water affairs
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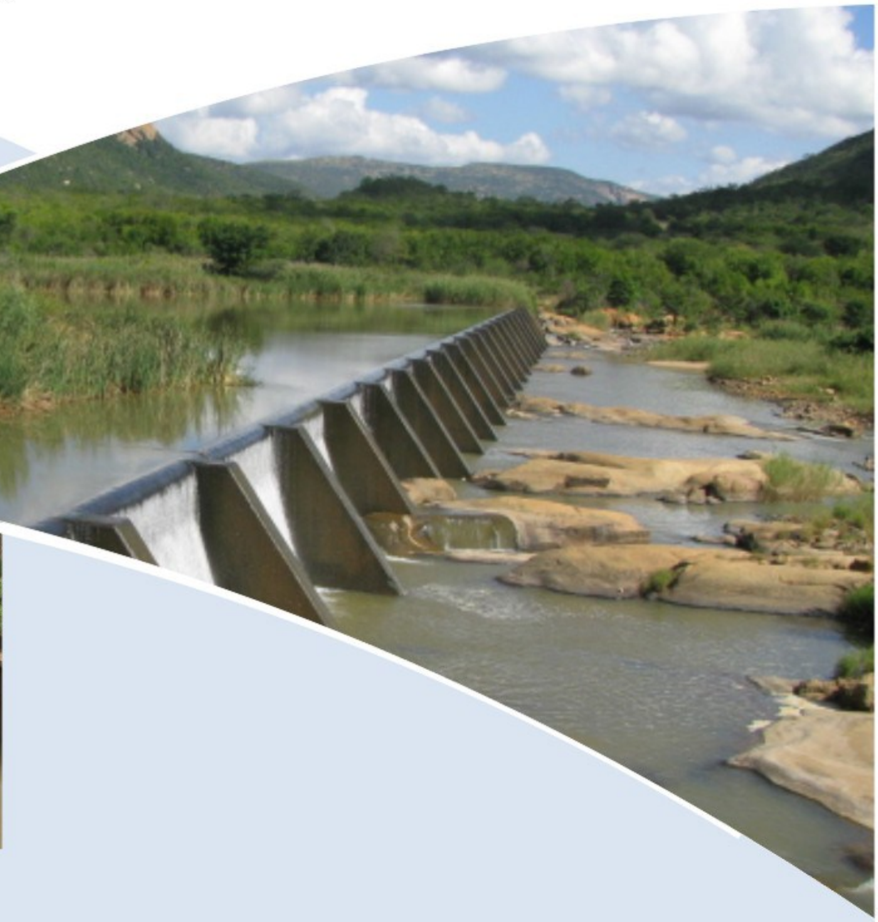

CONTRACT NO. WP 10276

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

IMPALA WATER USER ASSOCIATION

FINAL REPORT

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water affairs

Department:
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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

IMPALA IRRIGATION SCHEME WATER MANAGEMENT PLAN

FINAL

MARCH 2013

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EXECUTIVE SUMMARY

Background

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

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

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

Project Objectives and approach taken

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

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

- Compilation of a situation assessment of the current water use and irrigation water use practices in the fourteen irrigation schemes;
- Determination of the irrigation water balance assessment and establishing water use baseline for each irrigation scheme;
- Determination of the irrigation water management issues based on the situation assessment and water balance assessments prepared for each irrigation scheme;
- Identification of opportunities to improve water use efficiency in the agricultural sector;

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

- Benchmarking of irrigation water use efficiency and setting irrigation water use efficiency targets for each scheme;
- Preparation of an irrigation water management plan for each irrigation scheme;
- Capacity building of the GWS, Irrigation Boards (IB's) and WUAs to implement the identified opportunities to improve irrigation water use efficiency.

Overview of the Impala Irrigation Scheme

The Impala Irrigation Scheme receives its raw water supplies for nearly 60% of the time from the Pongola River. It is supplemented by the Bivane Dam which was built by the irrigators to address the water supply shortages and reliability of supply problems that the scheme was experiencing. The Bivane Dam has a total storage capacity of 115 million m^3. Water is only released to supply Impala Irrigation Scheme, when the Pongola River flow cannot meet the demands of the irrigators based on the weekly orders. The volume of water to be released is dependent on the volume of flow in the Pongola River system, which is measured at the Upper Pongola and Grootdraai weirs.

Figure 1 below provides a schematic layout of the Impala Irrigation Scheme.

Schedule of rateable area

The Impala Irrigation Scheme is situated in the Pongola-Mzimkulu Water Management Area in the Zululand District Municipality. The Scheme provides water to 17 012ha of agricultural area. The list of rateable area for the Scheme is 14 700 ha at an allocation of 10 000 ha/a, which includes canal as well as river irrigators. Approximately 2300 ha are registered water use. There are approximately 700 ha of emerging irrigators on the Scheme. The total water allocation for Impala WUA is 170 million m^3/a.

The main crops that are under irrigation, include sugar cane (15 869 ha.), citrus (370 ha), vegetables (approximately 730 ha.), maize (320 ha.), mango (120 ha.) and some pecan/macadamia. The importance of sugar cane at 91% of the irrigated area is well illustrated on a per hectare basis in the Impala Irrigation Scheme, with all other crops comprising 9% of the total. Therefore there is very little crop mix taking place in the scheme area as the scheme is driven by the need to meet the cane requirements of the Pongola sugar mill.

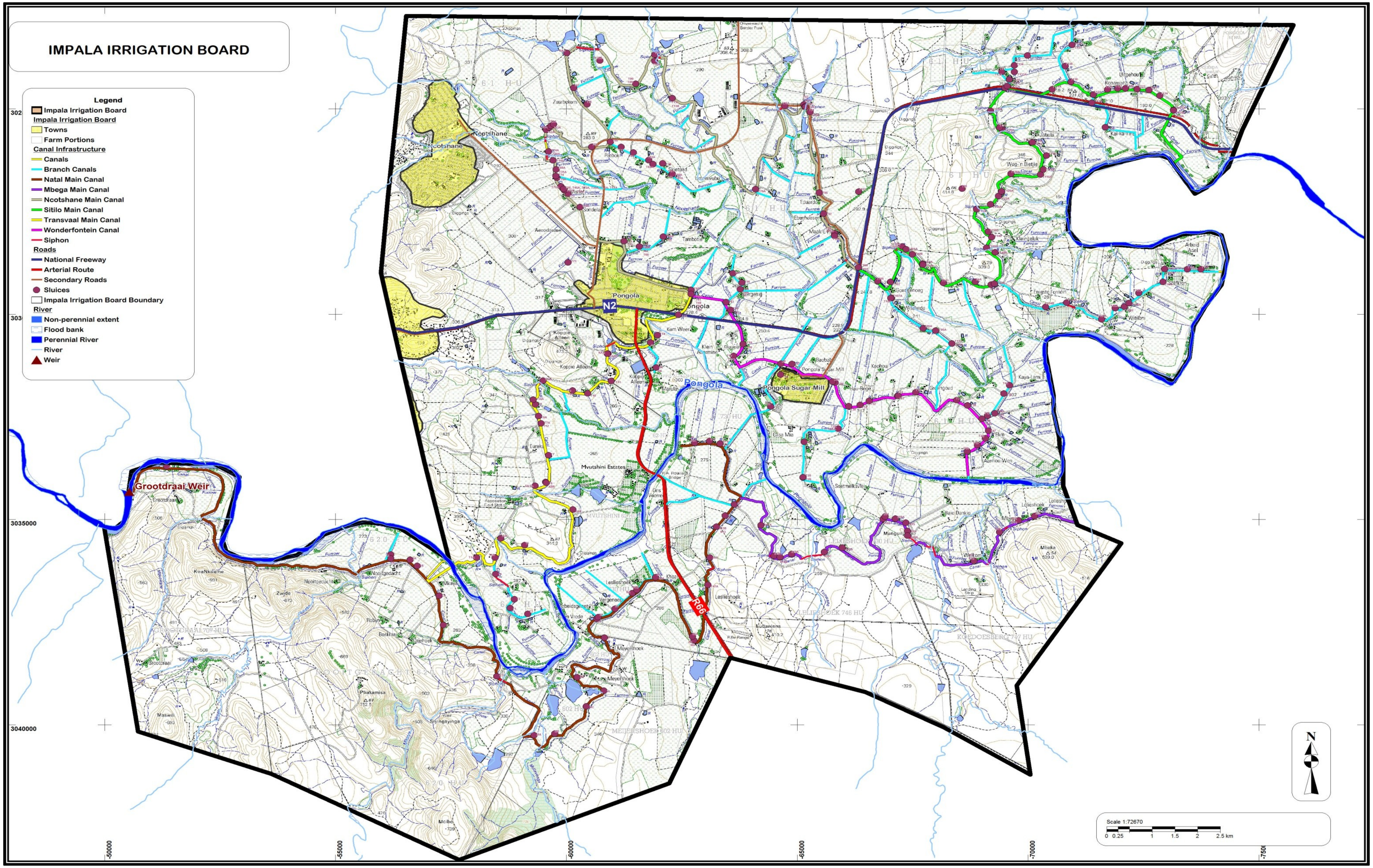

Figure 1: Impala Irrigation Scheme Layout

Conveyance and delivery infrastructure

Water to the water users in the Impala Irrigation Scheme is delivered through a system of canal infrastructure comprising two main canals namely the Transvaal canal as well as the Natal canal. There are branch canals from these two main canals which deliver water to the sluice gates at the irrigators' farms.

The total length of the canal infrastructure excluding drainage canals is 186 km with most of the canals concrete lined. This comprises 61 km of concrete lined canal for the Natal canal system and 125.6 km of concrete lined canals for the Transvaal canal system. The condition of the canals was found to be generally good to fair.

Besides the canal infrastructure there are outlet and measuring structures to measure the volume of water taken by each water user in the canal. There are 285 sluice gates in the Impala canal system.

Irrigation storage and regulation

There are no balancing dams in the Impala Irrigation Scheme which provide the balancing and regulation of flow to downstream water users besides the three for the emerging farmers to provide the buffer to the scheme.

Findings of the situation assessments

A situation assessment of the Impala Irrigation Scheme was conducted to determine the water management issues affecting the effective and efficient use of the available water to the scheme. The assessment was conducted at scheme level.

Best Management Practice - Expected water losses

An evaluation of the expected water losses based on the existing canal infrastructure and assuming the infrastructure is maintained was conducted for the Impala irrigation system. The analysis indicated that the unavoidable water losses due to evaporation losses and seepage due to the expected hydraulic conductivity of lined canals is 22.4 million m^3/a, which translates into 12% of the total volume of water diverted into the Impala canal system.

There are expected to be operational inefficiencies due to the canal filling required after the dry periods, the metering errors even after calibration as well as problems in matching supplies and demands when applicants make changes to their requirements during the week. Based on the WRC benchmark study the operational efficiency for the Impala scheme was 15% of the total release into the Impala canals.

Based on the evaluation of the unavoidable water losses and the expected operational inefficiencies for the Impala Irrigation Scheme, the water delivery Best Management Practice (BMP) should be based on the allowable water losses of approximately 27% of the total inflow into the Impala irrigation canal.

Water balance assessment

A water balance assessment that was conducted for the Impala irrigation scheme indicated that the water losses exceeded the minimum expected seepage and evaporation losses as well as the operational losses due to the benchmarked operational efficiency of the scheme. The average water loss based on the historic water use records was determined to be 41% of the total water diverted in the Impala canal system

The equivalent depth of water diverted per actual unit area irrigated was determined. The trend-line indicates an increase in the diversion per unit of irrigated areas from 2006 to 2012/13 water years for the Impala canal system (see **Figure 2** below). The increasing diversions per unit of irrigated land do not however take into account the climatic condition and cop rotation.

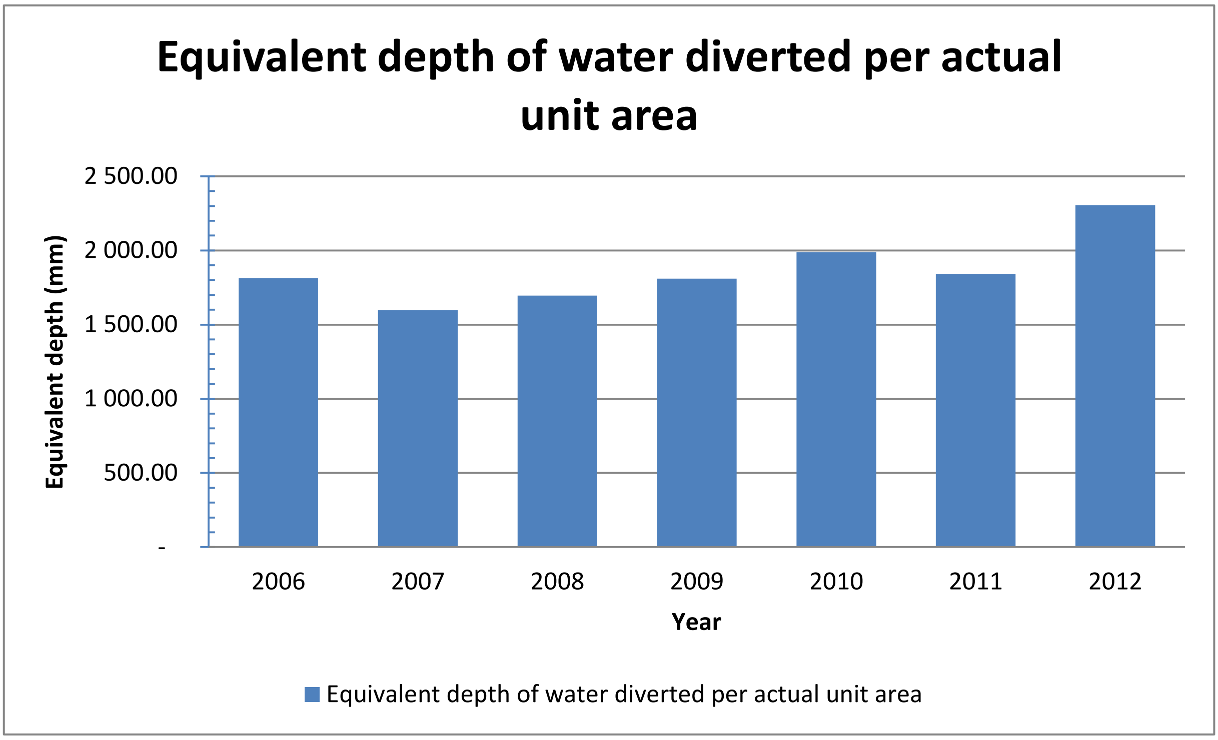

Figure 2: **Irrigation water released into Scheme expressed as an equivalent depth of water released per actual unit area irrigated for the Impala canals (m^3*10^3)**

Water Management Issues

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

(i) There is a lack of measurement recording at some of the critical points in the scheme for a comprehensive water balance assessment to be conducted. These include the three major tributaries from the Swaziland which are running in the scheme and not measured. Some of the spills at the canal tail ends are considered losses and can be avoided if regular flow measurements were taken to allow real-time adjustments in canal flow. Therefore the current water balances are not accurate as they are based on estimates.

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

(iii) Not all modules of the water administration system to manage water use is being utilised for sub-scheme water balance assessments.

(iv) The conditions of a small section of the canal infrastructure of the Natal to Wonderfontein siphon are in poor condition found to be poor. There are sections of the main canal which will require rehabilitation as the leakage levels are high. This is attributed to some flooding and the geological conditions above the canal system.

(v) The capacity of the Impala WUA is limited. This is because the existing irrigation infrastructure was constructed in the early 1960s and as a result of the age time and the resources to undertake there is major refurbishment required.

(vi) The current water rate structure does not have elements of incentive based pricing aspects.

Water Management Plan for the Impala Irrigation Scheme

Establishment of water saving targets at scheme level

The implementation of a Water Management Plan for the Impala Irrigation Scheme to reduce water losses will imply reducing the water diverted per unit of the land area irrigated in the scheme. As is expected this will not affect the yields of the crops being irrigated in the scheme area. The acceptable water losses have been determined for the scheme as illustrated in **Table 1** below.

Table 1: Estimated water saving targets for the Impala Irrigation Scheme (million m³/a)

Description	System Inflow	Present Situation - Losses					Acceptable Water Losses		Target Water Savings		
		Unavoidable losses	BMP for distribution losses	Avoidable losses	Total losses	% of Total Volume Released	Annual Volume	% of Total Volume Released	Annual Volume	% of Total Volume Released	Intervention measure
Seepages		21.29			21.29			12%	0	0%	None
Evaporation		1.15			1.15			1%	0	0%	None
Filling losses								23%			
Over delivery to users											
Leakages									4.06	2%	Refurbishment & resealing
Infrastructure condition			27.7	14.42	42.12				5.13	3%	Repair of leaking siphons
Operational Losses									8.88	5%	Flow measurement & monitoring & WAS

Description	System Inflow	Present Situation - Losses					Acceptable Water Losses		Target Water Savings		
		Unavoidable losses	BMP for distribution losses	Avoidable losses	Total losses	% of Total Volume Released	Annual Volume	% of Total Volume Released	Annual Volume	% of Total Volume Released	Intervention measure
Canal tail ends				10.95	10.95				2.19	1%	Management of operational spills at tail ends
Other											
Total		22.44	27.70	25.37	75.51	41%	55.25	30%	20.26	11%	
Loss as a % of total losses		30%	37%	33%	100%						
Loss as a % of total volume released into system		12%	15%	14%	41%			30%			
Total releases into Scheme	184.66										

Therefore reducing the water diverted per unit of land area would mean an increase in productivity per unit of water which would be a clear indication of progress towards greater efficiency for the Impala Irrigation Scheme assuming the scheduled quota of 10 000 m^3/ha/a remains constant.

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

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

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

(2) Preparation of more detailed water balance assessments for the Impala irrigation scheme, as well as the sub-schemes which include the Transvaal canal and its branches and the Natal canal and the main branch canals as well as the emerging farmers

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

(4) Refurbishment of the telemetry infrastructure to enable real time monitoring of irrigation water in the long term. This has since been implemented.

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

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

Conclusions and Recommendations

A water management plan for the Impala Irrigation Scheme was developed to address the water losses taking place in the scheme and to improve irrigation water management of the scheme. The identified measures for implementation to reduce the water losses from the current 41% to 30% of the total inflow into the irrigation scheme include the following:

(i) *Refurbishment of telemetry system* - It is considered as the most beneficial and important intervention measure to do as it is critical to addressing the operational problems quickly and more effectively than the current manual monitoring of the scheme. The estimated water savings are 8.8 million in the Impala canal system at an average incremental cost of R0.02 per m^3 of R180.49 per ha per year. This measure has already been implemented and the potential savings should start to be realised in the next water year

(ii) *Implementation of WAS programme on sub-schemes*- This measure is aligned to the first two measures and is considered to be important for implementation in the short term as well. It should be carried out at the same time as the first intervention measures.

(iii) *Conduct flow measurements and flow monitoring on all critical measurement points and calibration* - The evaluation of this measure has illustrated this to be the most beneficial to reducing water losses with the estimated water savings of 2.2 million m^3/a when applied with the full implementation of the WAS programme. A number of measurement equipment has been commissioned.

(iv) *Rehabilitation of the siphon between Natal and Wonderfontein* - This measure has the second most benefit with estimated water savings of 5.13 million m^3/a, at an average incremental cost of R0.06 per m^3 or R591.12 per ha per year. This measure has already been implemented.

(v) *Canal refurbishment and cleaning of siphons* - This measure although requiring significant capital investment will improve the condition of the infrastructure and reduce the high leakage losses. This will potentially save approximately 4.0 million m^3/a in the Impala canal system at an average incremental cost of R0.18 per m^3 or R1 807 per ha per year which is prohibitive.

(vi) *Incentive based pricing* - This measure is considered a national issue which does not only affect the Impala irrigation scheme. It is dependent on whether the irrigators would require changes to the current water pricing which is area based and the implications to revenue management by the irrigation scheme which may not be stable.

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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
WUA	Water User Association
IB	Irrigation Board
MAE	Mean Annual Evaporation
MAP	Mean Annual Precipitation
MISD	Matching Irrigation Supply and Demand
O&M	Operation and Maintenance
RAT	Remote Assessment Tool
RTU	Remote Telemetry Unit
SLA	Service Level Agreement
WARMS	Water Allocation Registration Management System
WAS	Water Administration System
WCA	Water Control Aid
WCD	Water Control Department

WC/WDM	Water Conservation and Water Demand Management
WCO	Water Control Officer
WMA	Water Management Area
WMP	Water Management Plan
WUA	Water User Association
WUEAR	Water Use Efficiency Accounting Report

GLOSSARY OF TERMS

Application efficiency The ratio of the average depth of irrigation water infiltrated and stored in the root zone to the average depth of irrigation water applied, expressed as a percentage

Applied water: Water delivered to a user. Also called delivered water. Applied water may be used for either inside uses or outside watering. It does not include precipitation or distribution losses. It may apply to metered or unmetered deliveries

Conduit: Any open or closed channel intended for the conveyance of water.

Conservation: Increasing the efficiency of energy use, water use, production, or distribution.

Consumptive use (evapo-transpiration) Combined amounts of water needed for transpiration by vegetation and for evaporation from adjacent soil, snow, or intercepted precipitation. Also called: Crop requirement, crop irrigation requirement, and consumptive use requirement.

Conveyance loss: Loss of water from a channel or pipe during conveyance, including losses due to seepage, leakage, evaporation and transpiration by plants growing in or near the channel.

Conveyance system efficiency: The ratio of the volume of water delivered to irrigators in proportion to the volume of water introduced into the conveyance system.

Cropping pattern: The acreage distribution of different crops in any one year in a given farm area such as a county, water agency, or farm. Thus, a change in a cropping pattern from one year to the next can occur by changing the relative acreage of existing crops, and/or by introducing new crops, and/or by cropping existing crops.

Crop water requirement: Crop consumptive use plus the water required to provide the leaching requirements.

Crop irrigation Quantity of water, exclusive of effective precipitation, that is needed

requirement: for crop production.

Crop root zone: The soil depth from which a mature crop extracts most of the water needed for evapo-transpiration. The crop root zone is equal to effective rooting depth and is expressed as a depth in mm or m. This soil depth may be considered as the rooting depth of a subsequent crop, when accounting for soil moisture storage in efficiency calculations.

Deep percolation: The movement of water by gravity downward through the soil profile beyond the root zone; this water is not used by plants.

Demand scheduling: Method of irrigation scheduling whereby water is delivered to users as needed and which may vary in flow rate, frequency, and duration. This is considered a flexible form of scheduling.

Distribution efficiency: Measure of the uniformity of irrigation water distribution over a field.

Distribution loss: See conveyance loss.

Distribution system: System of ditches, or conduits and their appurtenances, which conveys irrigation water from the main canal to the farm units.

Diversion (water): Removal of water from its natural channels for human use.

Diversion (structure): Channel constructed across the slope for the purpose of intercepting surface runoff; changing the accustomed course of all or part of a stream.

Drainage: Process of removing surface or subsurface water from a soil or area.

Drainage system: Collection of surface and/or subsurface drains, together with structures and pumps, used to remove surface or groundwater.

Drip (trickle) irrigation: An irrigation method in which water is delivered to, or near, each plant in small-diameter plastic tubing. The water is then discharged at a rate less than the soil infiltration capacity through pores, perforations, or small emitters on the tubing. The tubing may be laid on the soil

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

functions for which they were created.

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

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

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

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

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

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

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

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

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

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

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

Return-flow system	A system of pipelines or ditches to collect and convey surface or subsurface runoff from an irrigated field for reuse. Sometimes called a "reuse system or a "recovery system".
Risk cost	This is usually expressed as the product of the cost of damage caused by the actual hazard occurrence and the probability of occurrence.
Run-off	This is the water produced when irrigation water is applied to fields at rates and in amounts greater than can be infiltrated into the soil profile.
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 the need for the development of additional new water supplies, while ensuring that the natural environment is maintained or is not degraded further. The Department of Water Affairs (DWA) identified that, based on preliminary assessment of water losses in the agricultural sector, there was potential to implement measures to improve water use efficiency in the sector. The overall aim in reducing water losses and improving irrigation water use efficiency levels in the Water User Associations (WUAs)/Irrigation Boards (IBs)/Government Water Schemes (GWS) is that the limited available water can be optimally utilised to ensure a high economic return for the scheme area.

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

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

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, the Impala WUA and the DWA Regional Offices, this report provides the following:

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

1.2 Study Objectives

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

- Compilation of a situation assessment of the current water use and irrigation water use practices in the fourteen irrigation schemes;
- Determination of the irrigation water balance assessment and establishing water use baseline for each irrigation scheme;
- Determination of the irrigation water management issues based on the situation assessment and water balance assessments prepared for each irrigation scheme;
- Identification of opportunities to improve water use efficiency in the agricultural sector;
- Benchmarking of irrigation water use efficiency and setting irrigation water use efficiency targets for each scheme;
- Preparation of an irrigation water management plan for each irrigation scheme;
- Capacity building of the Government Water Schemes (GWS), Irrigation Boards (IBs) and Water User Associations (WUAs) to implement the identified opportunities to improve irrigation water use efficiency.

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

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

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

1.3 Structure of the report

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

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

Chapter 2 describes the catchment characteristics of the Pongola River catchment in which the Impala Irrigation Scheme is situated.

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

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

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

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

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

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

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

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

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

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

Chapter 13 provides a conclusion and recommendation for the Scheme.

2 CATCHMENT CHARACTERISTICS OF PONGOLA RIVER CATCHMENT

2.1 Overview

The Impala Irrigation Scheme is situated in the uPhongola Local Municipality, surrounding the town of Pongola. **Figure 2.1** presents the locality map of the Impala Irrigation Scheme area. The Pongola River has its headwaters in the Paulpietersburg area in the eDumbe Local Municipality. The major tributary of the Pongola River is the Bivane River. The total catchment area is estimated to 8 395 km^2. There are two major storage dams in the catchment, namely the Bivane Dam which was constructed and is owned by the Impala Water User Association (previously an Irrigation Board) to improve the security of supply to its irrigators; and the Pongolapoort Dam, situated downstream of the Impala scheme, in the gorge where the Pongola River cuts through the Lebombo Mountains.

The Pongola River flows from the gentle terrain before it joins the Usutu River and becomes the Rio Maputo in Mozambique. The Maputo River then flows through undulating and flat plains before discharging into the Indian Ocean on the southern shores of Maputo Bay. The topography of the catchment downstream of the irrigation scheme area is generally flat at an altitude of 900 m to 1200 m above mean sea level.

2.2 Climate and rainfall distribution

The climate and temperature variations of the Pongola River catchment are closely related to elevation. The study area experiences extreme conditions during the summer months (DWAF: 1999) with rainfall categorised into two climatic zones. The characteristics of the catchment indicate that there two climatic zones with the following mean annual precipitation:

- In the upper catchments where the catchment is characterised by rolling hills, the precipitation is between 900 mm and 1200 mm
- In the middle portion of the catchment, where the Impala Irrigation Scheme is situated, and the lower part of the catchment, the precipitation ranges between 600 mm and 700 mm. The low MAP indicates the need for irrigating the lands because of low rainfall in the Impala Irrigation Scheme area.

