two individuals and should they leave or pass away, nobody else knows how to operate the program. WAS is a standardised program in use on various schemes throughout the country with many trained operators handling the system. This reduces the risk of an in-house developed program and temporary personnel could assist with the upkeep of the system should the regular operator(s) leave of fall ill.

The whole WAS system does not have to be implemented at once and a phased approach is normally followed. This lessens the burden on the WUA and allows time to get all the necessary information and data in place before a module is implemented.

<u>Management Goal 3</u>

The management objective to address the above issue, is to undertake a feasibility study for the phased implementation of the WAS program.

4.3.2 Available datasets not integrated into a Management Information System

The Boegoeberg WUA has commissioned various studies in the past and has gathered and generated their own detailed datasets, ranging from individual sluice detail to water user address information. All these datasets are in standalone databases of spreadsheets and very little thereof are spatially linked. Having all this data in one integrated Management Information System will be a huge benefit and should enable quicker and better informed decision making.

4.3.3 Management Goal 4

The development of a spatially linked Management Information System that contains all the relevant and available datasets.

4.4 Infrastructure related issues

In order to properly develop the water management plan, it was essential that an assessment of the overall condition of the facilities to identify potential issues was carried out. As indicated in Chapter 4, a detailed condition assessment was undertaken by the Boegoeberg WUA. This included the operation and maintenance system as well as the conveyance and distribution system. No detailed assessment of the on-farm delivery systems was however conducted.

4.4.1 Limited scheme balancing capacity

Balancing dams decrease the pressure on the canal system and allows for shorter delivery periods to water users. They also intercept any surplus water in the system and act as backups to supplement supply should shortages arise (canal breaks, etc.). The Boegoeberg WUA only has the benefit of one balancing dam on the scheme.

Management Goal 5

The Boegoeberg WUA has a limited balancing system in place which limits the security of water supply during maintenance periods or major canal failures. The goal is to investigate the possibility of constructing additional storage capacity which will assist in operating the system as effectively as possible. (An additional dam at Leerkrans was investigated but no further actions were taken).

4.4.2 Canal maintenance

During the condition assessment of the existing canal infrastructure various defects were identified which reflects on the present procedures undertaken by the WUA when maintenance is conducted. When maintenance is conducted on the canal joints for example it was noted that the joints were plastered, therefore providing no room for expansion or contraction. This means that the seal is only performing for a short while before it cracks and starts to leak again. The present modus operandi when maintenance and repairs are undertaken should be investigated and improved where possible.

At present maintenance is reactionary and there is no formal maintenance plan.

Management Goal 6

Revision of the current actions taken when canals are maintained and/or repaired should be investigated and improved where possible and a formal maintenance plan should be developed within one year in order to avoid a catastrophic canal break.

4.4.3 Ownership of irrigation infrastructure

The Water User Association has two main elements that dictate their operations – water and infrastructure. The ownership of irrigation infrastructure can prove to be one of the main barriers to improvement in irrigation efficiency if it is not well managed. More specifically, it is the management of the infrastructure, more than the ownership of the irrigation infrastructure that can create problems with the ensuring the quality of the infrastructure is maintained.

In the Boegoeberg WUA, the Department of Water Affairs (DWA) still owns the irrigation infrastructure including the main and branch canals. However, the WUA operates the irrigation infrastructure as an agent of the DWA and undertakes the normal maintenance of the irrigation infrastructure.

Problems will most likely arise when the major infrastructure needs replacement/total refurbishment. It is unlikely that the WUA has the financial capacity to undertake the refurbishment of the assets which are owned by government. It is also difficult to borrow against the assets as they are owned by government. Therefore the responsibility for replacement of major assets lies with government, whose priorities may be different to those of the WUA.

Management Goal 7

The broad objective to address this issue around ownership of the irrigation infrastructure is to ensure that the levels of responsibility between the DWA and the WUA are further refined than the existing agreement. This is assuming that the DWA does not want to transfer the infrastructure to the WUA in the short to medium term.

4.5 Institutional Water Management Issues

4.5.1 Updating and implementation of the Water Management Plan

The CEO of the Boegoeberg WUA will amongst others, be responsible for the annual updating and implementation of the Water Management Plan (WMP) for the scheme. The roles and responsibilities of the CEO for the updating and implementation of the WMP will be the following:

- Take flow measurements and conduct a detailed water balance assessment on a monthly basis at scheme and sub-scheme level

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

Management Goal 8

Implementation, monitoring, reviewing and updating of the WMP by the CEO and reporting by him/her on the status of water losses, water saving targets, goals and objectives.