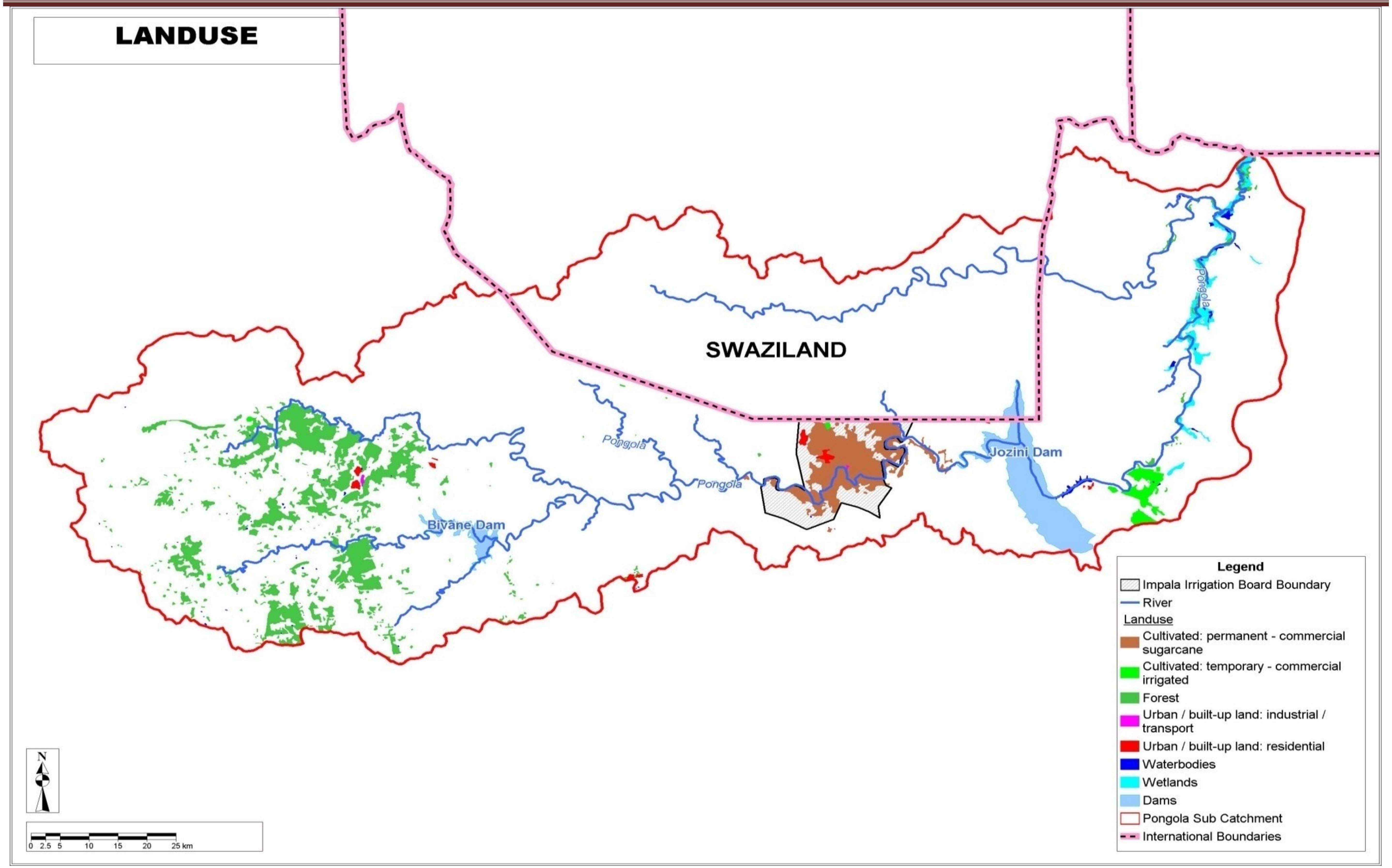

Figure 2:1: Land use Map of Impala Irrigation Scheme

The Pongola River catchment is divided into three evaporation zones. The headwaters of the Pongola catchment experience the lowest evaporation rate, estimated to range between 1300 mm to 1400 mm. From the Bivane Dam downstream, up to the confluence of Bivane and Pongola rivers, evaporation ranges between 1400 mm to 1500mm. The rest of the catchment has the highest evaporation where it ranges between 1500 mm to 1600 mm. It is also important to note that this is the zone where the Impala Irrigation Scheme is situated. This high evaporation zone also includes the Makhatini Flats, downstream of the Lebombo Mountain Range. The high evaporation rate has a direct correlation with the irrigation water use requirements.

2.2.1 Geology and soils of the catchment

The geology of the area supplied by Impala Water User Association (WUA) has predominantly an assemblage of sedimentary extrusive and intrusive rocks (see **Figure 2.2** below).

2.2.2 Geology and soils of the catchment

The geology of the area supplied by Impala Water User Association (WUA) is predominantly of the Pongola SuperGroup with assemblage of sedimentary extrusive and intrusive rocks towards the confluence with the sea.

There are three main soil types that are predominant in the Impala Irrigation Scheme area and are distributed across the scheme area as follows

(i) *Upper section of the scheme*: The soil depth downstream of the Grootdraai weir is moderate to deep clayey loam soils in steep terrain. The soils possess good balance between ability to convey water and the water holding capacity. The average soil depth is approximately 465 mm.

(ii) *Middle section of the irrigation scheme*: The soil depth in the middle and to the left bank of the Pongola River is moderate to deep clayey soils in undulating terrain. These clayey soils have a slow infiltration rate but a good water retention capacity. These soils are also more fertile because plant nutrients are retained within the soil. The average soil depth is deep at 942.5 mm. The water holding capacity of the clayey soils is very high compared to the clayey loam soils in the upper section of the scheme.

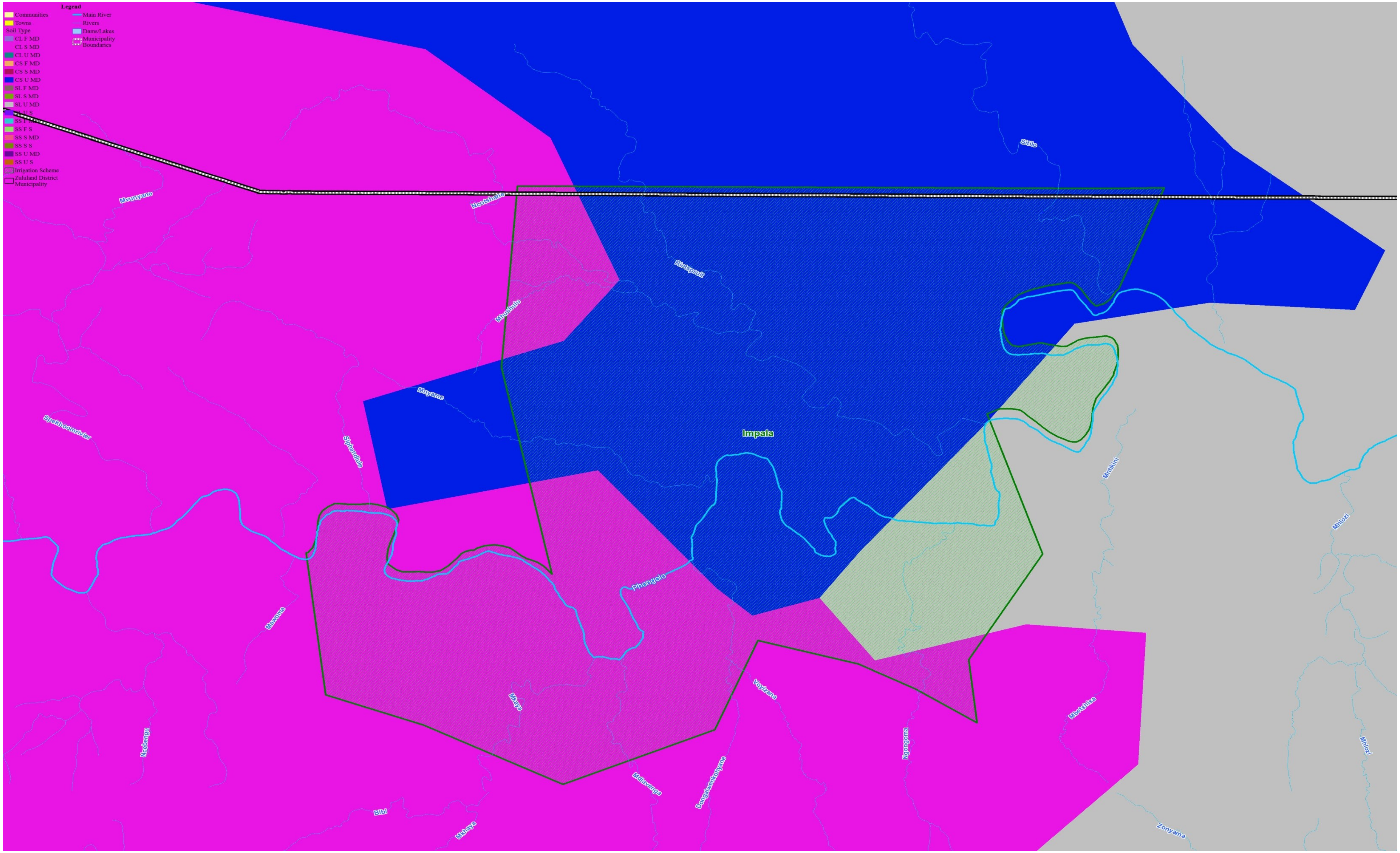

Figure 2:2: Soils Map of Impala Irrigation Scheme

(iii) *Lower parts of the Impala scheme* - The soils in the lower sections and the lower right bank of Pongola River are moderate to deep loam soils in undulating terrain. The soils have a lower water holding capacity compared to the rest of the scheme area. The average soil depth is approximately 650 mm.

Despite their substantial moisture reserves, fine-textured (clay) soils are generally less hospitable to plant roots than loamy soils. This is the reason for supplementary irrigation which is taking place in the Impala Irrigation Scheme.

3 OVERVIEW OF THE IMPALA IRRIGATION SCHEME

3.1 History of the scheme

This fertile valley of the Impala Irrigation Scheme is situated to the west of the Lebombo Mountains, upstream of the Pongolapoort Dam. The area was first settled in 1912, by Mr R.A. Rouillard, who formed Candover Estates. The Pongola Irrigation Settlement, as it was then known, was established by the Government, as an upliftment scheme and completed in 1935. The scheme was, at the time, fed by a gravity canal system, from the Grootdraai Weir, on the main stem of the Pongola River.

In 1954, nearly 20 years after completion of the scheme, a sugar mill from Esperanza on the KZN south coast was dismantled and reconstructed at Pongola.

The initial irrigated area of about 3 600 ha, increased over the years and the Department of Water Affairs later scheduled 6 959 ha at a quota of 18 000 m³/ha/annum. Despite efforts by the Department to constrain the area, it continued to increase over the years. DWA gave permission for expansion and the quota was later again reduced to 13 000 m³/ha/annum, to accommodate the increased area with the same volume of water. Irrigation, by pumping, above the canals, was only allowed with special permission, to replace lands below the canals which had become waterlogged and saline. A number of irrigators also started pumping directly from the river.

In 1992, the Impala Irrigation Board was formed, with a view to first taking over the operation of the scheme from the Department, and later the assets. Shortly after this, the Department commenced upgrading the canal system, to increase the capacity of the canals to accommodate peak summer flow demands. At that stage, an area of 10 652 ha was being irrigated from the canals. This upgrading is described in White Paper WP G-92 and the cost was estimated to be R 35 million, at April 1991 prices, but provision was made for escalation to R 60 million.

A new schedule under Section 88 of the 1956 Water Act was drawn up and approved by the Department in 1999. This schedule of 14 700 ha, of which 3 000 ha, was irrigated directly from the Pongola River, had a further reduced quota of 10 000 m³/ha/annum. This was partly as a result of pressure from the irrigators. Irrigation directly from the river had not been allowed previously.

Water shortages during the low flow months, continued to hamper cane production and after much negotiation with the Department, then Minister Kader Asmal agreed to assist Impala financially, with the construction of the Paris (now Bivane) Dam, on the Bivane River, a tributary of the Pongola River, upstream of the Grootdraai Weir. The site had previously been identified by the Department. With this assistance, the idea was proposed that the cost of the dam would be shared, with irrigators paying a third, DWA a third and Illovo Sugar a third.

During construction of the dam, the Impala Irrigation Board's proposal for transformation was accepted by the Minister of Water Affairs and Forestry and the Impala Water User Association (WUA), was established on 12 January 2001. This was done in terms of section 92 of the National Water Act, 1998, Act 36 of 1998. The Water User Association took over the duties and functions of the Impala Irrigation Board, and continued to operate the scheme as its own and Government will transfer the assets after a certain period of time after conclusion of the existing contractual agreement between the Department of Water Affairs and Impala Irrigation Board. The above schedule of 14 700 ha, forms an addendum to the WUA's Constitution.

The completion of the Bivane Dam meant that additional water would be available and as such, the Impala Irrigation Board proposed to the then Minister of Water Affairs and Forestry, Prof Kader Asmal, that an emerging farmer's settlement be established. The Minister approved the proposal and an additional 700 ha was to be developed for small black growers. An area of 535 ha was ultimately developed by the KZN Department of Agriculture and Environmental Affairs (DAEA) and 47 small growers were settled, on newly developed land, above the canal, at considerable expense. They are known as the Pumelela Farmers Association. During development of the scheme, the DAEA procurement process was delaying the establishment of the small growers and Impala had to use some of their Land Bank funds (with DWA permission) to complete the scheme. The interest from Land Bank Loan soared into the 23% which made it impossible to complete the dam and the Impala Board approached Rand Merchant Bank (RMB) for financing. The Impala Board requested Rand Merchant Bank to take over the Land Bank loan. Some irrigators objected to this and wanted to remain with the Land Bank, leading to dissatisfaction.

There were numerous other problems and the dam ended up costing more than double the budgeted estimate, owing to construction delays and high interest rates of up to 23%.

Illovo Sugar, who, at that stage, owned the Sugar Mill, did not agree to the idea of a third of the capital, but agreed opted for an incentive bonus to irrigators, for additional cane (as a result of the water from the dam) delivered to the mill. The bonus would be paid, provided a certain overall tonnage of cane was delivered to the mill. This would subsidise the Dam payments.

After much negotiation, the loan taken over by RMB and it was agreed, with the assistance of the DWA, that irrigators would pay a fixed payment of R 1 098 per ha per annum over 30 years.

However, all the irrigators were not happy. A group of dissatisfied irrigators canvassed support to not pay the perceived un-affordably high cost of the dam. In terms of obligations in the Impala Constitution and the National Water Act, Impala instituted section 59 notices of the arrear farmers who then took Impala to court in claims of spoliation. Unfortunately, the National Water Act, 1998, had not yet been tested in court and a number of high court cases followed, and three cases in the Supreme Court of Appeal. After many court cases, which dragged on for years, the court decided in the farmer's favour. Three of the cases ended in the Supreme Court of Appeal in Bloemfontein. With the escalation built into the funding agreement with RMB, the cost had by this time reached more than R 1 600 per ha/a, which was unaffordable. Impala continued negotiating with DWA and RMB and successfully negotiated lower charge, fixed at R 1 098 per ha/a. Both the Department and the RMB had to make substantial contributions to bring this about. DWA also contributed substantially towards Impala's legal costs, as the New Water Act was being tested.

The Illovo incentive scheme has been renegotiated with the new owners of the mill, TSB, and a conditional bonus is paid to all contracted sugar cane irrigators.

Since the construction of the Bivane Dam, Impala has enjoyed a much higher level of assurance of supply. When flows in the Pongola River are low, releases are made from the Dam and the water flows down the Bivane River, into the Pongola, supplementing the available water in the Grootdraai Weir. The Weir, the canals and structures are all still State-owned and the scheme is still a Government Water Scheme. The Impala Water User Association has a contractual agreement with DWA under which Impala manages the scheme as if it was its own and the Government will transfer the assets within a certain period of time after the conclusion of the said agreement.

3.1.1 Resource Poor Farmers

Forty-seven farmers from the Ntshangase, Similane and Ncotshane communities were selected to undertake sugarcane farming under irrigation at Pongola and have been operational since 2001. The arrangement with the Department of Water Affairs (DWA) was that the emerging farmers would not contribute towards the annual down payment as the construction loan of the dam as the grant contributions of DWA towards the Bivane Dam construction loan, is an offset towards the annual contributions of the emerging farmers.

3.2 Water use permits / licenses and contracts

3.2.1 Overview

The area of responsibility of the Impala Irrigation WUA area comprises 319 950 hectares with the irrigation area estimated to be 5% of the scheme area at 17 012 hectares. 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 Impala Irrigation Board was then transformed into a WUA on 12 January 2001. The scheme has a total scheduled area of 17 012 hectares, at a scheduled quota of 10 000 m^3/ha/a

3.2.2 Registered irrigation water use

The authorisation for the water use, within the Impala Water User Association's (WUA) area of jurisdiction, lies in the Schedule of rateable area for 14 700 ha, drawn up in terms of section 88 of the1956 Water Act, and approved by the Department in 1999. This Schedule forms an Annexure to Impala's WUA Constitution. This scheduled use is deemed to be an Existing Lawful Water Use under section 32 of the National Water Act, 1998 and as such, does not require a Licence, but does need to be registered. An additional area of 2 300 ha of commercial irrigation is not scheduled but registered. The irrigators have permission to continue irrigating this additional area until Compulsory Licensing takes place, provided they pay all charges due to Impala.

The current irrigated area is 17 012 hectares. Each of the irrigators in the Impala Irrigation Scheme area is registered individually and the Registration certificates reflect the scheduled as well as the non-scheduled areas. The permit for domestic water use in Pongola and surrounding communities supplied by the scheme is held by Zululand District Municipality as the Water Service Authority (WSA), while the permit for the industrial water use for the sugar mill is held by TSB.

The total allocations for the scheme is 170.01 million m^3/a, at 10 000 m^3/ha/a. A review of the Water Allocation Registration Management System (WARMS) database indicates that the total registered water use in the scheme area is 151 million m^3/a, which is supplied from the canal infrastructure while approximately 30 million m^3/a abstract directly from the Pongola River and do not benefit from the existing canal infrastructure.

3.2.3 Domestic and industrial water use allocation

Besides the water use permits and licences held by the irrigators, Impala WUA also supplies the Zululand District Municipality to meet domestic water requirements of the town of Pongola and surrounding areas through its conveyance infrastructure. The domestic water is registered with ZDM and is 2.038 million m^3/a. This is supplied through the Transvaal main canal and alternatively from the river during maintenance periods.

The Impala WUA also supplies industrial water to Pongola Sugar Mill which was recently acquired by TSB from Illovo Sugar. The registered water use for the mill is 2.5 million m^3/a, which is supplied via the Wonderfontein canal. The mill can also be supplied via the so-called D9 canal, fed by the Transvaal Main canal and they are also equipped to pump directly from the river during dry week maintenance period.

3.3 Irrigated areas and types of crops

3.3.1 Overview

The typical crop mix across the Impala Irrigation Scheme is indicated in **Table 3.1** below. The main crops that are under irrigation, include sugar cane (15 872 ha.), citrus (370 ha), vegetables (approximately 230 ha and varies.), maize (320 ha.), mango (120 ha.) and some pecan/macadamia. The table below illustrates the importance of sugar cane on a per hectare basis in the Impala Irrigation Scheme, with all other crops comprising 7% of the total. Therefore there is very little crop mix taking place in the scheme area as the scheme is driven by the need to meet the cane requirements of the Pongola sugar mill.

Table 3:1: Typical irrigated area in Impala Irrigation Scheme [a]

Crops	Hectares	%		Crops	Hectares	%
Sugar cane	15,872.00	93%		Maize	320.00	2%
Citrus	370.00	2%		Mango	120.00	1%
Vegetables	230.00	1%		Pecan/Macadamia	100.00	1%
				Total	17,012.00	100%

The above statistics were provided by Mr J. Boonzaaier.

3.3.2 Sugar cane

Approximately 93% (i.e. 15,872 ha) of the total area under irrigation is sugarcane in the Impala Irrigation Board area. All of the sugarcane is irrigated (*Boonzaaier, pers comm*).

In Pongola, sugar cane is planted throughout the year except during winter months (May to August). It should be noted that sugar-cane in South Africa is often grown for longer than 12 months. The sugarcane is harvested from March to December to supply the TSB sugar mill. The average production yield of sugarcane is 100 tonnes per hectare.

With the sale of the Pongola sugar mill to TSB, the mill has been refurbished and is now in a position to crush more cane than its original daily capacity of 4 500 tonnes or annual production of 1.415 million tonnes. This, together with the incentives given to sugar cane growers, is likely to see a significant increase in production, provided more efficient water conservation and farming methods are employed.

3.3.3 Citrus

Approximately 2% (370 ha) of the irrigated area in the Impala Irrigation scheme is under citrus.

3.3.4 Maize

At the time of the writing of the plan, approximately 400 ha in the Impala Irrigation scheme, are under maize. The planting season for Maize starts in September/October, with harvesting taking place in April. The average maize production could not be ascertained for the scheme area.

3.3.5 Mangoes

There are approximately 300 ha of mango in the Impala Scheme area.

3.4 Historic water use

The historic water use of the Impala Irrigation scheme obtained from available records from the limited records is provided in the **Table 3.2**.

3.4.1 Historic water use - Impala Irrigation Scheme

The most recent eight water years of available data (2005/2006 to 2012/13) demonstrate a range of water use in the Impala Irrigation Scheme. Irrigation agriculture water use over the period has ranged from 87.2 million m^3/a in 2010/11 up to 118.24 million m^3/a in 2011/12, with an eight-year average of 102.43 million m^3/a.

Table 3:2: Historic water use levels (million m^3/a) for Impala Irrigation Scheme area

User	2005/6	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	6 year (2005 -2013) average
Irrigation	118.14	96.81	115.87	112.80	99.66	87.271	118.235	70.64	102.43
Industry	0.68	0.74	0.73	1.06	1.43	1.35	1.292	1.027	1.04
Domestic	2.526	2.39	2.98	3.24	3.31	2.653	3.913	3.559	3.07
Downstream water use							17.399	8.078	12.74
Total	121.34	99.94	119.58	117.09	104.40	91.27	140.84	83.30	109.72
Inflow to Scheme	201.45	175.554	185.314	191.167	180.277	173.462	217.695	162.831	185.97
Gross water losses	80.11	75.61	65.74	74.08	75.88	82.19	76.86	79.53	76.25
	40%	43%	35%	39%	42%	47%	35%	49%	41%

- Gross water losses includes downstream uses below Mhlati Weir as well as releases for salinity

Over the 8 years approximately 62% of the water allocation was used by the irrigators in the Impala irrigation canal system. The other major water use is the municipal use. Domestic water use has ranged from 2.4 million m^3/a in 2006/07 to 3.9 million m^3/a in 2011/12 at an average domestic water use of 3.07 million m^3/a over the period.

The scheme also provides for process water by Illovo sugar mill. The household consumption has been constant over the 8 year period.

No historical records are available to determine the volume of water returned back to the river system at the tail water ends and canal discharge points from branch canals.

3.4.2 Historic volumes of water diverted into the canal system

The average volume of water diverted into the Impala irrigation canal system at the Grootdraai weir to match the irrigation and domestic water demands as well as the water losses due to evaporation and seepage losses was 185.97 million m^3/a (see **Table 3.2** above). When compared to the demands from the canal infrastructure the average additional water to meet the water losses and operational spills is 41% of the total demand.

4 INVENTORY OF THE EXISTING WATER INFRASTRUCTURE

4.1 Overview

The Impala Irrigation Scheme comprises a balancing weir, main irrigation canal infrastructure, primary irrigation conveyance infrastructure which diverts water from the Pongola River into the scheme, the main primary canal distribution system, i.e. the Transvaal and Natal canals which deliver the water ordered to the irrigators at their farm turnouts through a number of sluice gates and Parshall flumes to measure the volume of water delivered to the irrigator.

Prior to the construction of Bivane Dam, one of the aspects that were agreed upon between the Department of Water Affairs (DWA) and Impala Water User Association (WUA) was to increase the capacity of the irrigation canals. The primary canals where therefore raised to ensure that the peak summer crop demand could be delivered. The raising is described in White Paper WP G-92.

4.2 Storage Dams

4.2.1 Bivane Dam

Construction of the Bivane Dam commenced in 1996 with the dam being commissioned in 2000. Its purpose was to address the water shortages and restrictions that the farmers were experiencing during the low flow periods because of dependency on the run-of-river abstraction from the Pongola River.

The Bivane Dam has a capacity of 115 million m^3. Water is only released to supply Impala Irrigation Scheme, when the Pongola River flow cannot meet the demands of the irrigators based on the weekly orders. The volume of water to be released is dependent on the volume of flow in the Pongola River system, which is measured at the Upper Pongola weir.

It is important to note that in order to supply the irrigation water requirements; it takes between 36 to 48 hours for the water to reach the Grootdraai Weir from the time it is released from the Bivane Dam, depending on the immediate prior flow regime.

Besides releases for the Impala Irrigation Scheme, the Bivane Dam also continuously releases water to meet the downstream environmental water requirements (EWR) of the Pongola River System.

4.2.2 Grootdraai weir

The Grootdraai weir provides the diversion structure for the Pongola River system, including water released from the Bivane Dam and diverts the irrigation water into the Impala Irrigation

Scheme on the right bank of the Pongola River. As illustrated in **Photo 4.1** below, the capacity of the Grootdraai weir is being affected by the increasing siltation taking place.

Depending on the irrigation water requirements, based on the ordering schedule provided by the irrigators in the Impala Scheme, water is diverted into the main canal by adjusting the sluice gates at the weir. Because of the high siltation taking place upstream, there is a Impala trap before the irrigation water enters the main canal, where it is measured.

Photo 4.1: View of the Grootdraai weir from the Right Bank

4.3 Irrigation conveyance infrastructure

Figure 4.1 below illustrates the conveyance and distribution infrastructure of the Impala Irrigation Scheme. Water, is diverted at the Grootdraai Weir into the main canal, which then bifurcates into the two primary canals, the so-called Impala and Transvaal Canals. The canal infrastructure comprises primary and secondary canal systems, as well as siphons at river crossings.

There are also branch canals which form the distribution system to the irrigators in the irrigation scheme. The total length of the canal system is 217 km, most of which is concrete lined and with only 3 km of canal, not lined.

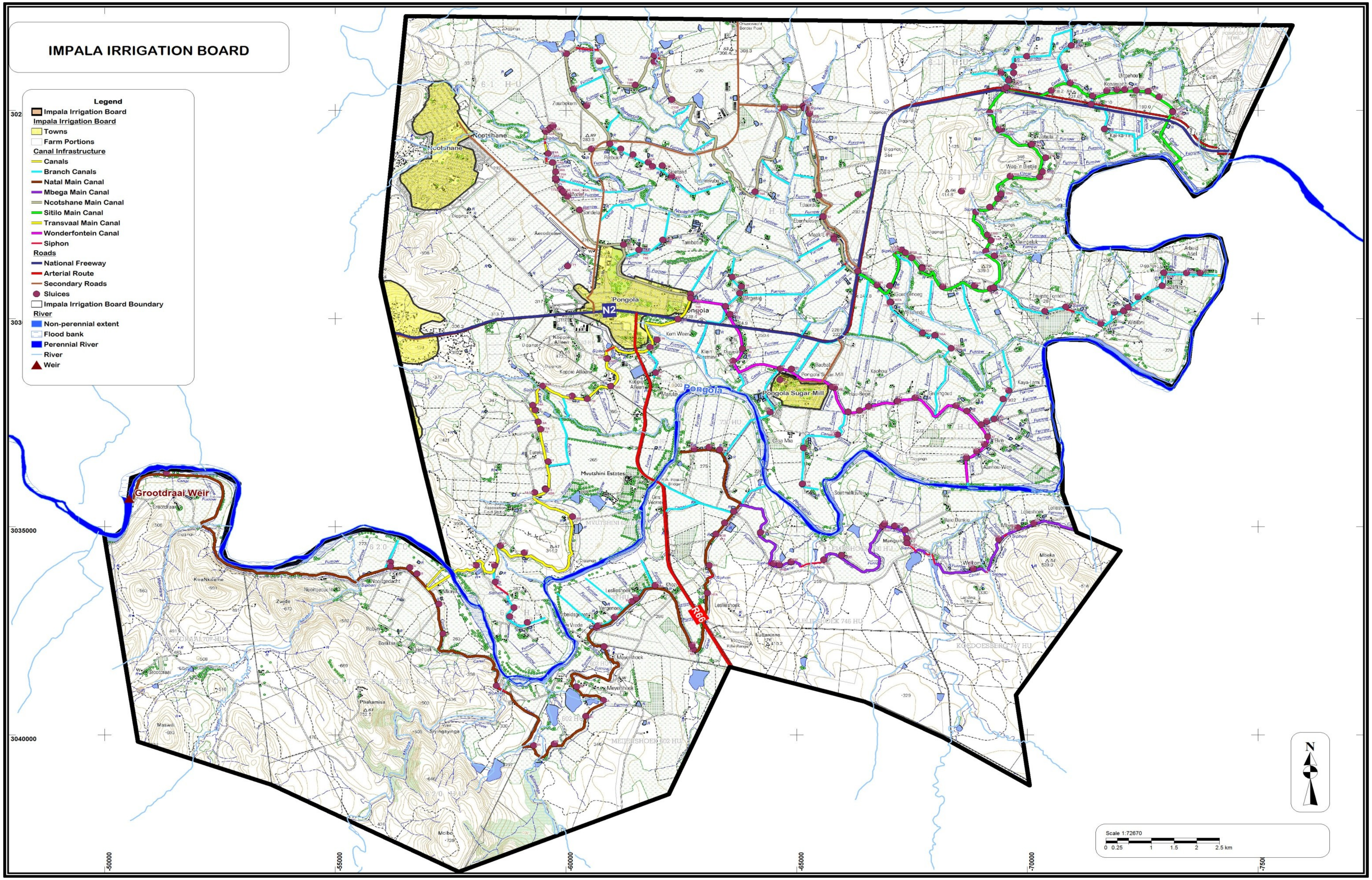

Figure 4:1: Impala Irrigation Scheme -Infrastructure

4.3.1 Main irrigation canal

The main canal comprises 9.4 km of concrete lined canal infrastructure. The maximum design capacity of the main canal is 10 m^3/s (or 315 million m^3/a). The canal system has a peaking factor of 1.85. There are 6 sluice gates on the main canal, as well as a branch canal supplying the irrigators along the main canal (see **Figure 4.1** below). The condition of the canal infrastructure where it traverses the mountain is fair but significant leakages are observed.

4.3.2 Right bank canal system

Table 4.1 below lists the canal infrastructure on the right bank of the Pongola River. On the right bank, there is the main canal from the Grootdraai weir as discussed above. Furthermore, there are three primary and a series of branch canal systems with a total length of 58.14 km which include the following:

(i) *Natal main canal*: This is the primary canal, which conveys the irrigation water on the right bank of Pongola River, after the bifurcation of the Main canal. It is estimated that there is 19.65 km of concrete lined canal infrastructure with a maximum hydraulic capacity of 2.9 m^3/a (or 91.5 million m^3/a.)

(ii) *Mbega canal*: This is the main canal on the right bank supplying the water users up to their scheduled quota. It is approximately 4.79 km of concrete lined and 6.2 km of earth canal system. The canal has a maximum hydraulic capacity of 1.4 m^3/s (44 million m^3/a).

(iii) *Wonderfontein secondary canal:* This is the secondary canal on the left bank, supplying the water users with their scheduled quota. It is approximately 11.65 km of concrete lined canal system and has a maximum hydraulic capacity of 1.4 m^3/s (44 million m^3/a).

(iv) *Branch canals:* - There are four branch canals with a total length of 7.4 km. There are two branch canals on the Natal main canal and two branch canals on the Wonderfontein canals. The hydraulic capacity of these branch canals vary as their geometry is different.

Table 4:1: Impala Irrigation Scheme – Canal Infrastructure on the right bank of Pongola River

Item No	Canal Name	Type of canal	Length of canal		Total canal
			Concrete lining	Earth canal	
1	Main canal	Primary canal,	9.4	0	9.4
2	Natal Main Canal	Primary canal,	19.65		19.65
3	Mbega canal	Primary canal,	4.79	6.2	10.99
4	Wonderfontein	Primary canal,	10.71	0	10.71
	Total length of main canals		*44.55*	*6.2*	*50.75*
5	Ntk 1	Branch canals	1.69	0	1.69
6	Ntk 2	Branch canals	0.73	0	0.73
7	Wtk 3	Branch canals	2.91	0	2.91
8	Wtk 4	Branch canals	2.06	0	2.06
	Total length of branch canals		*7.39*	*0*	*7.39*
Total length of canal system right bank (km)			51.94	6.2	58.14

4.3.3 Left bank canal system

Table 4.2 below lists the canal infrastructure on the left bank of the Pongola River. This is where most of the irrigation scheme is situated. On the left bank, there is one primary canal, three secondary canals and a series of branch canal systems with a total length of 125.06 km of canal infrastructure which includes the following:

(i) *Transvaal primary canal:* This primary canal bifurcates from the main canal on the right bank and passes under the Pongola River via a siphon to the left bank. It

comprises approximately 15.65 km of concrete lined, half lined and earth canal infrastructure and conveys irrigation water for the emerging farmers. The total length of the half lined and earth canal infrastructure, is 1.71 km. The Transvaal canal is the largest primary canal, with a maximum design capacity of 7.1 m^3/s (or 223.9 million m^3/a) in reach 1 and 6.4 m^3/s (201 million m^3/a) in reach 2. The canal system has a peaking factor of 1.85.

(ii) *Ncotshane secondary canal*: This is the secondary canal which conveys the irrigation water for downstream irrigators. It is estimated that there is 24.6 km of concrete lined and earth canal infrastructure with a maximum hydraulic capacity ranging from 2.3 m^3/s (or 72.5 million m^3/a) in reach 1 to 1.5 m^3/s (47.3 million m^3/a).

(iii) *Sitilo secondary canal*: This is the secondary canal on the left bank, supplying the water users with their scheduled quota. It is approximately 11.65 km of concrete lined, half line and earth canal system. The total length of the half lined and earth canal infrastructure is 2.12 km. The canal has a maximum hydraulic capacity, ranging from 1.8 m^3/s (56.8 million m^3/a) to 1.2 m^3/s (44 million m^3/a).

(iv) *D9 Canal*: This is the secondary canal on the left bank, supplying water users. This canal is approximately 3.6 km of concrete lining.

The total length of the main canals on the left bank is estimated to be 60.89 km of which approximately 17.58 km of the canal is unlined. There 15 branch canals in the Transvaal main canal system. The total length of these branch canals is approximately 27.88 km of concrete lined canals.

Table 4.2 below provides details of the canal infrastructure supplying the scheme.

Table 4:2: Canal Infrastructure on the left bank of Pongola River

Item No	Canal Name	Type of canal	Length of canal		Total canal
			Concrete lining	Earth canals	
1	Transvaal canaal	Primary canal	5.54	10.11	15.65
2	Notchane canaal	Primary canal	22.29	3.21	25.5
3	Sitilo canaal	Primary canal	11.88	4.26	16.14
4	D9 canaal	Primary canal	3.6	0	3.6

Item No	Canal Name	Type of canal	Length of canal		Total canal
			Concrete lining	Earth canals	
	Total length of main canals		*43.31*	*17.58*	*60.89*
5	Tk 1	Branch canal	2.3	0	2.3
6	Tk 4	Branch canal	0.75	0	0.75
7	Tk 5 A	Branch canal	1.44	0	1.44
8	Tk 5 B	Branch canal	1.25	0	1.25
9	Tk 6	Branch canal	1.66	0	1.66
10	Tk 7	Branch canal	2.96	0	2.96
11	Tk 8	Branch canal	0.36	0	0.36
12	Tk 9	Branch canal	0.03	0	0.03
13	Tk 10	Branch canal	3.07	0	3.07
14	Tk 11	Branch canal	6.15	0	6.15
15	Tk 12	Branch canal	3.41	0	3.41
16	Tk 13	Branch canal	1.05	0	1.05
17	Tk 14	Branch canal	1.87	0	1.87
18	Tk 15	Branch canal	1.58	0	1.58
	Total length of branch canals		*27.88*	*0*	*27.88*
Total length of canal system left bank (km)			**71.19**	**17.58**	**88.77**

4.4 Irrigation storage and regulation system

4.4.1 General

It is important and significant to note that besides the balancing dam on the small grower's system, there are no other balancing storage dams on either the left bank or the right bank of the Impala Irrigation Scheme. This provides significant operational challenges to Impala WUA depending on the distribution of users requesting water for the week.

For example, consider a scenario where, for the week, the main requests for water for the following week are the downstream users such as in the Sitilo primary canal. This will require the WUA diverting water from the Grootdraai weir for approximately 40 km before it is diverted into the branch canals and released at the sluice gates and measured at the Parshall flume outlets.

Given the canal geometry of the Transvaal primary canal, it is likely that there will be significant evaporation losses and leakages of the irrigation. The implications of a lack of balancing dams in the Impala Irrigation Scheme are discussed in more detail in the irrigation water budget section and water management issues.

4.5 Irrigation infrastructure distribution system

As illustrated in **Figure 4.1** and **Tables 4.1** and **4.2** above, there are approximately 18.65 km of branch canals on the right bank of the Pongola River which distribute the irrigation water to approximately 50 sluice gates.

On the left bank, which is where most of the irrigation scheme lies, the distribution canal infrastructure comprises a total length of 57.85 km. The canals distribute the water to approximately 285 sluice gates.

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

The hydraulic capacity of the different distribution canal infrastructure was available; which can be used to compare with the maximum and average demands expected in the different irrigation sections.

4.5.1 Farm Dams

The irrigation water supplied by the Impala WUA is delivered mainly to the irrigator's farm dams. The actual water use is therefore dependent on the irrigation scheduling requirements of the individual farmer from the farm dam based on the crop water requirements and the timing of irrigation as required from the soil-water requirements.

4.6 Flow Measurement and telemetry system

4.6.1 Measurement of flow into the scheme area

Figure 4.2 below provides the existing location of the flow measurement system required to manage the irrigation water requirements in the Impala irrigation scheme. As illustrated, the first measurement of the water diverted from the Pongola River system takes place at the Grootdraai weir. The weir measures the total volume of water released into the main canal to the Impala Irrigation Scheme. It is important to note that of the 390 abstraction points to the irrigators approximately 40 abstraction points are directly from the Pongola River, within the Impala Irrigation Scheme area.

4.6.2 Measurement into the various canal systems

The Impala Irrigation Scheme has two main irrigation canals, namely the Natal primary canal supplying the water users on the right bank of the Pongola River, and the Transvaal primary canal supplying the water users on the left bank of the Pongola River. There are flow measuring weirs constructed at the inlets of these canals. This is illustrated in **Figure 4.1** below.

There is flow measurement devices installed at the inflow into the three primary canals as follows:

(i). *Transvaal and Natal main canals* – There are two flow measurements devices to enable measurement of flows into the Transvaal as well as into the Natal main canals from the main canal connecting these canals with the Grootdraai weir

(ii). *Transvaal canal tail end, Ncotshane, D9 and Sitilo canals* – There are flow measurements at the tail end of the Transvaal canal. The flow measurement devices allows for the inflow into the Ncotshane, D9 canal which connects the Wonderfontein as well as inflow into the Sitilo main canals to be measured as well as monitor flows ito each canal system.

(iii). *Mbega canal measurement* – there is a measurement device at the inflow into the Mbega canal (iv). Canal tail ends – there are flow measurements at three canal tail ends which are the Sitilo canal tail end, the Wonderfontein canal tail end as well as the Mbega canal tail end.

No other direct measurements of water, including the 15 branch canal end returns are currently performed in the system.

4.6.3 Measurement at user outlets

The Impala Water User Association (WUA) measures the weekly volume of water delivered to the water users at the farm gate using sluice gates and Parshall flumes. There are approximately 390 sluice gates in the irrigation scheme area.

There is a telemetry system at Grootdraai weir, where water is diverted into the primary canal and at Mhlati weir where the return flow is measured to complete a water audit of actual water use in the irrigation scheme area taking into account the non-measured flow from the three main tributaries from Swaziland.

4.6.4 Existing telemetry system

The Impala Irrigation Scheme has a telemetry system which it uses to monitor the flow at various sites of the scheme (see **Figure 4.2** below).

A telemetry system was installed to cover 20 diversion points for the Impala Irrigation Scheme to periodically, and on demand, poll for data from the field devices (remote telemetry unit (RTU)), process the data into a central data base (base computer) at the Impala WUA offices, send controls to field devices and display the data in useful formats to water operation personnel.

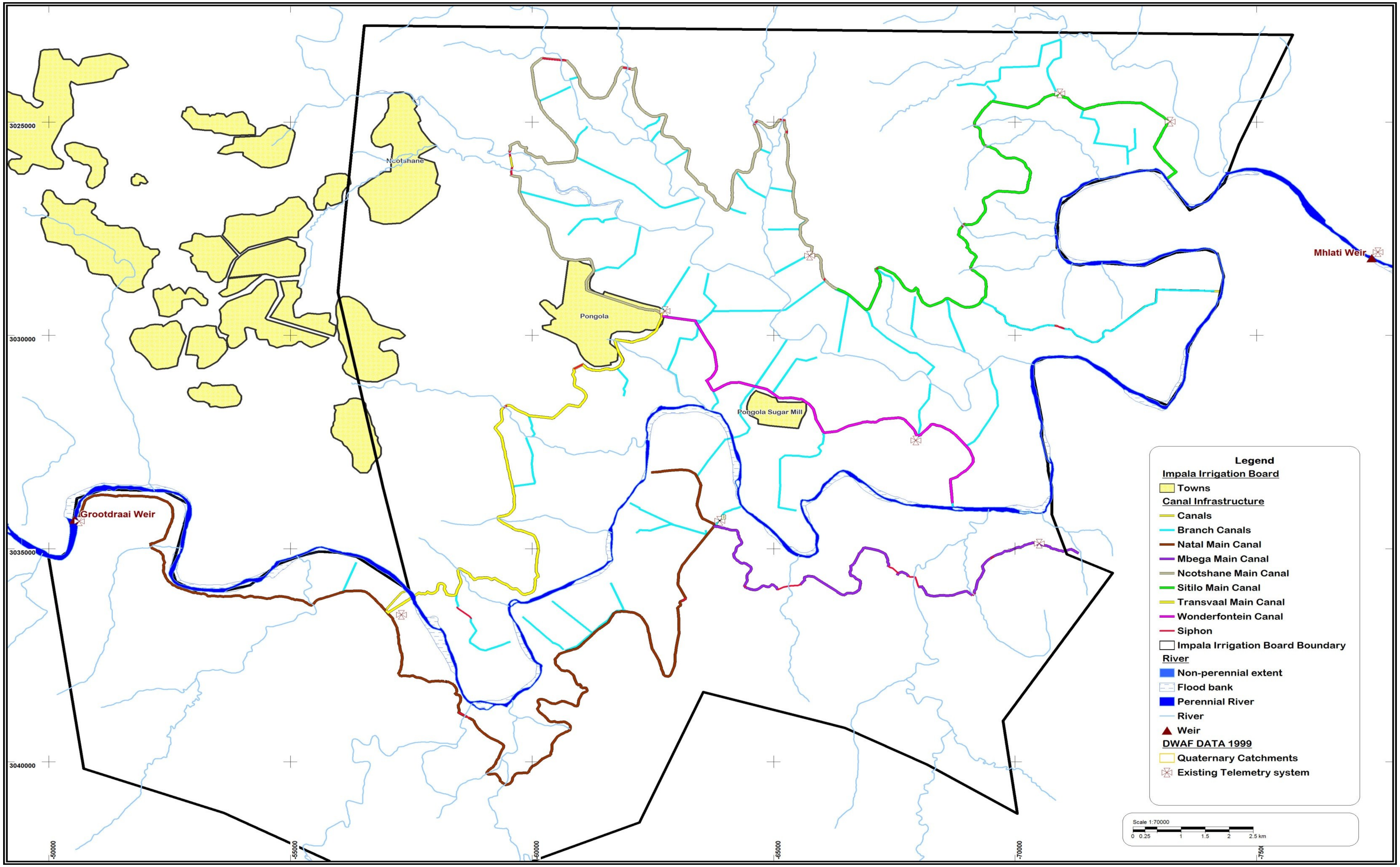

Figure 4:2: Schematic layout of the Impala Scheme with the existing water measurement system

A Base System is located at the Impala WUA Offices in the town of Pongola and consists of a base computer, which holds the central database to store and convert all of the data from the RTUs, and an antenna to receive from and transmit data to the remote telemetry systems. The base computer is equipped with software that will display current, last 24 hours and monthly water and flow level data of any or all of the RTUs. It also stores all engineering and conversion data necessary for converting flow.

Photo 4.2: Telemetry system at the main canal downstream of Grootdraai weir

A remote telemetry unit outstation was installed at each of the 13 flow measurement sites. Each system consists of the following:

- Remote Telemetry Unit (RTU)
- Radio and RF Modem
- AC/DC Linear Power Supply.

These items have been mounted inside steel enclosures. The RTU has been connected to the Parshall flumes and the system programme with the calibration coefficients for each site to provide the flow reading when in operation.

The above mentioned Android System was not compatible with the existing WAS system. This had resulted in the telemetry not being utilised because of compatibility problems. As a result, the Water Control Officers (WCO) at the Grootdraai weir and Impala / Transvaal diversion point were manually reading the flow levels and telephoning the records on a 2-hourly basis to the office. This process is subject to human error with the consequent result that the integrity of existing flow records are likely to questioned at times. However, the compatibility issue with WAS has since been rectified.

5 INFRASTRUCTURE CONDITION ASSESSMENT

5.1 Overview

In order to determine the condition of the canal infrastructure, a methodology has been developed known as the Rapid Assessment Tool (RAT). However this was not used. This is a combination of methodologies designed to provide a quick and cost-effective analysis of condition within an irrigation scheme.

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

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

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

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

There have been no condition assessment surveys that were conducted on behalf of the Impala Water User Association (WUA) that were available. This will be required in future to enable proper planning on the refurbishment and renewal of the canal infrastructure.

5.2 Canal Condition Evaluation

Although it was not possible to undertake condition assessment of the irrigation canals of the Impala Irrigation Scheme, because at the time of developing the WMP, there were no dry periods to inspect the canals, our preliminary investigations have been used to provide a broad situation assessment of the condition of the infrastructure.

Before discussing the condition of the Impala irrigation canal system, a list of criteria for undertaking canal condition assessment was developed for use in the implementation phase. The Canal Condition Evaluation component of RAT includes visual rating methodologies on:

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

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

- general condition of the canals
- presence of cracks (hairline, pencil-size, and large)
- amount of patchwork
- vegetation in canal and along embankment

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

Table 5:1: General Condition rating

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

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

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

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

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

Table 5:4: Vegetation growing in canal lining

Rating	Definition
0	None
1	Sparse
2	Moderate
3	Dense

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

Rating	Definition
1	Normal; rain-fed weeds only
2	Canal fed grass or small weeds only

3	Moderate; bushes & some small to no trees with no water near levee or drain
4	Dense; more bushes & larger trees, little or no standing water, little or no aquatic vegetation
5	Dense and lush; bushes, trees, lots of aquatic vegetation with standing water

5.3 Results and analysis of canal infrastructure condition assessment

5.3.1 Overview

The preliminary condition assessment of the canal infrastructure of the Impala irrigation scheme was done based on the field visit conducted in April 2011. These are discussed below. The findings of the condition of the infrastructure are provided in **Table 5.6** below as provided by the scheme managers and are discussed in the following sections.

As illustrated in the Table below the general condition of the main canals are in a good to fair condition. However the smaller branch canals are fair to poor. However this only comprises approximately 24% of the total length of the canal and these are the smaller canals. The conclusion that could be reached is that the condition of the canal infrastructure is in a good to fair condition.

5.3.2 Condition evaluation of the headwork's

Although no detailed condition assessment could be undertaken on the Impala Irrigation Scheme because the canals were operational, a preliminary assessment was however conducted during the site visit that was conducted in April 2011. Figures 3.3 -3.8 contain photographs which illustrate some of the rating criterion based on the site visit to the Impala Irrigation Scheme. These are discussed below.

As illustrated in **Photo 5.1** below, the Grootdraai weir which diverts the irrigation water requirements into the Impala Scheme indicates significant sediment build up from the land-use practices upstream. This has reduced the capacity of the diversion weir.

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

Table 5:6: General condition of the canal infrastructure in Impala Irrigation Scheme

Item No	Canal Name	Type of canal	Length of canal		Total canal	General Condition
			Concrete lining	Earth canals		
1	Main canal	Primary canal,	9.4	0	9.4	Fair
2	Natal Main Canal	Primary canal,	19.65		19.65	Poor
3	Mbega canal	Primary canal,	4.79	6.2	10.99	Fair
4	Wonderfontein	Primary canal,	10.71	0	10.71	Fair
5	Transvaal canaal	Primary canal	5.54	10.11	15.65	Good
6	Notchane canaal	Primary canal	22.29	3.21	25.5	Poor
7	Sitilo canaal	Primary canal	11.88	4.26	16.14	Fair
8	D9 canaal	Primary canal	3.6	0	3.6	Good
9	Ntk 1	Branch canals	1.69	0	1.69	Fair
10	Ntk 2	Branch canals	0.73	0	0.73	Fair
11	Wtk 3	Branch canals	2.91	0	2.91	Fair
12	Wtk 4	Branch canals	2.06	0	2.06	Poor
13	Tk 1	Branch canal	2.3	0	2.3	Poor
14	Tk 4	Branch canal	0.75	0	0.75	Fair
15	Tk 5 A	Branch canal	1.44	0	1.44	Poor
16	Tk 5 B	Branch canal	1.25	0	1.25	Poor
17	Tk 6	Branch canal	1.66	0	1.66	Poor
18	Tk 7	Branch canal	2.96	0	2.96	Poor
19	Tk 8	Branch canal	0.36	0	0.36	Poor
20	Tk 9	Branch canal	0.03	0	0.03	Poor
21	Tk 10	Branch canal	3.07	0	3.07	Fair
22	Tk 11	Branch canal	6.15	0	6.15	Fair
23	Tk 12	Branch canal	3.41	0	3.41	Poor
24	Tk 13	Branch canal	1.05	0	1.05	Poor
25	Tk 14	Branch canal	1.87	0	1.87	Poor
26	Tk 15	Branch canal	1.58	0	1.58	Fair
Total length of canal system right bank (km)			**123.13**	**23.78**	**146.91**	

Photo 5.1: Photo of the Grootdraai weir illustrating build-up of sediment

Although the weir was overflowing, a preliminary visual inspection indicated that the weir did not exhibit any hairline, pencil size or large cracks. Therefore the condition rating on cracks was considered to be none to sparse which is a rating of 1. However the vegetation and sediment build up as illustrated in the above photo was considered to be moderate to dense with a rating of 3

5.3.3 Condition evaluation of the main canal section

Although no formal condition assessment was carried out on the main canal section of the Impala Irrigation Scheme, a review of the aerial photographs of the sections, as well as discussions with the Chief Executive Manager and the Water Control Officer, were conducted. It is understood that the concrete at the first section of the main canal along the mountain (the so-called Krantz section), is deteriorating in a few locations, with an apparent leak in one of the tunnels. Repairs are needed to prevent further damage. Some repairs have subsequently taken place. There are also sections of cracked concrete through which water is leaking. In places, the stability of the canal structure on the mountainside needs assessment.

Other problematic structures on the main canal include erosion around the sides of the drain culverts that pass under the canal and concrete deterioration on the super passages.

5.3.4 Condition evaluation of the primary canals

Photo 5.2 below indicates the pencil size marks and patchwork on the section of the canal. However, there is no structural damage that could be identified during the site visit.

Photo 5.2: Pencil marks and patchworks

5.3.5 Condition of the branch canal

Photo 5.3 below, however, indicates large cracks and leaks, which were identified on one of the branch canals on the Impala main canal. The condition of the canal section was considered to have continuous cracks and was given a rating of 5. The condition of such branch canals were considered to represent poor section of the canal infrastructure.

Photo 5.3: Photo of the large cracks on the branch

5.3.6 Condition evaluation of the siphons

Photo 5.4 below indicates the leakages that were identified along the siphon on the branch canal between the Natal canal and Wonderfontein canal before it was repaired. The length of the siphon was estimated to be nearly 3 km long and passes under the Pongola River. There were no air valves that were identified. Indications were that the siphon was blocked and because of the fact that there may have been air entrapment, this may have caused siphon breakage. The siphon has subsequently been repaired and is no longer leaking.

Photo 5.4: Leakage from the Wonderfontein siphon

Photo 5.5: Leakage due to blockage on Wonderfontein siphon (*as at 23 April 2011*)

6 SCHEME OPERATIONS AND OPERATING PROCEDURES

6.1 General scheme options

Before the construction of Bivane Dam, to improve the assurance of supply for the irrigators, the scheme used to experience shortages on an annual basis, during the low flow periods of the Pongola River. This was addressed with the construction of the Bivane Dam, which provides the irrigators' scheduled quota throughout the year. Since the dam became operational, the irrigation scheme has only experienced restrictions twice in 2003 and 2012, where the scheduled quotas have not been delivered to the farmers.