Table 4-1: Boegoeberg Irrigation Scheme: Identified water management issues

Item No.	Issue description	Comments
1	No flow measurements at reject points are taking place and no water budget can be compiled.	Identification of operational reject points and the installation of measuring equipment.
2	Irrigation water budget cannot be conducted in detail. Data from the monitoring system and other measurements is used for monitoring purposes only and it is impossible to disaggregate the losses.	Break down losses.
3	WAS is not utilised on scheme.	Investigate the use of WAS.
4	Available datasets not integrated into a Management Information System. Having all this data in one integrated system will be a huge benefit and should enable quicker and better informed decision making.	Develop and implement a Management Information System.
5	Limited scheme balancing capacity.	Constructing additional storage capacity which will assist in operating the system as effectively as possible.
6	Maintenance plan and procedures	The maintenance plan should be formalised. Revision of the current actions taken when canals are maintained should be investigated and improved where

Item No.	Issue description	Comments
		possible.
7	Ownership of irrigation infrastructure	Responsibility between the DWA and the BWUA should be further refined.
8	Updating and implementation of the Water Management Plan	Implementation, monitoring, reviewing and updating of the WMP is responsibility of the Scheme Manager as well as scheduled reporting by him/her on the status of water losses, water saving targets, goals and objectives.

5 ESTABLISHING WATER SAVINGS TARGETS

5.1 Acceptable water losses

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 Boegoeberg WUA.

A Water Research Commission (WRC) study (Report TT465/10) 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 (Reinders 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 scheme. This amounts to 31 million m^3/a based on the average inflow into the canals. This together with the unavoidable losses has been used in setting the water saving and water loss targets.

5.2 Water savings targets

The unavoidable water losses in the Boegoeberg WUA were determined to be 15.3% of the total releases into the canal system. This water is additional to the irrigation water use required at the farm edge.

As illustrated in Table 5-1 below, the acceptable 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 is 25.3% of the total releases into the canal system.

Table 5-1: Target water losses for the Boegoeberg WUA

Description	System inflow (x $10^6 m^3$)	Present situation - Losses				Acceptable water losses		Water savings targets	
		Unavoidable losses (x $10^6 m^3$)	Avoidable losses (x $10^6 m^3$)	Total Losses (x $10^6 m^3$)	% of total volume released	Annual volume (x $10^6 m^3$)	% of total volume released	Annual volume (x $10^6 m^3$)	% of total volume released
Seepages		46.50	0	46.50	15.00%	21.011	15.0%	0	0.00%
Evaporation		0.93	0	0.93	0.30%	0.93	0.30%	0	0.00%
Filling losses Leakages Spills Over delivery Canal end returns			52.7	52.7	17.00%	31.0	10.0%	21.7	7.0%
Other		0	0	0	0.00%	0	0.00%	0	0.00%
Total	**310**	**47.3**	**52.7**	**100%**	**32.3%**	**78.4**	**25.3%**	**21.7**	**7.0%**
% of total volume released into system		**15.3%**	**17.0%**	**32.2%**					

Based on the projected water saving targets, the Boegoeberg WUA can achieve a 3% reduction in water losses in a relative short period (3 years and less).

5.2.1 Short term water saving targets

For the short term which has been taken as 3 years, the total water savings that can be achieved through implementing the flow measurement and monitoring plans is some 9.3 million m^3/a.

5.2.2 Long term water saving targets

For the long term a further 12.4 million m^3/a saving is envisaged by optimising the operations and refurbishment of the canal infrastructure. The long term target is to reduce the water losses to approximately 25% of the total diversion.

6 IMPLEMENTATION PLAN

An evaluation of the potential measures for implementation in the Boegoeberg WUA area in order to improve water use efficiency and reduce water losses indicates that all the measures are economically justified for implementation based on the unit cost of water saved.

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

(i) *Identify "obsolete" return structures in order to minimise measurement.*

(ii) *Devise methods to protect measuring equipment.*

(iii) *Installing measurement devices to improve management of the water delivery system and undertake water budgets based on measured data.*

(iv) *Disaggregate losses and conduct water budgets at sub-scheme level.*

(v) *Revise and improve current maintenance procedures and actions.*

(vi) *Undertake study to identify suitable locations for additional balancing capacity.*

(vii) *Incorporate all relevant data in a custom Management Information System.*

The action plan for implementation is presented in Table 6-1.

Table 6-1: Boegoeberg WUA Action Plan

Priority	Goal	Action Plan	Timeline	Responsible Authority
1	Measurement and identification of losses	(i) Identify "obsolete" return structures in order to minimise measurement points. (ii) Devise methods to protect measuring equipment. (iii) Installing measurement devices to improve management of the water delivery system and undertake water budgets based on measured data. (iv) Undertake sub-scheme water budgets. (ii) Prioritise areas/sections with significant water losses.	Apr '13 – Mar '14 Apr '13 – Mar '14 Apr '13 – Mar '15 Apr '13 – Mar '15 Apr '13 – Mar '14	Boegoeberg WUA
2	Increase operational efficiency	(i) Investigate the implementation of WAS. (ii) Measurement of direct abstractions from the river. (iii) Re-evaluate possibility of balancing dam at Leerkrans. (iv) Incorporate data in a custom Water Management Information System.	Apr '13 – Mar '14 Apr '13 – Mar '15 Apr '13 – Mar '14 Apr '13 – Dec '14	Boegoeberg WUA
3	Reduce losses in irrigation canal infrastructure	(i) Revise and improve current maintenance procedures.	Apr '13 – Aug '14	DWA / Boegoeberg WUA