The dam is owned and operated by the Impala Water User Association (WUA). Water is only released for two reasons; (i) to meet the environmental water requirements (EWR) of the Bivane River and the lower reaches of Pongola River upstream of the Pongolapoort Dam; and (ii) releases for Impala Irrigation Scheme when the flows in the Pongola River, excluding the EWR, are lower than the weekly requested demands from users in the scheme area.

6.2 Water ordering and delivery procedures

6.2.1 Overview

The Impala WUA has formalised and documented scheme regulations that describe the procedures for application and delivery of water to users in the scheme. The irrigation water year runs from 1 March to 28 February of the following year.

In order to ensure that the irrigators receive their scheduled quota or a portion of their scheduled quota, if the available water is not sufficient to meet the full allocation as and when required, the Impala WUA operates the irrigation scheme based on "delivery on request" where each water user (irrigator) must submit a written request on a weekly basis. Water is delivered to some 390 abstraction points along the canal systems.

6.2.2 Operation of matching irrigation supply and demand

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

(1) Each irrigator determines how much water they require to order for the following week from the scheme, based on their irrigation scheduling which is dependent on the type of crops being irrigated as well as their available scheduled quota.

(2) The irrigators submit their requests to the Impala WUA on the appropriate application form, before Thursday, for their irrigation water requirements to be delivered the following week. Irrigators must specify their needs clearly on the request form and the WUA will endeavour to supply the water, as requested.

(3) The scheme operators at the Impala WUA then reconcile the total requested volume from the beginning of the water year with each irrigator's scheduled quota. The total volume of water required in each branch canal, is then calculated to determine how much water should be supplied within the maximum of 160 hours in each of the different sections of canal systems based on the request. This is compared with the hydraulic capacity of the canal section to ensure that either the volume of water ordered is above the threshold for delivery into the canal section or the volume of water ordered including the expected canal losses does not exceed the maximum hydraulic capacity of the canal system.

(4) The above process is repeated from the branch canals up to the Impala main canal to determine how much water needs to be released from the Grootdraai weir. This includes the total transmission (compensation) losses required to deliver the requested water.

(5) The requested water, including the transmission losses are then reconciled with the current flows in the Pongola River. In the event that the requested volume including transmission losses exceeds the current flow in the Pongola, water is then requested from Bivane Dam in time to meet the requested water for the following week.

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

(7) In order to reduce the water losses, the Impala WUA also determines the minimum volume of water that can be delivered in each canal system without significant water losses. If the requests amount to less than the minimum threshold for release, then the irrigators in that particular section will not receive their requests.

(8) The Water Control Department (WCD) of Impala WUA sets up a flow chart of levels of the sluice gates and partial flumes based on the water requests of the week.

(9) Based on the availability and priorities, decisions are then made to release from Grootdraai weir into the different canals based on the calculated volumes for the week to be delivered continuously during the week. The cycle commences on the Monday morning and ends on the Sunday evenings, when the cycle is completed.

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

The water ordering and delivery procedures described above are documented by way of Board meeting minutes and circulars that are distributed to all members. Internal instructions to the procedures are also communicated by means of management discussions and memorandums to the appropriate personnel.

It is important to note that, in the Impala Irrigation Scheme, water is supplied continuously to the users, including during weekends through sluice gates, which are adjusted according to the water level (i.e. pressure) in the canal system. Each outlet from the canal has a sluice gate as well as a measuring device which is either a Parshall flume or long weir. The sluice gates close or open water flow towards the flume.

The continuous running of water in the canals and laterals reduces the system losses that can occur due to stop and start of canal systems in those schemes which do not operate on weekends. Due to the pressure variance in the canal system there is a margin of error in the volume of water delivered to the water user and water users are requested to accept a margin of error of 10%.

6.3 Procedures during water supply shortages

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

(i) At the start of the water year, the available water from the Pongola River as well as the Bivane Dam that can be supplied to irrigators is reconciled with the scheduled quota. Where it is envisaged that less water is available, the allocations to irrigators are reduced equitably regardless of the types of crops irrigated.

(ii) A percentage of the scheduled allocation is then published to enable the irrigators to plan the type of crops to plant or to manage the existing crops.

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

(iv) The available water is reviewed during the course of time depending on the rainfall and any necessary adjustments are then made to either the annual water allocation or by increasing the weekly supply.

6.4 Water Transfers

6.4.1 Temporary water transfers

There may be periods when existing irrigators exhaust their scheduled quota before the end of the water year and may require additional irrigation water. The scheme regulations allow for applications to be made for temporary transfer of water from one property to another depending on the following conditions:

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

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

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

Currently the WUA is not involved in any of the negotiations as the water use entitlements are held by the individual water user.

6.5 Water pricing structure

6.5.1 Structure of irrigation water charges

On most Government Water Schemes, the Department of Water Affairs (DWA) sets the water use charge for irrigation water, based on the pricing strategy. This is not the case with Impala. The pricing structure for the Impala Water User Association is based on their budgeted operation and maintenance costs and the cost of servicing of the loans that the WUA took on behalf of the irrigators to construct Bivane Dam.

The total annual cost is divided by the scheduled hectares in the irrigation scheme. The irrigators who pump directly from the river pay a lesser charge, which excludes canal operation and maintenance. It would therefore appear to be beneficial for the scheme area to expand, in order to reduce the water use charge per hectare and to improve the financial viability of the scheme, but DWA is not in favour of this, as there is a much more pressing need for development, downstream of the Pongolapoort Dam, on the Makhatini Flats.

The Impala WUA has set the financing cost portion of the water use charge for all irrigators using the dam (i.e. scheme and river irrigators) at R1 098 per ha per year. Besides the Bivane Dam, there is a charge for the operation and maintenance of the canal infrastructure which is set at R737 per ha/a. Therefore the total water use charge for irrigators in the scheme area who are supplied through the canal infrastructure is R1 835 per ha/a, while the water use charge for the river irrigators is R1 167 per ha per year.

Besides the water use charge, the pricing strategy requires that all users pay for the management of the catchments including the cost of managing the Reserve, dam safety control, etc. This is the water resource management (WRM) charge. The current WRM charge for irrigation agriculture in the Usutu to Mhlatuze Water Management Area, in which the Impala Irrigation Scheme is located for the 2010/11 financial year, is 0.74 c per m^3. With the scheduled allocation of 170 million m^3/a, the Impala Irrigation Scheme pays approximately R1.26 million per year or each irrigator pays R73.95 per hectare per year.

6.5.2 Collection of the irrigation water use charges

The Impala WUA is responsible for collection of the water use charges which it uses to pay for the loans received for the construction of Bivane Dam which is owned by the Impala WUA. The WUA also collects the money for the O&M charge, which it uses to pay for the operation and maintenance of the irrigation scheme.

Irrigators, domestic and industrial users are billed directly by DWA for the WRM charges.

7 DETERMINATION OF UNAVOIDABLE WATER LOSSES IN IMPALA IRRIGATION SCHEME

7.1 Overview

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

This is discussed in the following sections of this chapter.

7.2 Overview of the water losses

7.2.1 Overview

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

1) Part of the water is consumed in evaporation (e.g. from channels) and transpiration (e.g. vegetation growing next to the channel).
2) Some water percolates to surface or subsurface areas (e.g. canal seepage or deep percolation) and cannot be recaptured (e.g. in the vadose zone, the ocean, or a salt sink) or can be recaptured (e.g. interceptor drains into a drainage canal or a drainage well) and used as an additional supply.

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

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

7.2.2 Unavoidable water losses due to canal seepage

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

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

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

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

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

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

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

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

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

Where

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

The seepage loss per unit length was then calculated using the hydraulic conductivity of the concrete lining; the canal geometry and the seepage rate based on the wetted perimeter. The expected seepage losses for the different canal sections in the Transvaal and Natal canal system are indicated in **Table 7.1** and **Table 7.2** below.

As illustrated in **Table 7.1** below, the minimum seepage losses expected in the Transvaal canal system is 12.13 million m^3/a in order to supply the irrigation water requirements in the sub-scheme area. The minimum seepage losses that should be provided as additional to the scheduled allocation in the Transvaal sub-scheme area was not determined separately.

Table 7:1: Expected seepage losses in the Transvaal canal system

Canal Name	Design capacity (m^3/s)	Seepage Loss q_s(m3/d per unit length)	Length of canal km	Expected Seepage losses (million m3/a)
Transvaal Canal	7.1 - 6.4	0.53489	15.65	3.06
Ncotshane canal	2.3 - 1.5	0.47489	25.5	4.42
Sitilo canal	1.8 - 1.2	0.23646	16.14	1.39
Wonderfontein canal	2	0.23653	10.71	0.92
D9 Canal	2	0.23653	3.6	0.31
Branch canals		0.19946	27.88	2.03
Total Seepage Losses Transvaal Canal System			99.48	12.13

In the case of the Natal canal system including the main canal from the Grootdraai weir, the minimum expected seepage losses is 9.16 million m^3/a.

Table 7:2: Expected seepage losses in the Impala canal system

Canal Name	Max. Hydraulic capacity (m^3/s)	Seepage Loss, qs(m3/d per unit length)	Total Length of canal (km)	Expected Seepage losses (million m3/a)
Main canal	10	1.11949	9.4	3.84
Natal canal	2.9	0.53489	19.65	3.84
Mbega canal	1.4	0.23465	10.99	0.94
Branch canals		0.19946	7.39	0.54
Total Seepage Losses Main & Natal Canal System			47.43	9.16

The total minimum seepage losses for the whole of Impala Irrigation Scheme was determine to be 21.29 million m^3/a. This is the seepage expected taking into account the age of the canal infrastructure but assuming the canal system is well maintained and the renewal and refurbishment requirements are carried out on time in order for the canal system to deliver the expected level of service to the irrigators. The expected seepage losses are therefore approximately 12% of the scheduled allocation of 170 million m^3/a.

When the above percentage seepage losses are compared with the best management practices, canal seepage would range between 10% and 15% 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 and hydraulic profile of the canal, soil capillary tension, amount of sediment, algae, etc.

The minimum seepage losses as calculated above have been compared with the water losses of each canal system in the Impala Irrigation Scheme based on the water balance assessment which is discussed in the following chapter. The difference in the water losses and the minimum seepage losses were taken as avoidable water losses.

7.2.3 Unavoidable losses due to surface evaporation

Evaporation loss depends on (1) the supply of energy to provide the latent heat of vaporization and (2) the ability to transport the vapour away from the evaporating surface, which in turn depends on the wind velocity over the surface and the specific humidity gradient in the air above the water surface.

The evaporation loss, expressed as a percentage of total inflow was determined based on the total surface area of the irrigation canals, the mean annual evaporation (MAE) based on the A-pan evaporation figure for the 1959 - 1980 hydrological record. The total annual evaporation from the irrigation canal surface area was determined to be 1.135 million m^3/a. This was taken as the average over the six years records. Based on the calculated evaporation losses, the evaporation losses as a percentage of the total inflows was determined to be 0.625%. This is much higher than the estimated evaporation losses at approximately 0.3% of total inflow volume (Reid, Davidson and Kotze; 1986).

Therefore the BMP evaporation loss in the Impala Irrigation Scheme area that was used was 0.6% of the total inflows which was taken as the unavoidable evaporation losses for the scheme area. This amount has been taken out of the gross water losses (i.e the return flow not used for irrigation).

8 IMPALA IRRIGATION SCHEME WATER BALANCE ASSESSMENT

8.1 Overview

The key aspects in developing and implementing water management plans (WMP) in the agricultural sector, is to understand:

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

This approach provides the irrigation water balance assessment to account for any inefficiency in the current irrigation water management practices in the scheme.

The Impala Irrigation Scheme uses the Water Administration System (WAS) to account for the water used by the scheme and the water use efficiency accounting report (WUEAR) for reporting on matching irrigation supply and demand (MISD).

The purpose of calculating the water balance and water balance assessment is to help Impala Irrigation Scheme to answer three questions:

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

The irrigation water balance assessment for the Impala Irrigation Scheme was undertaken at the overall water balance assessment, with a view to determining the extent of water losses at an irrigation scheme level. No disaggregation was done to date to determine the water balance assessments for the Transvaal canal system and the Natal canal system.

8.2 Quality and integrity of the available information

8.2.1 Sources of information

It is however important to note the available records from the WUEARs that were used to conduct the water balance assessment for the Impala irrigation scheme are for the period 2006/07 to 2012/13.

Another source of information for the canal geometry was from the DWA, canal section. This was used to determine the unavoidable losses as discussed above.

This has been used to determine the water balance assessment as discussed later in this section.

8.2.2 Integrity of the available data and information

The data and information used to date to carry out the water balance assessments for the Impala irrigation scheme was from the available WUEARs prepared by the Water User Association (WUA). The data used to prepare the WUEARs were based on measured data of the inflows into the canal irrigation as well as measured data of the irrigation water requested. Although there are measured data at the entrance to each of the primary canals, this could not be compared with the irrigation applications as the applications were not disaggregated into each of the primary canals at this stage. This is one of the recommendations being made in this management plan.

The WUEAR do not provide the measured data of the spills at the canal tail ends and the downstream demands for the years until 2011/12 when measurements of downstream uses are now being taken.

The water balance assessment has not included the precipitation during delivery of water to irrigators. The assumption made is that the amount of precipitation during delivery of irrigation water is negligible. This may not be the case during the rainy season and consideration of incorporating information regarding precipitation should be made in future irrigation water use accounting.

8.3 Evaluation of the operational losses

8.3.1 Overview

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

Avoidable losses occur as a result of inefficient management in the operation of the canal system and can mainly be attributed to poor canal maintenance (leaks), incorrect 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.

8.3.2 Determination of the water losses

The water balance assessment for the Impala Irrigation Scheme has been based on the average of the 8 years of records from 2006/07 to 2012/13 water year of records. The water balance was based on information from the data on applications and releases provided by the scheme operators.

8.4 Overall water balance assessment – Impala canal system

8.4.1 Inflows into Impala canal system

8.4.1.1 Releases from Grootdraai weir

The first measurement of water takes place at the Grootdraai weir, where water is diverted from the Pongola River into the main irrigation canal. There are three further locations on each of the two main canals that measure the flow of water into the canal system from Grootdraai weir. Weekly records of the inflows into the main canal at the Grootdraai were evaluated. The records were aggregated into monthly records. Monthly records from 2006/07 water year to 20012/13 water year, were generated as illustrated in **Table 8.1** below.

The total average diversion at Grootdraai weir for the past 6 water years, was determined to be 184.023 million m^3/a with the monthly diversion averaging 15.4 million m^3. The maximum diversion took place in the 2011/12 water year when the total diversion for the year was 217 million m^3/a.

The lowest volume of irrigation water diversion occurred in the 2007/08 water year when 167 million m^3/a, was recorded at the Grootdraai weir to have entered the main canal. Only eleven months of records were available for the 2012/13 water year and therefore it was not taken as the lowest year when water was abstracted. The 2007/08 water year is considered to have been a very wet year and could have contributed to the lower diversion rate than the previous years.

8.4.1.2 Precipitation

No precipitation data is currently being included in the WAS programme and therefore was not included as an input into the water balance assessment.

Table 8:1: Water Balance Assessment for the Impala canal system for the 2006/07-2012/13 water years

Scheduled Area	
Canal Irrigators -area	14,000.00
River irrigators - area	3,012.00
Total scheduled area	**17,012.00**
Scheduled qouta	10,000.00

Scheduled allocation	
Scheduled Qouta	10,000.00
Canal Irrigators	140,000,000.00
River Irrigators	30,120,000.00
Total scheduled allocation	**170,120,000.00**

Unavoidable Losses			
Expected Seepage Loss	21,707,627.88	11.76%	16%
Evaporation Losses			0.6%

WATER YEAR	MONTH	INFLOWS					CONSUMPTIVE USE						GROSS WATER LOSSES			UNAVOIDABLE WATER LOSSES			AVOIDABLE WATER LOSSES			UTILISATION
		Grootdraai Weir	Storage release	Balancing Dam	Precipitation	Total inflows	Irrigation water application	Industrial	uPhongolo Municipality	Households	Downstream demands	Total Consumptive Use	Total water losses	% of inflow	Water Use Index	Evaporation	Seepage	Unavoidable water losses	Operational wasteage	Leakage & spills	% avoidable water losses	% of scheduled volume
																0.6%	12%		20%			
2006/07																						
	March	16,320.00				**16,320.00**	9,687.00	59.00	294.00			**10,040.00**	**6,280.00**	38.5%	1.63	102.00	1,958.40	2,060.40	2,008.00	2,211.60	25.9%	
	April	17,817.00				**17,817.00**	8,924.00	89.00	230.00	12.00		**9,255.00**	**8,562.00**	48.1%	1.93	111.36	2,138.04	2,249.40	1,851.00	4,461.60	35.4%	
	May	9,926.00				**9,926.00**	4,241.00	55.00	192.00	20.00		**4,508.00**	**5,418.00**	54.6%	2.20	62.04	1,191.12	1,253.16	901.60	3,263.24	42.0%	
	June	14,377.00				**14,377.00**	7,444.00	72.00	23.00	16.00		**7,555.00**	**6,822.00**	47.5%	1.90	89.86	1,725.24	1,815.10	1,511.00	3,495.90	34.8%	
	July	17,408.00				**17,408.00**	10,426.00	48.00	263.00	16.00		**10,753.00**	**6,655.00**	38.2%	1.62	108.80	2,088.96	2,197.76	2,150.60	2,306.64	25.6%	
	August	11,547.00				**11,547.00**	6,108.00	55.00	262.00	20.00		**6,445.00**	**5,102.00**	44.2%	1.79	72.17	1,385.64	1,457.81	1,289.00	2,355.19	31.6%	
	September	11,866.00				**11,866.00**	6,764.00	71.00	286.00	16.00		**7,137.00**	**4,729.00**	39.9%	1.66	74.16	1,423.92	1,498.08	1,427.40	1,803.52	27.2%	
	October	16,836.00				**16,836.00**	9,654.00	68.00	205.00	16.00		**9,943.00**	**6,893.00**	40.9%	1.69	105.23	2,020.32	2,125.55	1,988.60	2,778.86	28.3%	
	November	14,454.00				**14,454.00**	6,723.00	52.00	277.00	20.00		**7,072.00**	**7,382.00**	51.1%	2.04	90.34	1,734.48	1,824.82	1,414.40	4,142.78	38.4%	
	December	17,579.00				**17,579.00**	8,836.00	67.00	211.00	16.00		**9,130.00**	**8,449.00**	48.1%	1.93	109.87	2,109.48	2,219.35	1,826.00	4,403.65	35.4%	
	January	15,206.00				**15,206.00**	7,399.00	60.00	254.00	20.00		**7,733.00**	**7,473.00**	49.1%	1.97	95.04	1,824.72	1,919.76	1,546.60	4,006.64	36.5%	
	February	17,123.00				**17,123.00**	10,666.00	55.00	188.00	16.00		**10,925.00**	**6,198.00**	36.2%	1.57	107.02	2,054.76	2,161.78	2,185.00	1,851.22	23.6%	
	Subtotal	**180,459.00**	**-**	**-**	**-**	**180,459.00**	**96,872.00**	**751.00**	**2,685.00**	**188.00**	**-**	**100,496.00**	**79,963.00**	**44.3%**	**1.80**	**1,127.87**	**21,655.08**	**22,782.95**	**20,099.20**	**37,080.85**	**31.7%**	57%
2007/08																						
	March	11,415.00				**11,415.00**	9,629.00	44.00	-	12.00		**9,685.00**	**1,730.00**	15.2%	1.18	71.34	1,369.80	1,441.14	1,937.00	-	17.0%	
	April	17,823.00				**17,823.00**	14,767.00	108.00	233.00	20.00		**15,128.00**	**2,695.00**	15.1%	1.18	111.39	2,138.76	2,250.15	3,025.60	-	17.0%	
	May	11,402.00	-	-	-	**11,402.00**	9,623.00	78.00	229.00	16.00		**9,946.00**	**1,456.00**	12.8%	1.15	71.26	1,368.24	1,439.50	1,989.20	-	17.4%	
	June	13,254.00	-	-	-	**13,254.00**	6,436.00	33.00	245.00	16.00		**6,730.00**	**6,524.00**	49.2%	1.97	82.84	1,590.48	1,673.32	1,346.00	3,504.68	36.6%	
	July	10,733.00	-	-		**10,733.00**	6,855.00	39.00	210.00	20.00		**7,124.00**	**3,609.00**	33.6%	1.51	67.08	1,287.96	1,355.04	1,424.80	829.16	21.0%	
	August	8,275.00				**8,275.00**	5,301.00	26.00	224.00	16.00		**5,567.00**	**2,708.00**	32.7%	1.49	51.72	993.00	1,044.72	1,113.40	549.88	20.1%	
	September	20,639.00	-	-	-	**20,639.00**	15,546.00	66.00	255.00	20.00		**15,887.00**	**4,752.00**	23.0%	1.30	128.99	2,476.68	2,605.67	3,177.40	-	15.4%	
	October	10,212.00				**10,212.00**	4,157.00	59.00	232.00	16.00		**4,464.00**	**5,748.00**	56.3%	2.29	63.83	1,225.44	1,289.27	892.80	3,565.94	43.7%	
	November	15,096.00				**15,096.00**	6,367.00	66.00	254.00	16.00		**6,703.00**	**8,393.00**	55.6%	2.25	94.35	1,811.52	1,905.87	1,340.60	5,146.53	43.0%	
	December	14,011.00				**14,011.00**	4,991.00	61.00	310.00	20.00		**5,382.00**	**8,629.00**	61.6%	2.60	87.57	1,681.32	1,768.89	1,076.40	5,783.71	49.0%	
	January	16,275.00				**16,275.00**	9,226.00	55.00	236.00	16.00		**9,533.00**	**6,742.00**	41.4%	1.71	101.72	1,953.00	2,054.72	1,906.60	2,780.68	28.8%	
	February	18,726.00				**18,726.00**	13,220.00	56.00	258.00	16.00		**13,550.00**	**5,176.00**	27.6%	1.38	117.04	2,247.12	2,364.16	2,710.00	101.84	15.0%	
Sub-total		**167,861.00**	**-**	**-**	**-**	**167,861.00**	**106,118.00**	**691.00**	**2,686.00**	**204.00**	**-**	**109,699.00**	**58,162.00**	**34.6%**	**1.53**	**1,049.13**	**20,143.32**	**21,192.45**	**21,939.80**	**22,262.42**	**26.3%**	62%
2008/09																						
	March	28,868.00				**28,868.00**	19,380.00	81.00	293.00	24.00		**19,778.00**	**9,090.00**	31.5%	1.46	180.43	3,464.16	3,644.59	3,955.60	1,489.82	18.9%	
	April	16,663.00				**16,663.00**	9,380.00	60.00	233.00	16.00		**9,689.00**	**6,974.00**	41.9%	1.72	104.14	1,999.56	2,103.70	1,937.80	2,932.50	29.2%	
	May	7,970.00				**7,970.00**	4,916.00	42.00	203.00	16.00		**5,177.00**	**2,793.00**	35.0%	1.54	49.81	956.40	1,006.21	1,035.40	751.39	22.4%	
	June	20,493.00				**20,493.00**	10,711.00	94.00	415.00	20.00		**11,240.00**	**9,253.00**	45.2%	1.82	128.08	2,459.16	2,587.24	2,248.00	4,417.76	32.5%	
	July	10,153.00				**10,153.00**	4,180.00	41.00	253.00	16.00		**4,490.00**	**5,663.00**	55.8%	2.26	63.46	1,218.36	1,281.82	898.00	3,483.18	43.2%	
	August	20,390.00				**20,390.00**	14,508.00	102.00	515.00	20.00		**15,145.00**	**5,245.00**	25.7%	1.35	127.44	2,446.80	2,574.24	3,029.00	-	14.9%	
	September	17,294.00				**17,294.00**	12,522.00	67.00	-	16.00		**12,605.00**	**4,689.00**	27.1%	1.37	108.09	2,075.28	2,183.37	2,521.00	-	14.6%	
	October	18,273.00				**18,273.00**	13,516.00	109.00	278.00	16.00		**13,919.00**	**4,354.00**	23.8%	1.31	114.21	2,192.76	2,306.97	2,783.80	-	15.2%	
	November	17,030.00				**17,030.00**	9,413.00	133.00	560.00	20.00		**10,126.00**	**6,904.00**	40.5%	1.68	106.44	2,043.60	2,150.04	2,025.20	2,728.76	27.9%	
	December	16,567.00				**16,567.00**	10,633.00	101.00	-	16.00		**10,750.00**	**5,817.00**	35.1%	1.54	103.54	1,988.04	2,091.58	2,150.00	1,575.42	22.5%	
	January	16,431.00				**16,431.00**	10,038.00	140.00	290.00	16.00		**10,484.00**	**5,947.00**	36.2%	1.57	102.69	1,971.72	2,074.41	2,096.80	1,775.79	23.6%	
	February	12,929.00				**12,929.00**	5,454.00	98.00	261.00	16.00		**5,829.00**	**7,100.00**	54.9%	2.22	80.81	1,551.48	1,632.29	1,165.80	4,301.91	42.3%	
Sub-total		**203,061.00**	**-**	**-**	**-**	**203,061.00**	**124,651.00**	**1,068.00**	**3,301.00**	**212.00**	**-**	**129,232.00**	**73,829.00**	**36.4%**	**1.57**	**1,269.13**	**24,367.32**	**25,636.45**	**25,846.40**	**23,456.52**	**24.3%**	73%
2009/10																						
	March	16,974.00				**16,974.00**	7,526.00	70.00	230.00	20.00		**7,846.00**	**9,128.00**	53.8%	2.16	106.09	2,036.88	2,142.97	1,569.20	5,415.83	41.2%	
	April	17,067.00				**17,067.00**	11,385.00	105.00	139.00	16.00		**11,645.00**	**5,422.00**	31.8%	1.47	106.67	2,048.04	2,154.71	2,329.00	938.29	19.1%	
	May	13,353.00				**13,353.00**	9,713.00	179.00	99.00	20.00		**10,011.00**	**3,342.00**	25.0%	1.33	83.46	1,602.36	1,685.82	2,002.20	-	15.0%	
	June	10,502.00				**10,502.00**	6,818.00	138.00	34.00	16.00		**7,006.00**	**3,496.00**	33.3%	1.50	65.64	1,260.24	1,325.88	1,401.20	768.92	20.7%	
	July	13,775.00				**13,775.00**	7,804.00	101.00	-	16.00		**7,921.00**	**5,854.00**	42.5%	1.74	86.09	1,653.00	1,739.09	1,584.20	2,530.71	29.9%	
	August	16,916.00				**16,916.00**	6,633.00	69.00	896.00	20.00		**7,618.00**	**9,298.00**	55.0%	2.22	105.73	2,029.92	2,135.65	1,523.60	5,638.76	42.3%	
	September	15,619.00				**15,619.00**	8,578.00	107.00	253.00	16.00		**8,954.00**	**6,665.00**	42.7%	1.74	97.62	1,874.28	1,971.90	1,790.80	2,902.30	30.0%	
	October	11,324.00				**11,324.00**	6,898.00	113.00	245.00	16.00		**7,272.00**	**4,052.00**	35.8%	1.56	70.78	1,358.88	1,429.66	1,454.40	1,167.95	23.2%	
	November	12,841.00				**12,841.00**	3,123.00	190.00	555.00	20.00		**3,888.00**	**8,953.00**	69.7%	3.30	80.26	1,540.92	1,621.18	777.60	6,554.22	57.1%	
	December	14,408.00				**14,408.00**	6,450.00	117.00	267.00	16.00		**6,850.00**	**7,558.00**	52.5%	2.10	90.05	1,728.96	1,819.01	1,370.00	4,368.99	39.8%	
	January	18,904.00				**18,904.00**	10,933.00	114.00	298.00	20.00		**11,365.00**	**7,539.00**	39.9%	1.66	118.15	2,268.48	2,386.63	2,273.00	2,879.37	27.3%	
	February	17,558.00				**17,558.00**	11,003.00	104.00	263.00	16.00		**11,386.00**	**6,172.00**	35.2%	1.54	109.74	2,106.96	2,216.70	2,277.20	1,678.10	22.5%	
Sub-total		**179,241.00**	**-**	**-**	**-**	**179,241.00**	**96,864.00**	**1,407.00**	**3,279.00**	**212.00**	**-**	**101,762.00**	**77,479.00**	**43.2%**	**1.76**	**1,120.26**	**21,508.92**	**22,629.18**	**20,352.40**	**34,843.44**	**30.8%**	57%
2010/11																						
	March	18,010.00				**18,010.00**	10,318.00	92.00	264.00	15.00		**10,689.00**	**7,321.00**	40.6%	1.68	112.56	2,161.20	2,273.76	2,137.80	2,909.44	28.0%	
	April	15,647.00				**15,647.00**	7,430.00	101.00	-	15.00		**7,546.00**	**8,101.00**	51.8%	2.07	97.79	1,877.64	1,975.43	1,509.20	4,616.37	39.1%	
	May	13,508.00				**13,508.00**	7,836.00	181.00	443.00	19.00		**8,479.00**	**5,029.00**	37.2%	1.59	84.43	1,620.96	1,705.39	1,695.80	1,627.82	24.6%	
	June	10,234.00				**10,234.00**	6,017.00	101.00	-	15.00		**6,133.00**	**4,101.00**	40.1%	1.67	63.96	1,228.08	1,292.04	1,226.60	1,582.36	27.4%	
	July	13,774.00				**13,774.00**	7,559.00	104.00	183.00	15.00		**7,861.00**	**5,913.00**	42.9%	1.75	86.09	1,652.88	1,738.97	1,572.20	2,601.83	30.3%	
	August	19,800.00				**19,800.00**	11,594.00	79.00	417.00	19.00		**12,109.00**	**7,691.00**	38.8%	1.64	123.75	2,376.00	2,499.75	2,421.80	2,769.45	26.2%	
	September	16,830.00				**16,830.00**	11,810.00	126.00	478.00	15.00		**12,429.00**	**4,401.00**	26.1%	1.35	105.19	2,019.60	2,124.79	2,485.80	-	14.8%	
	October	18,463.00				**18,463.00**	8,315.00	200.00	293.00	19.00		**8,827.00**	**9,636.00**	52.2%	2.09	115.39	2,215.56	2,330.95	1,765.40	5,539.65	39.6%	
	November	11,013.00				**11,013.00**	970.00	76.00	253.00	15.00		**1,314.00**	**9,699.00**	88.1%	8.38	68.83	1,321.56	1,390.39	262.80	8,045.81	75.4%	
	December	13,498.00				**13,498.00**	7,606.00	105.00	98.00	15.00		**7,824.00**	**5,674.00**	42.0%	1.73	84.36	1,619.76	1,704.12	1,564.80	2,405.08	29.4%	
	January	11,785.00				**11,785.00**	3,590.00	53.00	46.00	19.00		**3,708.00**	**8,077.00**	68.5%	3.18	73.66	1,414.20	1,487.86	741.60	5,847.54	55.9%	
	February	18,879.00				**18,879.00**	13,596.00	93.00	191.00	15.00		**13,895.00**	**4,984.00**	26.4%	1.36	117.99	2,265.48	2,383.47	2,779.00	-	14.7%	
Sub-total		**181,441.00**	**-**	**-**	**-**	**181,441.00**	**96,641.00**	**1,311.00**	**2,666.00**	**196.00**	**-**	**100,814.00**	**80,627.00**	**44.4%**	**1.80**	**1,134.01**	**21,772.92**	**22,906.93**	**20,162.80**	**37,945.34**	**32.0%**	57%

Scheduled Area	
Canal Irrigators -area	14,000.00
River irrigators - area	3,012.00
Total scheduled area	**17,012.00**
Scheduled qouta	10,000.00

Scheduled allocation	
Scheduled Qouta	10,000.00
Canal Irrigators	140,000,000.00
River Irrigators	30,120,000.00
Total scheduled allocation	**170,120,000.00**

Unavoidable Losses			
Expected Seepage Loss	21,707,627.88	11.76%	16%
Evaporation Losses			0.6%

WATER YEAR	MONTH	INFLOWS					CONSUMPTIVE USE						GROSS WATER LOSSES			UNAVOIDABLE WATER LOSSES			AVOIDABLE WATER LOSSES			UTILISATION
		Grootdraai Weir	Storage release	Balancing Dam	Precipitation	Total inflows	Irrigation water application	Industrial	uPhongolo Municipality	Households	Downstream demands	Total Consumptive Use	Total water losses	% of inflow	Water Use Index	Evaporation	Seepage	Unavoidable water losses	Operational wasteage	Leakage & spills	% avoidable water losses	% of scheduled volume
2011/12	March	20,139.00				**20,139.00**	14,656.00	101.00	268.00	15.00	-	**15,040.00**	**5,099.00**	25.3%	1.34	125.87	2,416.68	2,542.55	3,008.00	-	14.9%	
	April	19,510.00				**19,510.00**	12,096.00	105.00	340.00	15.00	1,024.00	**13,580.00**	**5,930.00**	30.4%	1.44	121.94	2,341.20	2,463.14	2,716.00	750.86	17.8%	
	May	14,272.00				**14,272.00**	7,927.00	71.00	355.00	19.00	752.00	**9,124.00**	**5,148.00**	36.1%	1.56	89.20	1,712.64	1,801.84	1,824.80	1,521.36	23.4%	
	June	12,256.00				**12,256.00**	6,652.00	129.00	263.00	15.00	748.00	**7,807.00**	**4,449.00**	36.3%	1.57	76.60	1,470.72	1,547.32	1,561.40	1,340.28	23.7%	
	July	18,073.00				**18,073.00**	8,810.00	126.00	348.00	19.00	1,582.00	**10,885.00**	**7,188.00**	39.8%	1.66	112.96	2,168.76	2,281.72	2,177.00	2,729.28	27.1%	
	August	14,098.00				**14,098.00**	7,068.00	130.00	271.00	15.00	1,220.00	**8,704.00**	**5,394.00**	38.3%	1.62	88.11	1,691.76	1,779.87	1,740.80	1,873.33	25.6%	
	September	18,688.00				**18,688.00**	11,446.00	79.00	268.00	15.00	25.00	**11,833.00**	**6,855.00**	36.7%	1.58	116.80	2,242.56	2,359.36	2,366.60	2,129.04	24.1%	
	October	23,689.00				**23,689.00**	13,230.00	143.00	406.00	19.00	771.00	**14,569.00**	**9,120.00**	38.5%	1.63	148.06	2,842.68	2,990.74	2,913.80	3,215.46	25.9%	
	November	20,139.00				**20,139.00**	4,528.00	89.00	281.00	15.00	7,340.00	**12,253.00**	**7,886.00**	39.2%	1.64	125.87	2,416.68	2,542.55	2,450.60	2,892.85	26.5%	
	December	16,874.00				**16,874.00**	9,384.00	104.00	346.00	15.00	982.00	**10,831.00**	**6,043.00**	35.8%	1.56	105.46	2,024.88	2,130.34	2,166.20	1,746.46	23.2%	
	January	22,628.00				**22,628.00**	12,093.00	130.00	438.00	19.00	1,866.00	**14,546.00**	**8,082.00**	35.7%	1.56	141.43	2,715.36	2,856.79	2,909.20	2,316.02	23.1%	
	February	17,329.00				**17,329.00**	10,345.00	85.00	329.00	15.00	1,089.00	**11,863.00**	**5,466.00**	31.5%	1.46	108.31	2,079.48	2,187.79	2,372.60	905.61	18.9%	
		217,695.00	***-***	***-***	***-***	***217,695.00***	***118,235.00***	***1,292.00***	***3,913.00***	***196.00***	***17,399.00***	***141,035.00***	***76,660.00***	***35.2%***	***1.54***	***1,360.59***	***26,123.40***	***27,483.99***	***28,207.00***	***21,420.56***	***22.8%***	**80%**
2012/13	March	10,133.00				**10,133.00**	5,625.00	59.00	229.00	12.00	-	**5,925.00**	**4,208.00**	41.5%	1.71	63.33	1,215.96	1,279.29	1,185.00	1,743.71	28.9%	
	April	25,824.00				**25,824.00**	14,717.00	148.00	422.00	19.00	-	**15,306.00**	**10,518.00**	40.7%	1.69	161.40	3,098.88	3,260.28	3,061.20	4,196.52	28.1%	
	May	11,878.00				**11,878.00**	5,922.00	43.00	332.00	15.00	-	**6,312.00**	**5,566.00**	46.9%	1.88	74.24	1,425.36	1,499.60	1,262.40	2,804.00	34.2%	
	June	12,522.00				**12,522.00**	7,439.00	143.00	275.00	15.00	-	**7,872.00**	**4,650.00**	37.1%	1.59	78.26	1,502.64	1,580.90	1,574.40	1,494.70	24.5%	
	July	15,600.00				**15,600.00**	7,867.00	131.00	526.00	19.00	-	**8,543.00**	**7,057.00**	45.2%	1.83	97.50	1,872.00	1,969.50	1,708.60	3,378.90	32.6%	
	August	11,557.00				**11,557.00**	6,135.00	54.00	227.00	15.00	-	**6,431.00**	**5,126.00**	44.4%	1.80	72.23	1,386.84	1,459.07	1,286.20	2,380.73	31.7%	
	September	12,444.00				**12,444.00**	2,402.00	103.00	341.00	19.00	318.00	**3,183.00**	**9,261.00**	74.4%	3.91	77.78	1,493.28	1,571.06	636.60	7,053.35	61.8%	
	October	16,652.00				**16,652.00**	5,929.00	57.00	254.00	15.00	416.00	**6,671.00**	**9,981.00**	59.9%	2.50	104.08	1,998.24	2,102.32	1,334.20	6,544.49	47.3%	
	November	12,933.00				**12,933.00**	3,438.00	103.00	346.00	15.00	693.00	**4,595.00**	**8,338.00**	64.5%	2.81	80.83	1,551.96	1,632.79	919.00	5,786.21	51.8%	
	December	19,750.00				**19,750.00**	6,485.00	121.00	428.00	19.00	3,639.00	**10,692.00**	**9,058.00**	45.9%	1.85	123.44	2,370.00	2,493.44	2,138.40	4,426.16	33.2%	
	January	13,538.00				**13,538.00**	4,681.00	65.00	179.00	15.00	3,012.00	**7,952.00**	**5,586.00**	41.3%	1.70	84.61	1,624.56	1,709.17	1,590.40	2,286.43	28.6%	
	February	-				**-**	-	-	-		-	**-**	**-**	#DIV/0!	#DIV/0!	-	-	-	-	-	#DIV/0!	
		162,831.00	***-***	***-***	***-***	***162,831.00***	***70,640.00***	***1,027.00***	***3,559.00***	***178.00***	***8,078.00***	***83,482.00***	***79,349.00***	***48.7%***	***1.95***	***1,017.69***	***19,539.72***	***20,557.41***	***16,696.40***	***42,095.19***	***36.1%***	**46%**
		184,655.57	-	-	-	184,655.57	101,431.57	1,078.14	3,155.57	198.00	3,639.57	109,502.86	75,152.71	41.0%	1.71	1,154.10	22,158.67	23,312.77	21,900.57	31,300.62	29.1%	61.8%

No water balancing storage is available in the Impala Irrigation Scheme. However the Grootdraai weir is acting as a water balancing dam. As illustrated in **Figure 8.1** below, the Grootdraai weir helps to reduce the releases from the Bivane Dam.

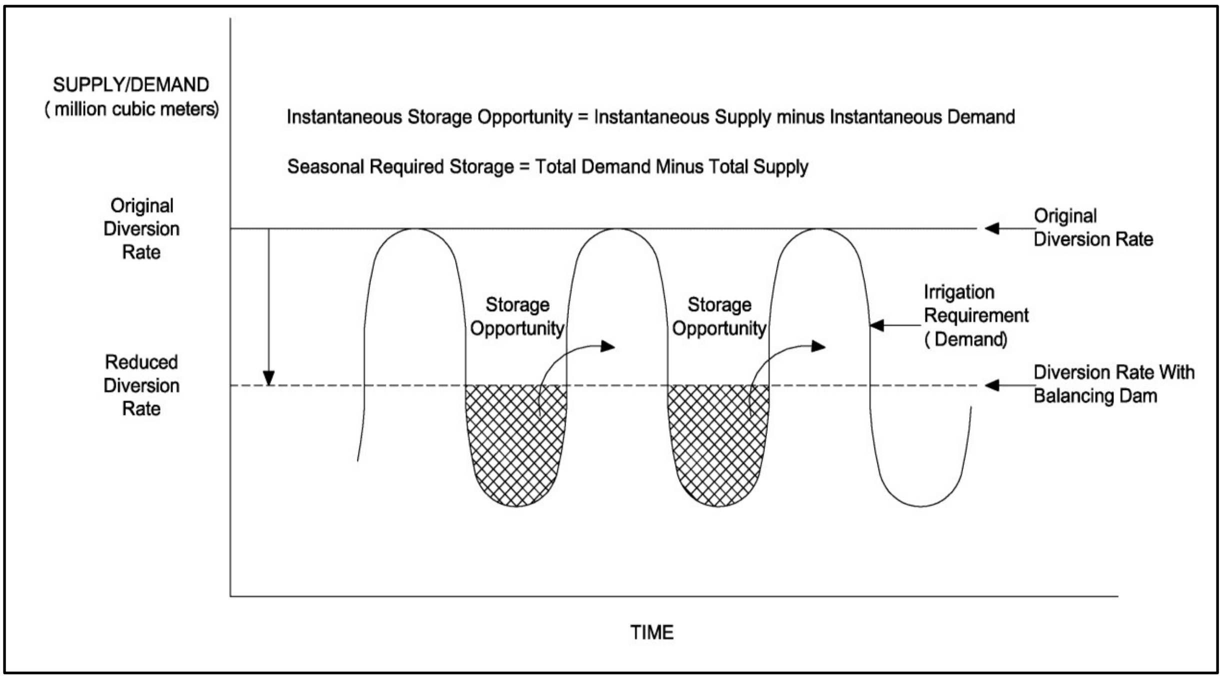

Figure 8:1: Possible demand and supply relationship and potential benefit in flexibility from a Grootdraai balancing dam

8.4.2 Demands

The supply to individual water users is measured (or rather administered) through the Parshall Flumes below the sluice gates. The WUA measures the head and the resultant pressure is then related to a specific volume of water (e.g. 50 m³/h, 70 m³/h, and 100 m³/h). The sluice gates are adjusted by hand in increments every 24 hours to supply irrigators' demands for the week at an average of 120 hours or 5 days before the sluices are closed. During peak periods irrigators are supplied up to 168 hours in a week.

Due to the water level and hence pressure variance in the canal system, there is a margin of error in the volume of water delivered to the water user and water users are requested to accept a margin of error of 10%. The weekly data on releases at the individual sluices and Parshall Flumes were aggregated in the WUEARs to provide monthly records of water requested and used by the irrigators. This was taken as the crop evapo-transpiration (ET).

Records of monthly deliveries to other water users, namely uPongola Local Municipality for domestic supply and for Pongola Sugar Mills was included in the water use.

8.4.2.1 Irrigation water demands

The volume of water that is requested by the irrigators in the Impala Irrigation Scheme area varies from year to year, as does the cropping pattern for each year. For the past 7 water years the irrigation water application has ranged from 96.6 million m^3/a in the 2010/11 to 124 million m^3/a in the 2008/09.

Over the past seven years, the average irrigation water demands was 101 million m^3/a. However, an additional 30 million m^3/a is taken by run-of-river irrigators making the total volume of water used in the Impala Irrigation Scheme approximately 77 % of the scheduled quota of 170 million m^3/a.

The average monthly applications were 9.2 million m^3, which is approximately 59% of the average monthly diversion.

8.4.2.2 Other demands

Besides irrigation water demands, the Impala Irrigation Scheme also supplies two major water users namely the uPongola Local Municipality for domestic water use mainly in Pongola town and the surrounding communities; as well as the Pongola sugar mill.

The sugar mills abstracted on average 1.0 million m^3/a over the last 7 years. However it is important to note that over the last 3 years, the average water demand by the mill has increased significantly to average approximately 1.3 million m^3/a. This represents an increase of nearly 30%.

The domestic water demand from the irrigation canal infrastructure has averaged 3.25 million m^3/a, with abstraction ranging from 2.68 million m^3/a to a maximum of 3.9 million m^3/a in 2011/12 water year.

The total average water use supplied by the Impala Irrigation canal system over the last 7 years to the water users has been 109.5 million m^3/a.

8.4.3 Comparison of monthly releases into the canal system with monthly water requirements

There is a correlation between the monthly releases from the Grootdraai weir into the Impala irrigation primary canal with the monthly water requirements as illustrated in **Figure 8.2** below. The irrigation water supplied is more than the water used by irrigators and other water users in the scheme as the scheme has tried to match the irrigation supplies with the irrigation demands. The difference in matching supply to the irrigation demand was to take into account the losses needed to deliver the water required by the irrigators.

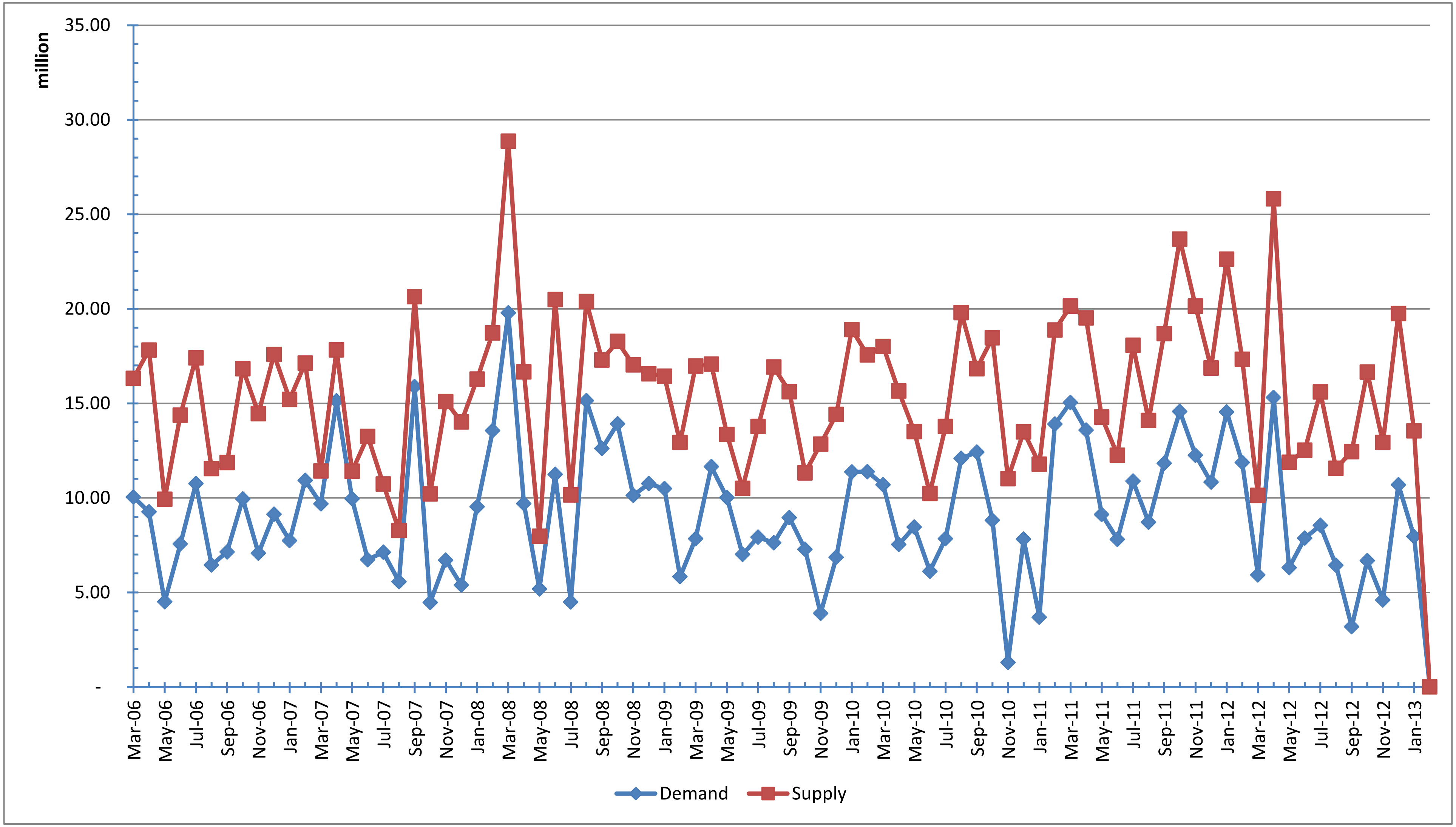

Figure 8:2: Comparison of deliveries and the demands in the Impala scheme (million m^3)

As illustrated in **Figure 8.2**, there is a significant difference in trying to match the water demands and the deliveries, as significantly more water needs to be diverted to meet the water ordered. The seven year average percentage of additional water required to meet the irrigation demands was determined to be 41.7% of the total water diverted.

The additional water can be attributed to irrigation water losses owing to seepage, leakage losses in the irrigation canals, evaporative losses from the open irrigation canal infrastructure and spills at the canal ends when the demands are not all taken up. There are also operational wastage that is expected in try to match the supply and the demand.

The above average percentage has been benchmarked against best management practice (BMP) in order to determine the extent required to meet the BMP for irrigation operation of the Impala Irrigation Scheme

8.5 Gross Water losses (return flows not used for irrigation)

Table 8.1 indicates that the average gross water losses including the return flow, has been 41% of the total diverted flow. This translates to approximately 75.1 million m^3/a of water losses in the Impala Irrigation Scheme area. This amount includes both avoidable water losses and unavoidable water losses. These include canal evaporation losses, seepage and leakage in the primary canals and distribution canals, percolation, and operational spills.

Figure 8.3 below provides a trend analysis of the total linear water losses and the estimated gross water losses.

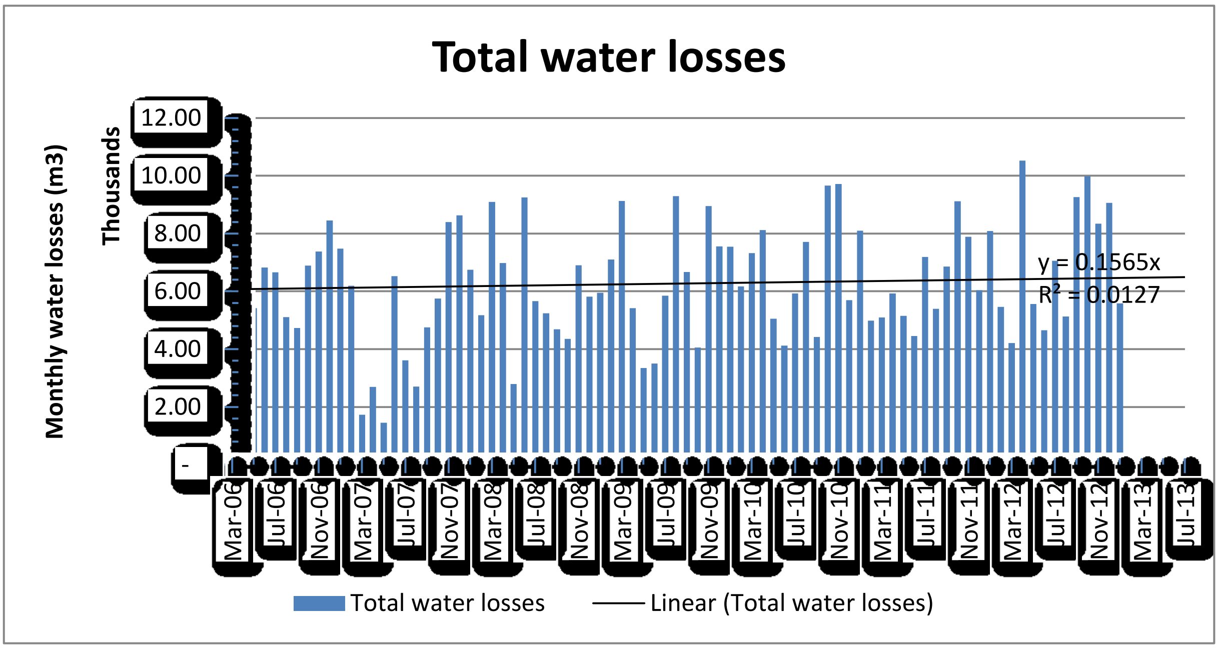

Figure 8:3: Water losses in Impala Irrigation Scheme

It is important to note that during the period between September/October to January the amount of water losses as a percentage of diverted volume is consistently higher than normal. This may be attributed to the fact that this is the period when the irrigation water requirements are low. Therefore the water losses due to seepage and leakage as the canals do not run full are higher as a percentage of the diversion amounts.

8.5.1 Unavoidable water losses in the Impala canal system

There was no data to disaggregate further the water losses into evaporation, seepage, leakage, filling losses and operational spills. There are also currently no records included of the flows at the canal tail ends to determine the operational spills. Direct measurement of operational spills at the canal tail end returns can be conducted as there are Parshall flumes at most canal tail ends which can be measured.

Table 8.2 below provides a summary of the water losses in the Impala canal system. As illustrated in the table, the minimum seepage losses as calculated in the previous chapter for the Impala canal system is 21.29 million m^3/a while the evaporation losses was calculated based on the canal surface area and the MAE as 1.15 million m^3/a. The total minimum unavoidable losses that has to be added to the irrigation water requirements or the schedule allocation is 22.44 million m^3/a, or 12% of the total water diverted into the Impala canal system.

Table 8:2: Summary of the water losses for the Impala Irrigation Canals (million m^3/a)

<table>
<tr><th>Description</th><th>Unavoidable losses</th><th>BMP for distribution losses</th><th>Avoidable losses</th><th>Total losses</th></tr>
<tr><td>Seepages</td><td>21.29</td><td></td><td></td><td>21.29</td></tr>
<tr><td>Evaporation</td><td>1.15</td><td></td><td></td><td>1.15</td></tr>
<tr><td>Filling losses</td><td></td><td rowspan="7">27.70</td><td rowspan="3">14.42</td><td rowspan="3">42.12</td></tr>
<tr><td>Leakages</td><td></td></tr>
<tr><td>Spills</td><td></td></tr>
<tr><td>Operational Losses</td><td></td><td rowspan="4">10.95</td><td rowspan="4">10.95</td></tr>
<tr><td>Over delivery to users</td><td></td></tr>
<tr><td>Canal end returns</td><td></td></tr>
<tr><td>Other</td><td></td></tr>
<tr><td>Total</td><td>22.44</td><td>27.70</td><td>25.37</td><td>75.51</td></tr>
<tr><td>% of total losses</td><td>30%</td><td>37%</td><td>33%</td><td>100%</td></tr>
<tr><td>% of total volume released into system</td><td>12%</td><td>15%</td><td>14%</td><td>41%</td></tr>
</table>

8.5.2 Avoidable water losses

8.5.2.1 Total avoidable water losses

The unavoidable losses calculated in the previous chapter were based on the assumption that the condition of the Impala Irrigation Scheme canals are being well maintained and are refurbished in time to maintain the level of service from the canals. This was considered to be the economic level of seepage (ELS) for the Impala canal system.

Having determined the unavoidable water losses which are required to deliver the irrigation water requirements, the remainder of the gross water losses are considered avoidable water losses to the scheme, although they are beneficial to downstream water users. This is because these losses can be prevented by implementing appropriate water management intervention measures. The total avoidable water losses for the Impala canal system was determined to be 53.1 million m^3/a, or 29% of the average annual diversion over the past seven years. The avoidable water losses include leakage, operational spills including operational wastages such as filling losses as well as releases for dilution due to salinity problems. Some of the avoidable losses cannot be completely saved. This is discussed later on the best management practices for the Impala Irrigation Scheme.

8.5.2.2 Operational losses and canal end returns:

There are water losses on the canal system which can be classified as operational losses due to the way the scheme is operated. Such losses include start-up and shut-down losses, operational wastage due to the lack of quick response to changes in demand, water not used (outflows) due to unexpected drops in demand and losses due to incorrect metering. These losses are estimated to fluctuate between 9% and 28% of the irrigation water losses (Reid, Davidson and Kotze, 1986).

On the Impala Scheme, because of the telemetry system now being operational, and the controls were manually operated these losses have been estimated to be high as the time to react to any changes in demands are likely to take longer. Therefore based on the assessment of the Impala scheme the figure used as operational losses is 10% of the total inflow (see **Table 8.1** above). This translates to approximately 10.95 million m^3/a, of the water losses that can be considered as operational losses as illustrated in **Table 8.2** above.

The operational losses at canal tail ends represent that more water is being diverted into the canal system than is necessary. This is necessary because of the need for dilution requirements because of the salt load from upstream operations. On the Impala irrigation canal system where the scheme is manually operated these losses are likely to be high as the time to react to any changes in demands are likely to take longer. There are automated sluice gates to remotely adjust flows in the irrigation scheme.

8.5.2.3 Water Losses due to calibration and metering error

Besides the operational spills at various points in the Impala canal system including the canal tail ends, there are metering errors on the Parshall Flumes due to calibration problems because of submergence conditions at some of the sluices.

Based on the literature review on the Parshall Flumes the percentage error due to calibration problems are around +/- 3% of the water losses increasing to as high as 10% of the irrigation water losses ((Kulin 1984), if submergence conditions are experienced.

8.5.2.4 Leakage losses:

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

An important factor that has a marked effect on leakages is therefore 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.

In the case of the Impala Irrigation Scheme, the leaks and spills have been taken as the difference between the unavoidable losses (i.e. evaporation losses and seepages) and the operational losses. As expected because of the age of the canal infrastructure and the condition of some sections of the canals, the leaks and spills are high at the average of 31.09 million m^3/a likely to be high, because of the continuous operation of the scheme.

8.5.2.5 Canal end return flow

At present the measurements are being taken from the canal tail ends but are not currently being included in the water balance assessment. The monthly gauge plate readings provided only reflect the inflows into the Main canal, the Transvaal canal and the Natal canal where the two split from the main canal.

There are 5 main discharges in the Impala scheme which have Parshall flumes; the Sitilo discharge has a 2 inch Parshall, the Ncotshane has a 4 inch Parshall, Wonderfontein has a 3 inch Parshall near the discharge point, the Transvaal has a 6 inch Parshall while the Mbega ends at an irrigator sluice gate. Besides the flow measurements at the canal end points, there are also 15 branch canals. There are no flow measurements at these branch canals as most of these canals end at the irrigators' farm dams.

A higher flow in the canal system is maintained to ensure sufficient hydraulic pressure in the canal (as a function of partial flume efficiency) and sustainable volume delivery at the canal end points for users. The additional water that flows back to the river is not considered an operational loss as it is accounted for at the inlets at the Grootdraai weir as well as downstream bifurcation points and is a salt dilution measure in the Pongola River for downstream riparian users

8.5.2.6 Aquatic weeds and algae:

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

(i) A negative influence on hydraulic capacity and flow speeds in the canals. This decrease in canal capacity occurs particularly when the water demand is at its highest.
(ii) Overestimation of the amount of water supplied, because of the artificially increased water levels that are measured at calibrated weirs.
(iii) Water loss because of the flooding of canals.
(iv) Impediment of floodgate and sluices at dividing structures.
(v) Water logging of long-weirs.
(vi) Structure (slab) failure of concrete-lined irrigation canals due to flooding.
(vii) Aquatic weed fragments block irrigation systems and filters at water purification plants.
(viii) The mechanical removal of the biomass is extremely labour intensive, expensive and mostly ineffective.

The aquatic weeds and algae is not a major issue in the Impala Irrigation Scheme and have not been considered as such.

8.5.2.7 Total avoidable water losses - Impala irrigation Scheme

The estimated avoidable water losses over the 7 year period have averaged approximately 53.1 million m^3/a (see **Table 8.2** above). The reason for the high losses may be due to a number of factors which include the following issues.

(1) Matching of supply and irrigation water deliveries

One of the main issues that may be contributing to the high avoidable water losses could be that, although there is weekly scheduling of deliveries and water is delivered only when needed, it is a very complicated challenge to match the deliveries with the water orders.

There may be periods when, although irrigators have requested particular volumes of water for the week, they determine that they may not require the full amount. This then creates a time lag in adjusting the volume required, not only at the sluice, but through the canal system to the Grootdraai weir. Given the fact that the sluices are adjusted after 24 hours, there is potential for operational spills to take place which may account for the high operational spills as illustrated in the irrigation water budget.

Furthermore, previously without the use of the existing telemetry system which was not operational and linked to the WAS, it was difficult to reduce the response time to such changes in demands and have the flexibility to respond by reducing the diversion rate. This will improve in future with implementation of the telemetry linked to WAS.

(2) Age and condition of the canal infrastructure

There could be significant canal leakages, because of the age and condition of the canal infrastructure. Leaks normally occur in broken sections of the canals and at the top sections of canal bodies and can be attributed to maintenance problems and the general deterioration of the canal network owing to its age.

However, there is the problem that it is difficult to assess which section or canal reach has significant leakages which would assist the Impala WUA to focus the maintenance and repairs as well as refurbishment on the canal sections or reaches with the highest leakage. This would provide a programme during the dry periods. Currently there is no information available to determine where significant leakages are taking place without undertaken sub-scheme water budgets.

(3) Meter reading errors:

With the current method of manual reading of the depth of flows by the WCOs, there is a likelihood of meter reading errors due to human error. Previously lack of effective use of the telemetry system may have contributed to the high avoidable losses over the last 7 water years.

9 EXISTING WATER MANAGEMENT MEASURES AND PROGRAMMES

9.1 Overview

Chapter 6 indicated that the water losses in the Impala WUA are generally high. The water balance assessment has indicated that there is a need to determine and implement water management measures to reduce irrigation water losses and improve the water use efficiency of the scheme.

Before determining the necessary water management measures to improve irrigation water management, an assessment of the existing water management measures and initiatives if any has been carried out. These have been identified based on discussions with the scheme operators on the programme in place as part of efficient and effective irrigation water management of the Impala WUA.

The Impala WUA has been implementing measures to improve the management of delivery to the irrigators. These have included the following:

(i) Flow measurement and preparation of WUEARs which provides an indication of the extent of water losses and scheme irrigation water use efficiency levels
(ii) Use of WAS
(iii) Carrying out maintenance of the canal system during dry periods to reduce avoidable canal losses.
(iv) Continuous flow delivery of irrigation water to reduce the amount of canal leakage.

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

9.2 Flow measurement

The Impala WUA has most of the flow measurement structures and systems at the critical diversion points to measure how much water is diverted at different points of the irrigation scheme. The existing infrastructure is sufficient to ensure that detailed water balance assessments can be conducted at scheme level as well as at sub-scheme level.

The problem currently experienced is that, although the measurement structures and systems are in place, the Impala WUA is not reading all the flow measurements, particularly the Parshall Flumes at the canal tail ends. The flows at Mhlati weir are not reflected in the Water Use Efficiency Accounting Report (WUEAR). Therefore detailed water balance assessments cannot be prepared even at scheme level let alone at sub-scheme level.

9.3 Continuous delivery of water requests

One of the ways Impala Irrigation Scheme has successfully managed to undertake delivery to users, is to operate the water deliveries on a continuous basis, including during weekends. Water is delivered on a continuous basis only as and when requested, based on the advanced ordering (demand) system for water deliveries, as described previously.

9.4 Irrigators responsibilities

Although the Impala Irrigation Scheme has the ability to check or shut down canals and branch canals to avoid spills, this can only be done after 24 hours because the system is not automated.

Therefore in order to ensure that irrigators only apply for the water they require, the Impala WUA has put the onus on irrigators to apply for any reduction in the water application in time. If there is any amount of the water that the irrigator does not take up for whatever reason such as the farm dam being full or rainfall during the week, the loss is taken to the account of the farmer who requested the water.

The problem with this principle, however is that there is a likelihood of reducing the level water losses if the reduction is not factored in the water balance assessment. Therefore the water not taken up may result as flow at canal tail ends, which will be a loss to the scheme.

9.5 Operation and maintenance of the canal infrastructure

The ownership of the canal infrastructure at the Impala River WUA is with the DWA. However the Impala WUA is responsible for the operation and maintenance of the canal infrastructure.

During dry periods, significant maintenance is carried out on the primary canal and secondary canals. However because the scheme does not have balancing dams, the amount of filling losses are generally higher than schemes with balancing dams.

9.6 Use of WAS

The Impala WUA is one of a number of schemes where the Water Administration System (WAS) has been installed to allow for water efficiency and accounting reporting to be done.

There are 7 modules of the WAS programme. However, the Impala WUA is currently not utilising the release module, which assists in releasing the correct amount of water at the correct time. The Scheme has found the release module very difficult to implement as they receive water from 2 systems, namely the Bivane Dam and the Pongola River as well as it being resource intensive. The Scheme has however a distribution chart, which they utilise for determining the releases required at different canal sections.

9.7 Refurbishment and Rehabilitation of water infrastructure

9.7.1 Operation and maintenance of the canal infrastructure

Although the ownership of the canal infrastructure at the Impala Irrigation Scheme 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 Impala WUA has an annual O&M budget, which is estimated to amount to R12.5 million per year, based on the canal charge of R737 per ha/a for the current 17 012 hectares that is scheduled.

9.7.2 Capital fund for refurbishment of infrastructure

The DWA is responsible for the capital fund of any major refurbishment and rehabilitation of the canal infrastructure. This is determined between the Impala WUA and DWA Infrastructure Branch.

9.8 Impact of existing water management measures

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

The water management issues contributing to the high water losses and the management to address these issues with a view to improving irrigation water management in the Impala Irrigation Scheme are discussed in detail in the following chapter.

10 WATER MANAGEMENT ISSUES AND GOALS

10.1 Overview the management issues

The water use performance benchmarking and water balance analysis of the Impala Irrigation Scheme which was presented in the previous chapter 8 together with discussions held with Impala WUA, has helped to identify several key water management issues.

The comparison between the expected water losses according to the best management practice (BMP) for irrigation water conveyance and the water balance analysis has identified that there are substantial losses taking place in the Impala Irrigation Scheme. There is insufficient data to clearly determine where and how losses are occurring. Currently there are no long term records as to how much water spills due to operational issues at the canal tail ends.

The water balance analysis did reveal, however, that on an annual basis, there is sufficient water to meet the Impala Irrigation Scheme's irrigation demands. It also highlighted that irrigators are currently not utilising their full water allocation.

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

Table 10:1: Impala Irrigation Scheme: Identified water management issues

Item No.	Issue description	Comments
1	Current water balances being conducted are at scheme level and not at sub-scheme levels and do not include canal tail-ends. (i) There are no sub-scheme water balances being conducted to assist in determining where the focus should be in repairs and maintenance of the irrigation canals during the dry periods; (ii) Not all the measured data is being used to generate comprehensive water balances at scheme and sub-scheme level (iii) Water balances contain estimates of water losses - there are no measurements being undertaken; (iv) Water balance assessment does not include precipitation.	Implement a detailed water balance including measurement at canal tail ends and balancing dams in order to disaggregate the water losses by sub-scheme.
2	Not all modules of the water administration system to manage water use is being fully utilised for sub-scheme water balance assessments: (i) The water release module is currently not being utilised to improve water management; (ii) It is difficult to pinpoint the exact scheme area experiencing water losses.	Implement use of WAS to conduct detailed sub-scheme irrigation water balance assessment. The distribution chart will be used in place of the WAS release module.
3	Gross water losses (return flows not used for irrigation) are substantially higher than the expected BMP for lined canal irrigation scheme	Review the operating rules of the scheme and consider lining of 23

Item No.	Issue description	Comments
	(i) Condition of sections of the canal infrastructure are in a fair state with some sections may be in a poor state. (ii) There are sections of the canals which are not lined. There is a likelihood that the level of leakage in these canals is high contributing to the high water losses (iii) The reaction to changes in irrigation demand during the week is slow because the scheme is not automated. This may be contributing to the spills at the canal tail ends and hence the high water losses	km of earth canals.
4	Irrigators are paying the WMA based on their full water allocation (i) Current pricing is area based (per ha) (ii) Irrigators are losing on the benefits of the use of their full water use entitlements (iii) Area based assessment encourage water waste and produce inequitable water costs between efficient and inefficient users.	Financial incentives are necessary to encourage efficient water use
5	There is significant over-irrigation taking place in the Impala Irrigation Scheme (i) Significantly more is being put on to the sugar cane than is necessary (ii) There is concern that there will be leaching of nutrients, thus reducing the quality of cane, particularly the sucrose content and the cane yield decreases (iii) Over irrigation is also resulting in increased salinity of return flow.	Encourage incentive based pricing of water within 2 years
6	With the conveyance infrastructure owned by the DWA, there are concerns around the following: (i) There are service level agreements between the DWA and Impala WUA regarding the roles	Review and update the existing Service Level Agreement between

Item No.	Issue description	Comments
	and responsibilities. However all the refurbishment requirements have not been completed at this stage. Assets are owned by DWA while the O&M is carried out by Impala WUA. There is a likelihood of a disjuncture in ensuring the assets are maintained until such time that the asset are refurbished according to the MOA, resulting in deterioration of the infrastructure and increase in water losses (ii) The lack of clarity may result in some of the issues such as refurbishment of the infrastructure not being carried out in time to reduce water losses from the canal infrastructure (iii) The priorities between the two entities may differ in terms of when to undertake rehabilitation of the infrastructure	the DWA and Impala WUA

10.2 Flow measurement data and assessments

10.2.1 Adequacy of flow measurement data

Good information is fundamental to making decisions on managing irrigation water at any irrigation scheme. **Figure 10.1** below provides the extent of flow measurement that is ideal for conducting an irrigation scheme water balance assessment. 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 balance analysis not only at scheme level but also for sub-schemes within the irrigation scheme.

As illustrated **in Figure 10.1** below, it would be ideal to have flow measurements at the inlet to the primary canals, at the main branch canals, at balancing dams as well as at the canal tail water ends. This would assist in determining the water losses in each section of the canal system, as well as the operational spills if there are any.

As indicated in **Figure 3.2**, the Impala Irrigation Scheme has adequate flow measurement structures in place at the ideal places to measure the flows. Although the WUA is currently taking the flow measurements at all measured points, they are not using all the information in generating the water balances at sub-scheme levels.

With the Impala Irrigation Scheme operating continuously and at normally high flows, devices such as sharp-crested weirs, short-throated flumes, rated sluice gates or submerged orifices do not operate well in high flow situations. Therefore there is scope for un-accounting of the water diverted and delivered to the irrigators.

Losses from canal tail-ends can be reduced by improving water control in channels through the use of channel control technology and/or changing management practices. Examples of measures to control outfalls include the automation of flow-control structures and measurement devices and the optimisation of channel operations, using computer software.

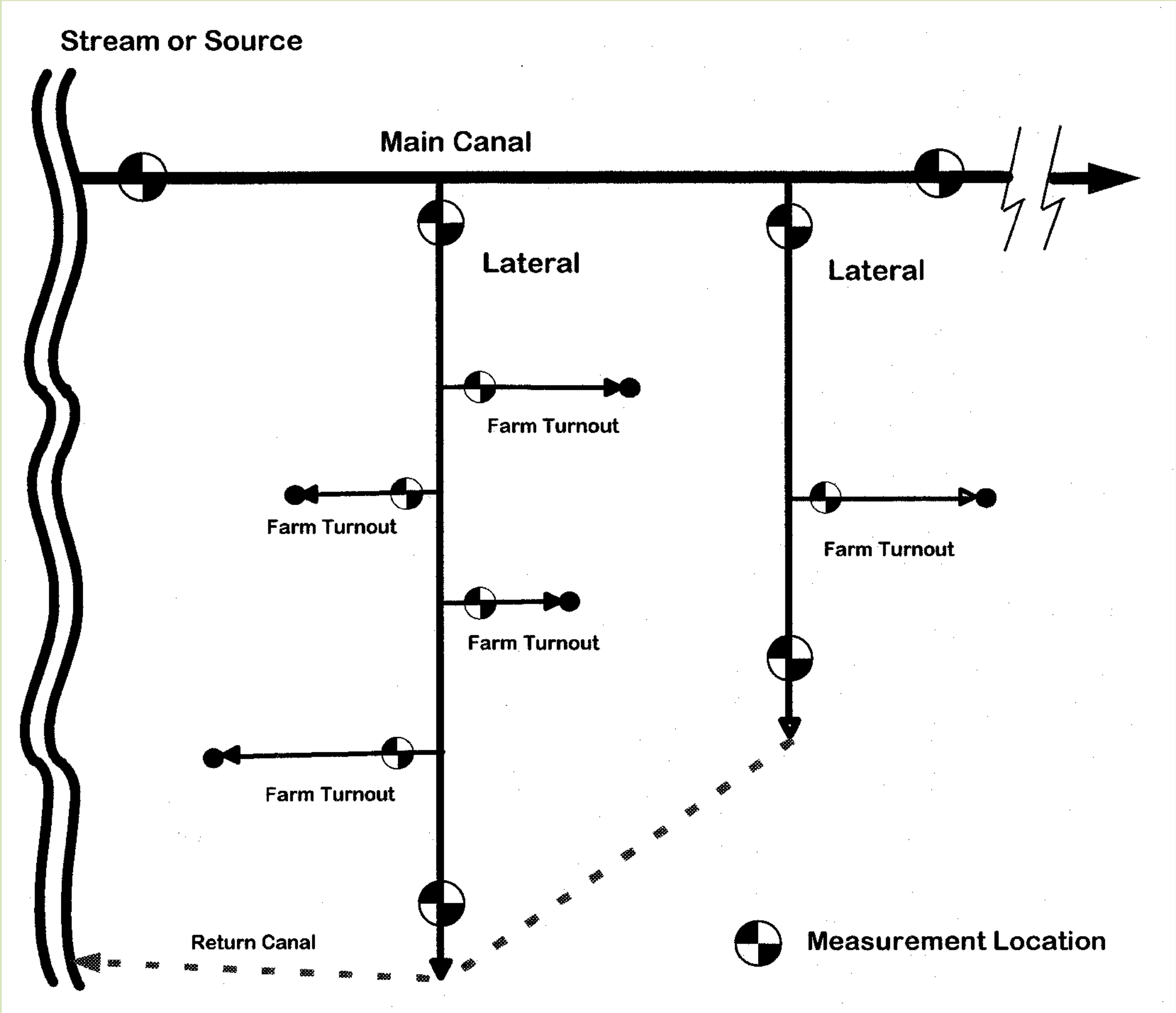

Figure 10:1: Irrigation Scheme with ideal water measurement system

Source: Bureau of Reclamation

10.2.2 Management Goal 1

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

(i) Regular measurement of flows into all primary and branch canals, as well as measurement at the tail ends of the canal system to enable detailed water balance assessments to be carried out;

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

10.3 Operationalise the Water Administration System

10.3.1 The installed WAS is currently not being fully utilised

The Water Administration System (WAS) was developed as a tool to be used by Irrigation Boards/Schemes to optimise their irrigation water management and minimise management-related distribution losses in irrigation canal systems. The WAS consists of seven modules, integrated into a single programme and these modules can be implemented partially or as a whole. The system includes the following seven modules:

10.3.1.1 Administration module -

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

10.3.1.2 Water order module

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

This module is very useful to determine the extent of additional requests, as well as the cancellations, as this will provide a clear indication of the extent of operational spills on rejects and tail ends in the case of cancellations. It will also highlight the flexibility that the Impala Irrigation Scheme has in responding to cancellations.

Currently there is no reporting from this water order module, which could assist the Impala WUA in responding to changes in water ordering system.

10.3.1.3 Water release module

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

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

The Impala WUA is not utilising the water release module due to the complex nature of the Scheme. It is however utilising a distribution chart for the similar purpose.

10.3.1.4 Measured data module

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

10.3.1.5 Other modules

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

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

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

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

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

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

10.3.2 Management Goal 2

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

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

10.4 Irrigation water balance assessment

10.4.1 Irrigation water balance is not conducted in detail

Although a lot of measurement structures are available including the Parshall flumes at branch canals as well as at canal tail-ends in the Impala Irrigation Scheme, the measured data is currently not all being used to determine water balance assessments for the sub-schemes. Currently the irrigation farms have not been disaggregated to the canals from which they are supplied from. For example the farmers supplied from the Ncotshane canal system can be aggregated and compared with inflow into the canal as well as the outflow at the canal tail end of the Ncotshane canal. All the measurement devices are available.

The Impala WUA could then conduct detailed water balance for the Ncotshane canal. By conducting the water balance assessments for each primary canal, the level of water losses in each sub-scheme can be determined. The results of the water balance can then be used to prioritise the focus areas where the losses are high for intervention at the sub-scheme level.

10.4.2 Management Goal 3

The goal to address the above issue is as follows:

(i) Ensure that flow measurements at the canal tail-ends and measurements into the main primary canals are taken on a continuous basis in the Impala Irrigation Scheme;

(ii) Ensure that all measured data forms the basis for conducting water balance assessments and calculating water losses at scheme as well as sub-scheme level.

10.5 Condition of the conveyance and measurement facilities

10.5.1 General

In order to properly develop the Impala Irrigation scheme 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 high level condition assessment together with discussions with the Impala WUA was undertaken. The included the operation and maintenance system, the conveyance and distribution system. No assessment of the on-farm delivery systems was conducted. The main issues that were identified are discussed in the following sections.

10.5.2 Natal to Wonderfontein siphon is leaking

During the site visit that was conducted in April 2011 and discussions with the Impala WUA, it was identified that the siphon linking the Natal canal and the Wonderfontein canal, was leaking badly. It would appear that there are no air valves nor the scour valves, as these could not be found. This may be the cause of the leakage as there may be air binding taking place in the siphon which has created water leakage on the section.

The siphon has since been repaired by the WUA.

10.5.3 Condition of canal infrastructure

Although there are no measurements being read to determine the actual avoidable water losses in the Impala Irrigation Scheme, the assessment carried out in the previous chapter have highlighted that there are likely to be very high water losses in the canal infrastructure.

A condition assessment of the existing canal infrastructure has not been conducted for this report. However an analysis of the upgrading of the raising of the canal infrastructure in 1998 indicates that there are sections of the canal infrastructure were the canal system was half lined and that there are some sections which were not lined. There is a strong likelihood that there may be leakage and canal losses that may be taking place on these sections or at the joints between the different canal sections.

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

10.5.4 Management Goal 4

The management objective to address the above issues, is to develop and implement a refurbishment programme to reduce irrigation canal losses within 5 years, so that unneeded natural flows can be stored in the Bivane Dam to provide security of water supply during drought periods.

10.6 Flexibility in scheme operation

10.6.1 Irrigators cannot be supplied sufficiently during canal maintenance period because of lack of balancing storage

The Impala Irrigation Scheme does not have regulating structures such as balancing dams to regulate the demands in different sections of the scheme. This creates problems, particularly during the two weeks' dry periods, when the WUA undertakes maintenance of the canal infrastructure as the whole.

For example, the Transvaal canal will be shut down in its entirety, if maintenance is being conducted on the primary canal. If there was a balancing dam strategically placed on the Transvaal canal section, the irrigators would benefit in that those downstream of the dam would continue to be supplied from the balancing dam.

In order to address this issue, the Impala Water User Association (WUA) has to employ significantly more personnel to carry out the maintenance during the dry periods. This may have increased the maintenance budget of the WUA, as opposed to having balancing dams which have sufficient storage capacity to regulate flows not only during the dry periods, thereby reducing the cost of maintenance.

The filling of the 146 km of canal after the dry period could also be reduced, if balancing dam(s) are constructed to enable operations of sections of the irrigation canal system even during dry periods. One of the benefits of having regulating structures such as balancing dams, is that balancing dams will reduce the time it takes to deliver water to the irrigators, thereby reducing the seepage losses and leakages in the conveyance system.

Before the balancing dams are considered, the Impala WUA must conduct a financial analysis of constructing balancing compared with the current system of season employing of personnel to undertake the maintenance during the dry periods. The second aspect is to encourage irrigators to construct larger storage dams to enable them to have sufficient storage particularly during the maintenance period.

10.6.2 Management Goal 5

The management goal is therefore to reduce the operational spills and wastage by building flexibility in the scheme operation. This can be done by encouraging irrigators to construct bigger storage to enable them to have sufficient water stored during dry periods and the WUA developing a balancing storage in the Impala Irrigation system with 5 years.

10.7 Lack of sufficient maintenance of the existing canal infrastructure

10.7.1 Limited time available to undertake maintenance

The Impala Irrigation Scheme experience maintenance constraints because the scheme does not have regulatory infrastructure such as a balancing dam. Because of the nature of the type of crop irrigated in the scheme area, the scheme operators can only close the sections of the canals from mid-May to mid-August. This time is not sufficient to maintain the canals taking into consideration the total length of the canal infrastructure in the scheme and the lack of balancing storage. As a result not all the canals are maintained during this dry period.

The lack of timeous maintenance of the canals may be resulting in a rapid deterioration of the canal infrastructure. This may therefore be one of the major reasons contributing to the high irrigation water leakages in the Impala Irrigation Scheme. Extending the dry period is likely to affect the yield of the sugar cane as it becomes extremely hot after August and the evaporation is very high during this time of the year.

Besides the lack of balancing dams there are no backflow canals that can provide the flexibility to supply irrigators during the dry period.

10.7.2 Management Goal 6

The goal to address this issue is for the Impala Irrigation Scheme to improve the maintenance of the canal infrastructure within 2 years with a view to reducing the irrigation water leakage in the irrigation system.

10.8 Ownership of irrigation infrastructure

10.8.1 Roles and responsibilities in infrastructure maintenance have not been clearly described

The irrigation boards and Water User Associations (WUAs) have 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 Impala Irrigation Scheme, the Department of Water Affairs (DWA) still owns the irrigation infrastructure including the Grootdraai weir, the main canal, and primary 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.

The problems will most likely arise, when the major infrastructure needs replacement/total refurbishment, as is the case with the siphon between the Natal and Wonderfontein canals. At present as was the case with the Wonderfontein siphon, the WUA undertook the refurbishment of the siphon.

It is unlikely that the WUA will always have 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 WUAs. This may lead to water losses in the future.

10.8.2 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 Impala WUA are further refined from 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.

10.9 Over irrigation on farms

10.9.1 Low on farm irrigation efficiency

The recent site visit to the Impala Irrigation Scheme as well as discussions with the scheme operators highlighted that there may be over-irrigation of the sugarcane in the scheme area. Because, traditionally sugarcane requires a significant amount of water and given the high evaporation in the Impala Irrigation Scheme area it is not known the extent of over-irrigation in the scheme.

Excess irrigation water in the root zone may induce leaching of the valuable nutrients beyond the root zone and may also create oxygen stress and therefore retard normal growth of plant instead of boosting the crop yield.

The over irrigation also results in high salinity return flows.

Given the fact that irrigators apply the fertiliser together with the irrigation water, the cost of over irrigation is an economic one of the irrigators which can be addressed by education and training.

10.9.2 Management Goal 8

The management goal to address this issue depending on the extent of over-irrigation is to provide incentives such as encouraging temporary transfers and water banking. Currently the WUA is not involved in water transfers except when informing the DWA regarding the transfers. It may be useful to ensure that there is a formalised approach to water transfers with the scheme operators assisting the irrigators and creating awareness through education and training programmes for irrigators on ways to improve their irrigation efficiency levels on farm.

The other aspects are to ensure that education and training is taking place for the sugarcane growers in the Impala Irrigation Scheme if this is not taking place. However this is likely to be taking place through the sugarcane growers association.

11 IDENTIFICATION AND EVALUATION OF WATER MANAGEMENT MEASURES

11.1 Overview

There are numerous water management measures that accomplish a wide range of the goals identified in the previous section. However, only a few of the measures have the capacity to accomplish the goals to improve irrigation water use efficiency in the Impala Irrigation Scheme.

The identified and priority water management measures to improve irrigation water use efficiency on the Impala Irrigation Scheme include the following:

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

(2) Preparation of more detailed water balance assessments for the Impala irrigation scheme, as well as the sub-schemes which include the Transvaal canal and its secondary canals and the Natal canal and the secondary canals.

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

(4) Update the existing telemetry infrastructure to enable real time monitoring of irrigation water in the long term as well control of sluice gates at the Grootdraai weir.

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

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

11.2 Best Management Practices for irrigation water management in Impala Irrigation Water Scheme

11.2.1 Overview

In order to evaluate the candidate water management measures it was important to first of all determine the water loss target by incorporating not only the unavoidable water losses but also determining the attainable level of water losses based on the Best Management Practices (BMP) envisaged in the Impala Irrigation that takes account of the technical and managerial capacity of the Water User Association and the operational practices of the scheme. This is discussed in the following sections.

11.2.2 Gross/Total water losses

The water losses in the Impala Irrigation Scheme are considered to be very high at 41% of the total release into the Impala canal system. The total water losses were determined to be 75.5 million m^3/a based on the 6 year average from 2006/07 to 2012/13 water years and the available records.

In order to determine the potential water that can be saved from the Impala irrigation scheme, the unavoidable water losses as well as the BMP for operational and distribution efficiency were determined.

11.2.3 Unavoidable water losses

It was determined in Chapter 7 that the unavoidable water losses due to evaporation losses and seepage due to the expected hydraulic conductivity of lined canals in the Impala canal system was 22.44 million m^3/a based on the total releases into the canal system for the 7 year period, which translates into 12% of the total volume of water diverted into the Impala canal system.

11.2.4 Best Management Practice for operational and distribution efficiency

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

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

(ii) *Operational performance losses* – The existing sluices and Parshall flumes have inherent errors that need to be included in the operational performance of the scheme even after improving the calibration of the flow measurements. Additional water is required to maintain the water levels in the canals to enable hydraulic performance of the Parshall Flumes. These metering errors have to be taken into account when determining the Best Management Practice (BMP) for in the Impala Irrigation Scheme distribution efficiency

(iii) Untimely deliveries of water that cannot be used as a result of cancellations which will take a minimum of 24 hours to make adjustments to the releases. These losses can result in either operational spills at the canal tail ends representing a loss to the scheme or excess water which is delivered to downstream storages or canals within the scheme.

(iv) *Releases to address salinity problems* – The Impala WUA releases additional water for dilution purposes because of the high salinity problems being experienced in the scheme and downstream of the scheme. However at this stage the WUA is not measuring the volume of water being used for dilution purposes. This volume of water is part of the total water losses that were determined for the scheme. It is required and can be considered as a demand. In the absence of flow measurements, it has been estimated that this is approximately 5% of the irrigation water diverted at the Grootdraai weir.

A Water Research Commission (WRC, TT466/10) which was conducted in 2010, has provided guidelines of the desired range of operational losses due to metering errors, canal filling losses after each dry period that have to be included in order to determine the BMP for operational and distribution efficiency (WRC 2010). . This is additional to the unavoidable losses determined in the previous sections. This desired range is expressed as a percentage of inflow into the irrigation scheme. With the lack of balancing dams, the desired range for operational losses (i.e. metering errors, canal fillings, dilution requirements, etc.) has been set at 15% 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 15% of the inflow into the Impala irrigation canal systems. This has been used in setting the water savings and the acceptable water losses of the canal systems.

11.2.5 Acceptable water losses in the Impala Irrigation Scheme

The unavoidable water losses in the Impala irrigation scheme were determined to be approximately 12% of the irrigation diversion into the Impala canals. This water is additional to the irrigation water use required at the farm edge.

Furthermore there are operational performance inefficiencies in operating the Impala scheme including trying to match the delivery to the irrigation applications as mentioned in the previous section. Based on the WRC study the attainable range of operational losses which are not likely to the recovered through water management intervention measures is 15% of the total releases into the Impala canal systems. **Table 11.1** below provides the water loss target for the Impala canal system.

Table 11:1: Acceptable water losses in the Impala canal system

Description	Unavoidable losses	BMP Distribution Efficiency	Acceptable water losses	Target water savings	Total losses
Seepages	21.29		21.29		21.29
Evaporation	1.15		1.15		1.15
Filling losses		27.70	27.70	25.37	53.07
Over delivery to users					
Leakages					
Spills					
Operational Losses					
Canal end returns					
Other					-
Total	22.44	27.70	50.14	25.37	75.51
% of total volume released into system	12%	15%	27%	14%	41%
% of total losses	30%	37%	66%	34%	100%
Total releases					184.66

As illustrated in **Table 11.1** 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, dilution requirements to reduce salinity as well as metering errors and canal filling losses will be 27% of the total releases into the Impala canal system.

Therefore based on the 7 year average, the expected water losses were determined to be 50.1 million m^3/a. When compared with the total losses of 75.5 million m^3/a for the same period, there is still potential to implement water saving measures to reduce the current water losses from 41% to the acceptable water losses of 27% of the total releases into the Impala canal system.

The identification and analysis of the candidate measures has been done based on determining the potential savings to achieve a total water savings of 25.37 million m^3/a. However it does not necessarily mean the intervention measures can save the full 25.37 million m^3/a.

11.3 Task 1: Flow measurements at critical points of the irrigation scheme, calibration of the flow measurements and detailed water balance assessment

11.3.1 Frequent measurement of flows at headworks, branch canals and canal tail ends

As indicated in the previous chapter, the Impala irrigation scheme has all the necessary flow measurement structures at the critical points in the scheme. There are Parshall Flumes which can be measured to determine the flow rate, and the volume of water diverted into the headworks and branch canals or returning to the river system at canal tail ends.

Therefore with the existing measurement infrastructure, the Impala irrigation scheme should be taking continuous flow measurement at all the branch canals as well as the canal tail ends. As a matter of priority the Impala WUA should commence with measurements at the canal tail ends. This will improve the information provided in the water use accounting reports submitted to the Department of Water Affairs (DWA).

This can be followed by taking flow measurements at the branch canals so that water balance assessments at sub-scheme level can be carried out.

11.3.2 Initial capital and operation and maintenance costs

There will be capital cost required for the Impala WUA install electronic flow measurement system in order to start taking electronic flow measurements at the canal tail ends or at the branch canals. However the functions and responsibilities of the existing scheme operators will need to be updated to include taking of flow measurements on a regular basis.

11.3.3 Calibration of the Parshall Flumes

There is an urgent need to carry out an inventory of the accuracy of the existing Parshall Flumes in order to calibrate those that are found to be inaccurate. Furthermore the existing Flumes may be operating in submergence conditions resulting in inaccurate measurement of actual water delivered to the farmers. An assessment of the extent of submergence conditions must be undertaken and evaluated in terms of its effect on losses.

11.3.4 Impact of the identified water management

Although it is difficult to determine exactly how much water will be saved by taking flow measurements electronically and calibrating the Parshall Flumes or replacing them with more robust measurement system such as Crump weirs, it was determined that the potential water that will be saved will be 8.8 million m^3/a based on the 7 year average.

The installation of accurate flow measurement will provide the Impala WUA with appropriate and relevant information on where the water losses are taking place and much better information on actual water delivered to its customers. For example by taking flow measurements at the canal tail ends, the Impala WUA will be able to determine by how much they can reduce the flow rate at the canal headwork's.

However there will be some cost related to the calibration of the Flumes to improve the accuracy of the measurement structures.

11.4 Task 2: Installation of flow monitoring system

11.4.1 Refurbishment of existing telemetry system to enable control of flows into the scheme

The need for continuous monitoring of water supply delivery to the irrigators and irrigation water management is considered to be critical in reducing operational losses such as operational spills at rejects and at the tail water ends. The likelihood of a significant portion of the gross water loss being due to operational losses is high. Therefore by improving the monitoring of irrigation water in the scheme through the telemetry system will see significant water savings for both the scheme as well as the downstream water users.

The Impala Irrigation Scheme already has the telemetry system in place. Initially in 2011, the telemetry system was not operational. However the Impala WUA has since undertaken the refurbishment of the existing telemetry infrastructure in 2012. The Android telemetry system is now operational and flow measurements from the 20 diversion points can be read into the Water Administration System (WAS), in real time.

It is envisaged that the results of the telemetry system being operational will start to be realised in this coming water when the WUA will be undertaking comprehensive water balance assessment and using the telemetry to monitor the spills at the canal tail ends for example.

11.4.2 Initial and O&M Costs

The Impala WUA has already invested in the refurbishment of the telemetry system. The Capital Expenditure was approximately R498 000-00 as indicated in **Table 11.2** below.

As indicated further in **Table 11.2** below, the expected water savings due to the refurbishment of the telemetry system, the alignment of the telemetry with the WAS programme and updating of the telemetry software, including training of the WCOs, is estimated to be approximately 50% of the avoidable water losses as determined in the previous section on best management operational efficiency. This has been estimated to be 8.8 million m^3/a allowing for an 80% success rate.

Some of the water saved will be available in the Bivane Dam for use during dry periods for both the canal and river irrigators. However because the Impala Irrigation Scheme relies on run-of-river, some of the water saved due to the refurbishment of the telemetry system will benefit the downstream users as the savings will end up in the Pongolapoort Dam.

The rand value water savings from refurbishment the telemetry system and linking it to the WAS programme is expected to be R0.59 million per year based on the water use charge of R0.02 per m^3 for canal irrigators.

The water saved can either be sold to the domestic water users namely the Zululand District Municipality. The demands for water in the town of Pongola and the surrounding communities of Ncotshane up to Belgrade have increased significantly. Therefore any water savings that the Impala Irrigation Scheme makes can be used to develop additional irrigation where practical or used to supply the domestic water at a higher tariff. This amount can be used to offset the capital investment required in refurbishment of the telemetry infrastructure.

Table 11:2: Summary of the costs and potential savings - Telemetry system update and alignment with WAS

Item	**Description**	**Water Savings million m^3/a**	**Cost Savings R per year**	**Sub-Total**	**Total**
Telemetry	Activity 1: Refurbish the existing Android telemetry system to be operational			498,000.00	
Installation period					Six months
Productive period					20 years
Initial Capital Investment Costs	Software				
	Telemetry expert time			148,000.00	646,000.00
Annual O&M Expenses	Software licence, replacement of parts, and batteries, etc			99,600.00	
Water Losses					
Estimated reduction in water losses due to metering errors	Meter reading errors	8.88	594,776.62		
Average Incremental Cost (AIC)					0.02

11.5 Task 3: Management Systems

11.5.1 Overview

One of the critical aspects of improving water use efficiency in the Impala Water User Association is to ensure that all the relevant technical, managerial, information system is available.

11.5.2 Task 3.1: Asset Management System including development of canal infrastructure management plan

Millions have already been invested in developing the Impala Irrigation Scheme with significant investment in canal infrastructure and related infrastructure. Therefore the performance and return on investment of their infrastructure needs to be managed having understanding (i) What infrastructure is being managed by the WUA; (ii) Where is it located?; (iii) What condition the infrastructure is in?; (iv) What on-going work is required?, as well as (v) What is the value of the assets?

The current environment generally requires better management of assets, more flexible operations, faster rectification of failures and more effective customer service. Being able to predict problems, develop proactive strategies (such as not waiting for failures to occur) and take the necessary action, are critical tasks of advanced asset management. In addition, it is important to fully understand the cost of maintenance services. Too often these services have been contracted out without fully understanding the costs. This can result in the contractor having all the knowledge of the costs associated with the network, and more importantly, the ability to be able to dictate terms to the WUA

In order for the Impala Water User Association (IWUA) to manage the existing canal infrastructure it is important that the WUA establish an infrastructure management system. This means that the IWUA should have an information management system such as GIS to enable the linking of the spatial information with the data on the location, capacity and performance as well as the condition of the assets.

11.5.3 Task 3.2: Implementation of WAS and alignment with the telemetry systems

11.5.3.1 Implementation of WAS release module

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

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

11.5.3.2 Review the current use of WAS

As mentioned earlier, the Impala Scheme does not have a comprehensive water accounting system, although they do use the reporting module of WAS, to not only track water deliveries but also determine the areas of improving irrigation water management. The scheme is not using the release module of the WAS programme due to the complex nature of the Scheme. They are however utilising the distribution chart.

11.5.4 Initial Capital Expenditure and O&M Costs

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

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

The estimated water savings has been included together with the refurbishment of the telemetry system and installation of water measurements discussed above. It is estimated that 8.7 million m^3/a, could be saved, by undertaking the installation of telemetry system and implementation of a water accounting system such as the full WAS programme.

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

11.6 Task 4: Conveyance infrastructure maintenance and refurbishment programme

11.6.1 General

The conveyance infrastructure rehabilitation programme is to carry out the refurbishment of the infrastructure in the conveyance system that was found to have significant leaks and seepage. The discussion with Impala WUA indicated that the major problem currently is the Natal to Wonderfontein siphon and the leakages on the main canal from Grootdraai weir. Further resealing of certain sections of the canal system is also required. This is discussed in the following section.

11.6.2 Conveyance infrastructure refurbishment and canal relining

Given the high water losses, due to structural failure of concrete lined irrigation canals, there is significant scope for refurbishment of the existing canal infrastructure, in order to reduce the current water losses. This will provide the WUA with the baseline to ensure efficient utilisation of the assets. These sections will require complete refurbishment at significant capital costs while other sections will require sealing of the wetted perimeter of the canal with polyfelt and bitumen emulsion that is sprayed.

The refurbishment of the canal infrastructure is likely to save approximately 4.0 million m^3/a. However this will come at a significant cost. The total cost estimate for relining of the canal sections with concrete and sealing of the wetted perimeter was determined to be R17.8 million while the operation and maintenance costs to maintain the infrastructure in good condition from thereon was calculated as R0.18 million per year.

A condition assessment of the canal system needs to be conducted and the results of the assessment should be used to develop a more comprehensive canal refurbishment and renewal programme for the Impala Irrigation Scheme.

The capital cost requirements to enable the Impala irrigation scheme to carry out the refurbishment of the infrastructure is beyond the normal maintenance costs for which the Impala WUA is responsible. The total construction and relining of canals requires significant capital investment which the DWA will need to provide, since they own the assets. This should be carried out to the poor canal sections once a detailed condition assessment has been finalised taking into account any surveys of the canals recently conducted.

Table 11:3: Summary of capital investment requirement & benefits - Rehabilitation of the canal infrastructure

Item	Description	Water Savings million m^3/a	Cost Savings R per year	Sub-Total	Total
Refurbishment of canal sections	*Construction of canal sections with concrete, relining and sealing of the wetted perimeter of the canal with bitumen emulsion*				
Installation period					Five years
Productive period					20 years
Initial Capital Investment Costs	Total construction & relining of canal sections			17,873,501.02	
	Sealing of canal with bitumen emulsion			-	17,873,501.02
Annual O&M Expenses	Repair & sealing of joints			2,033,000.00	
Water Losses					
Estimated reduction in water losses due to canal refurbishment	Leakage reduction	4.06	744,925.71		
Average Incremental Cost (AIC)					0.18

11.6.3 Refurbishment of the Wonderfontein siphon

The Impala WUA recently undertook the refurbishment of the Wonderfontein siphon at their own cost which had been identified to be leaking badly. It is envisaged that the refurbishment of the leaking will reduce the water losses that were taking place.

It was estimated that approximately 5.13 million will be saved after repairing of the leaking siphon. The cost of the refurbishment was part of the operation budget of the WUA and has therefore been considered as a sunken cost.

11.7 Task 5: Incentive based water pricing

11.7.1 General

To achieve an incentive for efficient water use, the price of irrigation water must be directly related to the volume delivered.

In order to encourage irrigators to use water efficiently, it is recommended that the existing pricing of water is reviewed to determine whether it provides the incentives for users to use water more efficiently. An incentive based water pricing structure for Impala Irrigation Scheme based on the current initiative should be considered. The implementation of incentive water pricing in irrigation agriculture, requires that comprehensive regulatory and operational criteria to be met before considering the economic criteria for incentive based pricing of irrigation water.

11.7.2 Regulatory aspects for incentive pricing

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

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

11.7.3 Operational aspects for incentive pricing

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

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

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

11.7.4 Economic aspects for incentive pricing

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

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

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

The potential savings are on the on-farm water use efficiency. The estimate is that there is likely to be savings of approximately 3% of the current irrigation water requirement, which translates to approximately 1.89 million m^3/a.

12 IMPALA WATER MANAGEMENT PLAN

12.1 General

12.1.1 Legal provision for developing and implementing a WMP

The development and implementation of a Business Plan is a legal requirement to be undertaken by a 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 a 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."

Although the above section of the act is not prescriptive, there is a business case in light of the above legal requirements for the Impala WUA to develop a WMP in terms of the provisions of the act to enable it to manage the irrigation water in the scheme effectively and efficiently.

12.2 Establishment of water saving targets for Impala Irrigation Scheme

12.2.1 Use of equivalent depth per actual unit area

The implementation of a Water Management Plan for the Impala Irrigation Scheme to reduce water losses will imply reducing the water diverted/released per unit of the land area irrigated in the scheme. As is expected this will not affect the yields of the wheat, maize and potatoes that are being irrigated in the scheme area. Therefore reducing the water diverted per unit of land area would mean an increase in productivity per unit of water which would be a clear indication of progress towards greater efficiency for the Impala Irrigation Scheme assuming the scheduled quota of 10 000 m^3/ha/a remains constant.

In the Impala Irrigation Scheme, the trend-line indicates an increase in the diversion per unit of irrigated areas from 2007 to 2012 water years for the Impala canal system (see **Figure 12.1** below). The increasing diversions per unit of irrigated land are a clear indication that there was a decline in irrigation water use efficiency during the period when the records were available. This may be due to the poor condition of the canal infrastructure particularly when the Wonderfontein siphon had not been repaired as discussed previously.

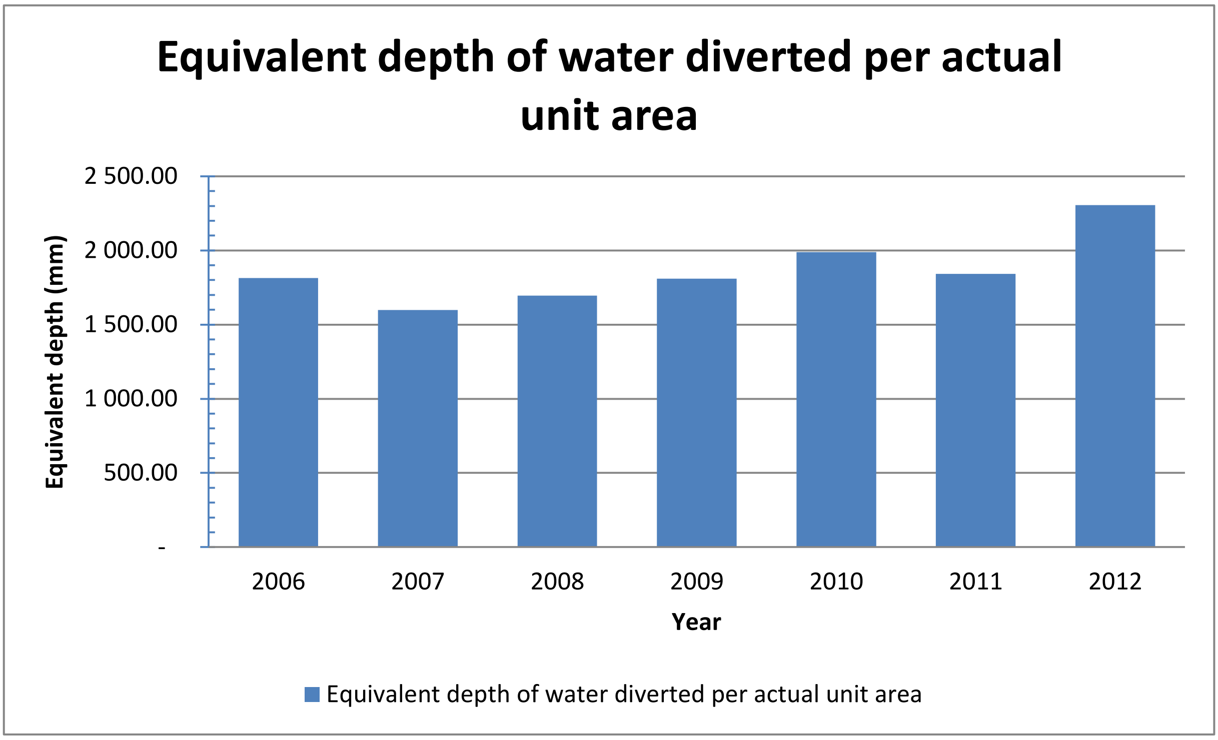

Figure 12:1: Trend line of increasing irrigation water diversion/released from Impala Dam expressed as an equivalent depth of water diverted per actual unit area irrigated for the Impala canals

This conclusion has however only been reached with very limited data as no other historical data was available and will need to be verified in time.

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

12.2.2 Recommended water saving targets

12.2.2.1 Water savings from the Impala irrigation scheme canal system

Because there has not been a decline in the trend-line of the diversions per unit area irrigated over the observed period for the Impala canal, it would appear there is significant scope in implementing the irrigation management intervention measures discussed in the previous chapter. The water that can be saved from implementing the identified water management measures for the Impala-canal system is provided in **Table 12.1** below.

Table 12:1: Projected water saving targets for the Impala-Canal system

Irrigation Component	Intervention	Target water savings (million m^3)	% of irrigation diversion	Time frame for implementation
Conveyance Infrastructure	Refurbishment of canals & replacement of Wonderfontein siphon	5.13	3%	5 to 8 years
	Resealing of canals	4.06	2%	5 years
Distribution infrastructure	Flow measurement & monitoring	8.88	5%	2 years
	Recalibration of Parshall Flumes		0%	2 years

Irrigation Component	**Intervention**	**Target water savings (million m^3)**	**% of irrigation diversion**	**Time frame for implementation**
Operational	Canal tail ends /	2.19	1%	1 year
	Operational spills		0%	
Sub-Total Scheme target		20.26	11%	
On Farm irrigation	Incentive pricing	1.83	1%	
	Irrigation systems		0%	

Based on the projected water saving targets, the Impala Irrigation Scheme can achieve an 11% reduction in irrigation distribution water losses relative to 2012 levels in the Impala, by the end 2022 based on the components provided in **Table 12.1** above.

12.2.2.2 Short term water saving targets

For the short term which has been taken as 3 years, the total water savings can be achieved as follows:

(i) *Refurbishment of the telemetry system and measurement* - This measure has already been implemented. It will provide the most benefit with estimated water savings of 8.8 million m^3/a, at an average incremental cost of R0.02 per m^3.

(ii) *Implementation of WAS programme on sub-schemes* - This measure is aligned to the first priority measure and is considered the second priority for implementation. It should be carried out now that the telemetry system has been refurbished. It is envisaged that with the near real-time monitoring that will be provided by the telemetry system, the target water savings from reducing spills at canal tail ends is estimated at 2.2 million m^3/a.

(iii) *Rehabilitation of the siphon between Natal and Wonderfontein* - This measure has also been undertaken and provides the second most benefit with estimated water savings of 5.03 million m^3/a.

The total water savings that have been targeted to be saved over a period of 3 years for the Impala Irrigation scheme until 2016 is estimated at 16.0 million m^3/a.

12.2.2.3 Long term water saving targets

For the long term a further 4.0 million m^3/a, is envisaged to be saved by refurbishment of the Impala canal infrastructure where it is identified that the condition of the infrastructure has deteriorated badly compared with the Impala canal infrastructure.

A total of 1.83 million m^3/a in the Impala, could potentially be saved through implementing incentive based pricing. This will require amendments to the current water pricing strategy which is currently being reviewed. It is unlikely that these water savings can be realised in the next three years. They are considered for the medium to long term in this water management plan. Therefore because of the complexities in implementing incentive based pricing and the timeline, it is recommended that this measure be implemented last.

The long term target is however to reduce the water losses to approximately 30% of the total inflow into the whole of the Impala Scheme. The annual water savings targets are discussed together with the action plans for implementation of the identified measures.

12.3 Implementation plan to achieve the water saving targets

12.3.1 General

The evaluation of the potential measures for implementation in the Impala Irrigation Scheme area, to improve water use efficiency and reduce water losses, indicates that there are some financial and socio-economic imperatives to implement the identified water management based on the envisaged water savings. There is potential in the Impala Irrigation Scheme to expand irrigation areas based on the gross margins from growing citrus and grape fruit.

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

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

As discussed in the previous chapters, the Impala irrigation scheme has most of the measurement structures to enable the WUA to take flow measurements at all critical points albeit by manually reading the flow levels and converting these levels to flow rates.

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

Priority	Goal	Action Plan	Timeline	Responsible Authority
1	To measure all critical points in the Impala irrigation scheme	(i) Continue measurement of flows at the critical points including the inflow into branch canals and the spills at the canal tail ends.	June 2013	Impala WUA
		(ii) Calibrate measurement structures as required	June 2013	
		(iii) Install gauging stations at the three tributaries traversing the Impala Irrigation Scheme	March 2015	DWA
2	Undertake detailed water balance assessments of the scheme	(i) Split the Impala scheme into the Impala sub-schemes and prepare a water balance assessment and WUEAR for each sub-scheme to DWA	June 2013	Impala WUA
		(ii) For the Impala canal system split the scheme into the Transvaal and the main branch canals	June 2013	
		(iii) Prepare detailed water balance assessment for the sub-schemes and split the losses to reflect operational losses from canal tail ends	June 2013	
		(iv) Set water saving targets based on updated information to reduce operational losses at canal tail ends	June 2013	

Priority	Goal	Action Plan	Timeline	Responsible Authority
3	To enable real or near real time flow monitoring	(i) Detailed design of the flow measurement and remote telemetry units (RTU) required for flow measurement	Oct. 2013	Impala WUA
		(ii) Refurbish the existing telemetry system infrastructure including software to ensure compatibility with WAS (iii) Calibrate the flow measurements such as flumes to improve the accuracy in flow measurement (iv) Prioritise areas of significant water losses	Undertaken May 2014 June 2014	
4	To implement the WAS programme on sub-schemes	(i) Review current use of WAS programme modules (ii) Set up WAS programme to carry out water balances at scheme and sub-scheme level	May 2013 June. 2013	Impala WUA
5	To conduct the refurbishment of the canals	(i) Classify the condition of all canal segments based on the condition of the canals. In cooperation with scheme personnel, conduct field reconnaissance to obtain attribute data and rate the condition of segments;	June 2013	Impala WUA

Priority	Goal	Action Plan	Timeline	Responsible Authority
		(ii) Prepare a motivation to DWA for refurbishment of the canals;	Oct. 2013	
		(iii) Engage with the DWA Infrastructure branch to motivate for refurbishment of the identified canal sections;	November 2013	DWA / Impala WUA
		(iv) If applicable prepare tender documents & specifications for total re-construction of canal sections and relining of the canals. n	March 2014	DWA
		(v) Assess water savings made from total construction of sections of the Impala canal and relining of canal sections	May 2019	DWA
		(vi) Hand over the refurbished canals to Impala WUA for on- going maintenance in accordance with the formal service level agreement between the two parties	June 2020	
6	To implement incentive pricing structure for the	(i) Review current irrigation water pricing strategy and update administration systems (ii) Provide inputs in updating the DWA water pricing strategy	June 2013 July 2013	DWA / Impala WUA

Priority	Goal	Action Plan	Timeline	Responsible Authority
	WMA in 3 years	(iii) Engage with irrigators on incentive pricing structure (iv) Install accurate flow measurement & implement water billing based on incentive pricing rate (v) Update the operating rules of Bivane Dam to supply irrigators based on incentive pricing rate	August 2013 March 2014 June 2014	
7	To implement management systems to assist in water savings	(i) Install an Asset Management system including Geographic Information System (ii) Update the WAS programme to enable sub-scheme water balances (iii) Financial systems – Review current pricing structure and update for future sustainable maintenance (iv) Administration systems – Review the roles & responsibilities of current personnel (v) Assess and revise additional administration requirements to enable	June 2013 June 2013 May 2014 October 2013 June 2014	Impala WUA

Priority	Goal	Action Plan	Timeline	Responsible Authority
		implementation of the plan		
8	To align the WMP to the catchment management plan	(i) Engage with the catchment forum to present the WMP (ii) Align activities between the catchment process and the WMP (iii) Update the WMP including the tasks and related activities from the catchment process	June 2013 July 2013 August 2013	Impala WUA/ Catchment Forum
9	Undertake water quality monitoring of the river upstream and downstream of the Impala canals.	(i) Identify water sampling points. (ii) Taking water samples for analyses (i.e. Microbiological and Chemical) from identified points. (iii) Feedback Analyses reports to users.	March 2013 May 2013 June 2013	

It is therefore considered a priority that the Impala WUA initiates the electronic reading of flow measurements at the following critical points:

(i) All the main canal tail ends of the Impala canal system.

(ii) At the primary canals at Transvaal and Natal main canals, in the Impala canal system.

(iii) At the main branch canals particularly such as Ncotshane, Sitilo, Mbega, D9 canal, and Wonderfontein canals in the Impala canal system

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

In order for the Impala WUA to benefit from taking the flow measurements, detailed water balances should be prepared to incorporate actual flow measurements. Currently the WUA is not conducting the water balance assessment at sub-scheme levels. As a first step, two water balance assessments, one for the Transvaal and the other for the Natal sub-schemes should be conducted including the measurements at the canal tail ends which can be measured.

12.3.4 Target 3: Refurbishment of the telemetry system for real time flow and level monitoring

Telemetry basically refers to accessing the data and controlling the system by remote means. With a telemetry setup, the Impala WUA can program the system to run automatically and the WUA can assess the system at any time to find out the status of a canal system. If something goes wrong with the system, it can be set up to alarm the WUA.

Figure 12.2 below provides a layout plan of where the installation of the telemetry has been completed. As indicated all the critical points have flow measurement devises together with the telemetry system to monitor the flows in the scheme.

With the refurbishment of telemetry system already being completed, the Impala WUA will be in a position to conduct the real time flow measurements at all critical points of the Impala irrigation scheme, including the spills at the canal tail ends as well as the flow into the different branch canals. The scheme can now determine where any critical changes to the expected flows such as at canal tail ends can be done thereby allowing the scheme operators to react to any operational losses or even theft of irrigation water.

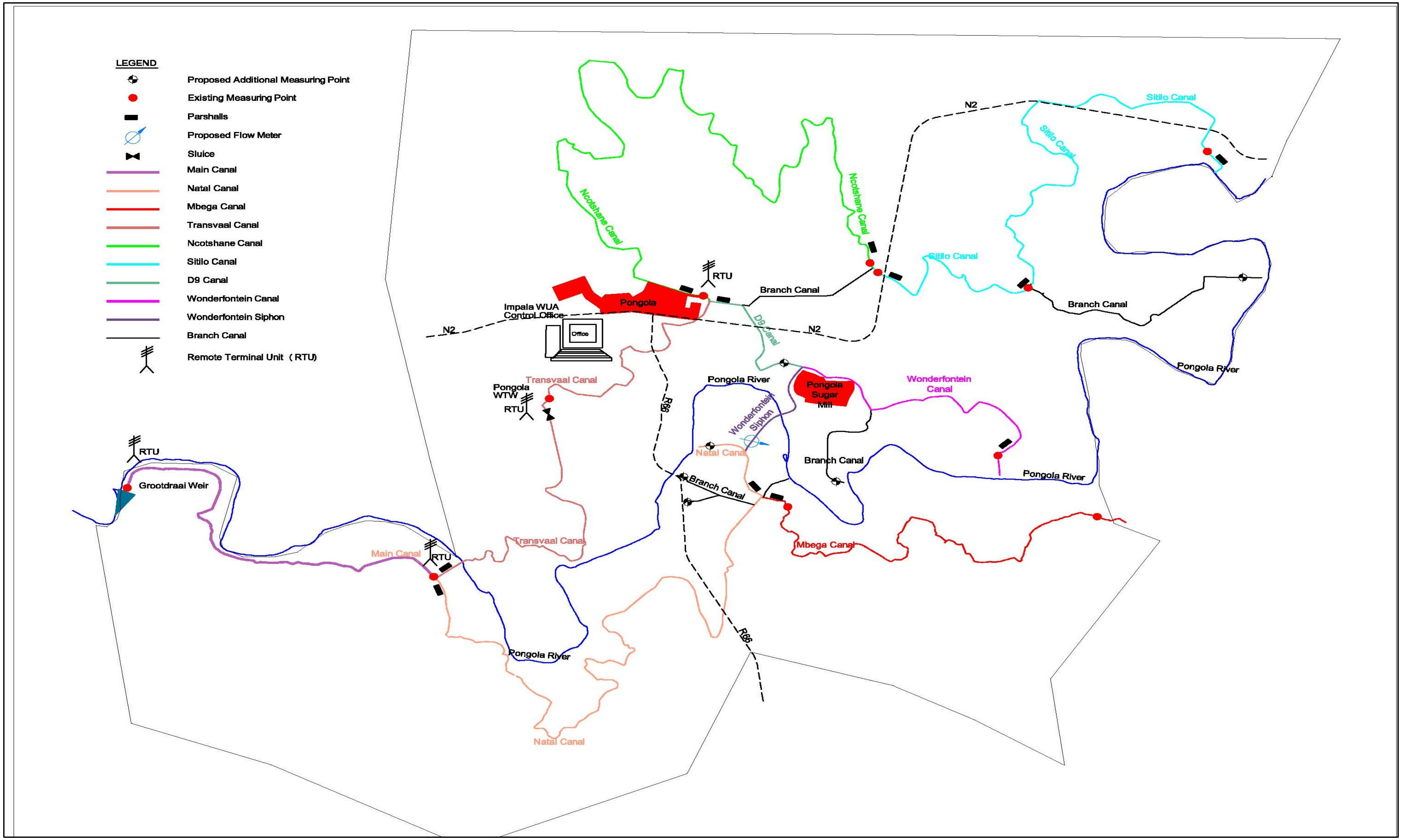

Figure 12:2: Proposed telemetry system for the Impala Irrigation Scheme

Besides the monitoring of flows, the Impala WUA is now in a position to conduct detailed irrigation water balances for the scheme as well as at sub-scheme level. This will enable the scheme operators to determine which of the sub-schemes has the highest water losses and therefore develop specific intervention measure to reduce water losses. Furthermore, the scheme operators will be able to determine the different types of water losses.

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

12.3.5 Target 4: Implementation of WAS programme on sub-schemes

The implementation of the WAS programme, together with the telemetry system, will substantially improve the operation of the Impala Irrigation Scheme and reduce current operational losses in particular, which are considered to be high. The Impala Scheme however does not implement the release module of WAS due to the complex nature of the Scheme. They do have a distribution chart which helps with releases to farmer and is an effective tool for their purpose.

12.3.6 Target 5: The refurbishment of concrete panels on the Impala Main canal

Besides the need to reduce operational spills and losses through improving irrigation water management using the flow measurement and the WAS programme, the leakages were also determined to be high. Therefore priority in the rehabilitation of the conveyance infrastructure is an imperative.

The losses due to the deteriorating condition of the concrete canal can be reduced by rehabilitating the canal. This requires first engaging with the DWA to inform them of the major leaks due to the canal breakage which requires significant capital to replace and leaks from siphons resulting in deterioration of the canal infrastructure. As they own the asset, it is envisaged that the DWA can utilise the refurbishment balance assessment to replace the canal and siphon.

The actions to be undertaken are indicated in **Table 12.2** above. It is important to note that because the actual amount of leakage has not yet been fully established, a pond test is recommended to determine how much water is lost before a final decision is made on replacing the siphon. Once the pond test indicates that the amount of leakage justifies replacing the pipe, this can be implemented within the time frame as illustrated in **Table 12.2** above.

12.3.7 Updating and implementation of the Water Management Plan

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

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

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

(ii) Compile Water Use Efficiency Accounting Reports and submit it on a monthly basis to the DWA Regional Office;

(iii) Do recommendations on observations regarding water conservation issues and report to the DWA on ways to address the identified issues;

(iv) Develop activities that build on and complement other WC/WDM initiatives taking place at other water schemes;

(v) Present water conservation information and training to irrigators and inform other scheme managers about success stories undertaken by the scheme;

(vi) Maintenance and modernisation of the irrigation infrastructure;

(vii) Liaise with DWA and other scheme managers to ensure consistent, efficient and effective deployment of water conservation messages, resources and services throughout the scheme;

(viii) Monitor the plan and schedule for implementing water conservation program components;

(ix) Report quarterly to DWA on the implementation status of the WMP, i.e. actions taken to reduce water losses and achievements towards achieving water saving targets, goals and objectives;

(x) Annually review and update the WMP with a water conservation program for the scheme with goals, objectives, improved water saving targets, action steps, measures, and timelines taking into consideration the latest measured Implement incentive pricing.

This requires a review and updating of any regulatory and operational criteria required to enable the Impala WUA to implement incentive based pricing. The action plans and time frame including the responsible authority are indicated in **Table 12.2** above. Although the Impala WUA is indicated as the responsible authority, the DWA will need to play a significant role to ensure that the structuring of the incentive based pricing is done within the framework of the water pricing strategy. The focus is in trying to reduce any over-irrigation and the current volume of on-farm irrigation water by implementing incentive based pricing.

Implementation of incentive based pricing requires a review and updating of any regulatory and operational criteria required to enable the Impala WUA to implement incentive based pricing. The action plans and time frame including the following:

(i) Review and update the regulatory aspects of incentive based water pricing structure by proving inputs into the updating of the water pricing strategy;
(ii) Evaluate the average actual water use by irrigators as a percentage of their scheduled allocation. This can be done through a questionnaire and reviewing the historical records of irrigation demands;
(iii) Determine the fixed operation and maintenance costs of the Impala Irrigation Scheme and assess the revenue requirements for sustainable operation of the scheme;
(iv) Establish the base price of irrigation water per unit of water based on the revenue requirements of the scheme to meet the O&M costs;
(v) Determine the marginal costs per unit of water in excess of the base price and design one or more pricing levels above the base price;
(vi) Establish that the operational and accounting aspects of water pricing are in place;
(vii) Implement the incentive based water pricing structure for Impala Irrigation Scheme.

Besides the additional revenue that the Impala Irrigation Scheme may benefit from implementing incentive based pricing, the reduction in on-farm irrigation will help the scheme to:

(i) Reduce erosion;
(ii) Improve the crop yield and quality;
(iii) Reduce fertiliser leaching; and
(iv) Reduce drainage problems and downstream water quality problems.

As the DWA's water pricing strategy is currently under review and update, where amendments may be required to encourage incentive based pricing in the strategy, this should be considered.

12.4 Funding of the Impala Irrigation Scheme WMP

12.4.1 General

All of the Water Conservation and Demand Management measures involve an initial capital investment requirement including the replacement costs over the useful life of the infrastructure. This is followed by on-going operations and maintenance which is required to ensure the installed infrastructure assets can provide the required performance for its intended use.

It has been proven in the analysis of the identified water management measures that implementation of these measures provides the most viable option at present to improving irrigation water use efficiency and reduce water losses in the Impala Irrigation Scheme. This was done using the least cost planning approach where the average incremental costs (AIC) of each intervention measure were determined.

However the financing of the candidate measures should take into account the beneficiaries from water savings made during the implementation of the above identified measures. This is discussed in the following section.

12.4.2 Financing by Impala WUA

The benefits in taking flow measurement and implementing real time monitoring of the flows at critical points in the irrigation scheme will directly benefit the Impala WUA. However this will not provide a relief to the financial pressures irrigators are currently experiencing because of capital investment in improving the security of supply to the Impala irrigation scheme. The resultant savings will also become available to Impala for additional agricultural expansion and use in Pongola.

Therefore based on the fact that the beneficiaries are the irrigators in the Impala Irrigation Scheme, the financing of the following aspects have been and will be borne by Impala;

(i) Conducting measurement of flows at the identified critical points to enable detailed water balance assessments to be done at scheme and sub-scheme level;

(ii) Refurbishment of the telemetry system infrastructure to enable real or near real time flow monitoring with a view to enabling quick response to water management and therefore reduce operational losses currently taking place in the scheme;

(iii) Providing the operation of the WAS programme to enable water accounting on a sub-scheme basis to be conducted as well as to fulfil the legal requirements in terms of the Act to provide annual reporting to the DWA on the irrigation water management for the scheme;

12.4.3 Financing by the DWA

The canal infrastructure in the Impala Irrigation Scheme is owned by the Department of Water Affairs (DWA) who has a draft service level agreement with the Impala WUA to operate and carry out annual maintenance of the infrastructure.

However as the condition of some of the infrastructure has deteriorated to the extent that there are a number of sections which require total construction of lined canals and relining of some of the canal sections, the cost of refurbishment is prohibitive and requires the DWA to provide the necessary financing necessary to reduce the high leakage losses due to the poor condition of the infrastructure.

It is therefore recommended that the DWA provide the funding necessary to reduce water losses for the following:

(i) Installation of additional flow measurements at critical points to enable comprehensive water balance assessment to be conducted
(ii) Refurbishment of the sections of the canal that are identified to require refurbishment.
(iii) Refurbishment of the sections of irrigation canals which are in a bad condition which are identified through a ponding test.
(iv) Implementation of the incentive based pricing by Impala WUA

12.4.4 Financing by other users

There are downstream water users in the Pongolapoort Dam who require additional water for use on the Makhatini Flats. The water from the Pongolapoort Dam has all been allocated and the possible Tongaat-Hulett/Irrimec Sugar Project requires an additional 60 million m^3/a. These users could provide funding for the implementation of some of the identified intervention measures. The water saved from these measures can be supplied to the downstream users with a service level agreement between the Impala WUA and the downstream users.

The measures that downstream users could provide funding include the following:

(i) Implementation of the incentive based pricing by Impala WUA
(ii) Providing capital funding for the refurbishment of the irrigation canals through the DWA

13 CONCLUSIONS AND RECOMMENDATIONS

13.1 Conclusions

The following can be concluded from the assessment of the water supply/requirements conducted for the Impala Irrigation Scheme area and can be summarised as follows:

- The Impala Irrigation Scheme is situated in the Usutu to Mhlatuze Water Management Area in the Zululand District Municipality. The scheme has a scheduled of rateable area of 14700 ha at an allocation of 10 000 ha/a, which includes canal as well as river irrigators. The total water allocation for Impala is 170 million m^3/a.
- The main crops that are under irrigation, include sugar cane (15 869 ha.), citrus (370 ha), vegetables (approximately 730 ha.), maize (320 ha.), mango (120 ha.) and some pecan/macadamia. The importance of sugar cane at 91% of the irrigated area is well illustrated on a per hectare basis in the Impala Irrigation Scheme, with all other crops comprising 9% of the total. Therefore there is very little crop mix taking place in the scheme area as the scheme is driven by the need to meet the cane requirements of the Pongola sugar mill.
- The Impala Irrigation Scheme receives its raw water supplies for nearly 60% of the time from the Pongola River. It is supplemented by the Bivane Dam which was built by the irrigators to address the water supply shortages and reliability of supply problems that the scheme was experiencing. The Bivane Dam has a total storage capacity of 115 million m^3. Water is only released to supply Impala Irrigation Scheme, when the Pongola River flow cannot meet the demands of the irrigators based on the weekly orders. The volume of water to be released is dependent on the volume of flow in the Pongola River system, which is measured at the Upper Pongola weir.
- The Grootdraai weir provides the diversion structure for the Pongola River system, including water released from the Bivane Dam and diverts the irrigation water into the Impala Irrigation Scheme on the right bank of the Pongola River.
- The irrigation water is diverted into the main canal before it splits into the Transvaal and Natal canals which supply the left bank and right bank respectively. The Impala Irrigation Scheme has a total length of approximately 186 km of irrigation canal which supplies the irrigators as well as Pongola and the sugar mill. The canals distribute the water to approximately 390 sluice gates and Parshall flumes.
- Although no detailed condition assessment could be undertaken on the Impala Irrigation Scheme because the canals were operational, a preliminary assessment was however conducted during the site visit that was conducted in May 2011. It was

determined that there were significant leaks on the Wonderfontein siphon which required urgent attention. This was attended to by the Impala WUA and will have an impact in reducing leakage levels in the scheme. There were also leakages taking place on the main canal.

- In order to ensure that the irrigators receive their scheduled quota as and when required, the Impala WUA operates the irrigation scheme based on “delivery on request” where each water user (irrigator) must submit a written request on a weekly basis and the water is delivered to some 390 abstraction points along the canal systems. These procedures are not all formerly documented.
- Irrigation water use in Impala has averages 101.09 million m^3/a. The sugar mill industrial use, ranges from 0.68 million m^3/a in 2006/07 up to 1.43 million m^3/a, in 2009/10, while the six year average, is 1.0 million m^3/a. The domestic water use however has shown a steady increase in water consumption, ranging from 2.39 million m^3/a in 2006/07 up to 3.9 million m^3/a, in 2011/12 water year.
- The average total water diverted within the Impala Irrigation Scheme during the same seven year period, was 184.66 million m^3/a. An unknown volume of this water was returned to the river at 5 tail water discharges and about 15 smaller discharge points from branch canals.
- An irrigation water balance assessment conducted for Impala Irrigation Scheme indicated that the water losses averaged 41% of the total water diverted at Grootdraai weir over the seven year of records. This amount of 75.5 million m^3/a, was considered to be very high.
- The total water losses were disaggregated to determine the unavoidable and avoidable water losses with a view to establishing the irrigation water delivery BMP for Impala Irrigation Scheme. The total unavoidable water losses comprising of evaporation losses and unavoidable seepage due to the age and condition of the infrastructure was determined to be 22.44 million m^3/a or 12% of the total water diverted.
- The BMP operational efficiency of the Impala irrigation scheme was determined to be 15% of the diversion. This was based on the WRC research but taking into account local conditions such as dilution requirements because of salinity problems in the scheme area. This amounts to 27.7 million m3/a.
- Based on the unavoidable water losses and the BMP operational efficiency, there is still water losses of 25.4 million m^3/a. There is therefore potential to reduce irrigation water losses and improve irrigation efficiency in the Impala Irrigation Scheme. The potential water that can be saved was considered to be operational wastage and

leakage and spills. However some of the water losses were considered to be beneficial as the water is used by downstream users in the Pongolapoort Dam area.

- The irrigation water balance assessment together with discussions with Impala WUA highlighted that there were number of management issues which included the following:
  - (i) Although there is sufficient flow measurement with the exception of a few tail water ends, Impala was not including all the measurements into the water budget
  - (ii) The existing telemetry system which was not operational and was also not compatible with the WAS programme was now operational.
  - (iii) Not all the modules of the WAS programme which was installed are being utilised to undertake water use accounting reports. The release module is not being implemented due to the complexity of the Scheme; however the distribution chart has been developed and implemented.
  - (iv) There were no detailed irrigation water balance assessment being conducted at both scheme and sub-scheme levels as the flow measurements at the canal endpoints and tail water ends as well as at each diversion where flow measurements are being taken was not being included. There was a need to address this in order to clearly determine where and how much water can be considered as water losses.
  - (v) The condition of the canal infrastructure particularly the Wonderfontein siphon was in a very poor state resulting in significant water leakages at the start of the assessment. This was then repaired in 2012.
  - (vi) There were constraints in the flexibility of the operation of the scheme during the dry periods because of lack of regulatory storage to allow for sufficient time for maintenance to be conducted.
  - (vii) The Impala WUA identified that there was over-irrigation taking place in the scheme. This was attributed to a number of issues including the current pricing structure, and the lack of capacity of some irrigators to undertake irrigation scheduling.
- Based on the above water management issues, a number of measures were identified to address the issues with the main management goal being to reduce the high water losses and improve irrigation water use efficiency in Impala. These measures were evaluated and prioritised based on the water savings and the average incremental cost (AIC) of implementing the measures.

13.2 Recommendations

13.2.1 Impala Water Management Plan

A water management plan for the Impala Irrigation Scheme was developed to address the water losses taking place in the scheme and to improve irrigation water management of the scheme. The identified measures for implementation to reduce the water losses from the current 41% to 30% of the total inflow into the irrigation scheme include the following:

(vii) *Refurbishment of telemetry system* - It is considered as the most beneficial and important intervention measure to do as it is critical to addressing the operational problems quickly and more effectively than the current manual monitoring of the scheme. The estimated water savings are 8.8 million in the Impala canal system at an average incremental cost of R0.02 per m^3 of R180.49 per ha per year. This measure has already been implemented and the potential savings should start to be realised in the next water year

(viii) *Implementation of WAS programme on sub-schemes*- This measure is aligned to the first two measures and is considered to be important for implementation in the short term as well. It should be carried out at the same time as the first intervention measures.

(ix) *Conduct flow measurements and flow monitoring on all critical measurement points and calibration* - The evaluation of this measure has illustrated this to be the most beneficial to reducing water losses with the estimated water savings of 2.2 million m^3/a when applied with the full implementation of the WAS programme. A number of measurement equipment has been commissioned.

(x) *Rehabilitation of the siphon between Natal and Wonderfontein* - This measure has the second most benefit with estimated water savings of 5.03 million m^3/a, at an average incremental cost of R0.06 per m^3 or R591.12 per ha per year. This measure has already been implemented.

(xi) *Canal refurbishment and cleaning of siphons* - This measure although requiring significant capital investment will improve the condition of the infrastructure and reduce the high leakage losses. This will potentially save approximately 4.0 million m^3/a in the Impala canal system at an average incremental cost of R0.18 per m^3 or R1 807 per ha per year which is prohibitive.

(xii) *Incentive based pricing* - This measure is considered a national issue which does not only affect the Impala irrigation scheme. It is dependent on whether the irrigators would require changes to the current water pricing which is area based and the implications to revenue management by the irrigation scheme which may not be stable.

13.2.2 Financing options for the WMP

All of the Water Conservation and Demand Management measures involve an initial capital investment requirement including the replacement costs over the useful life of the infrastructure. However the financing of the candidate measures should take into account the beneficiaries from water savings made during the implementation of the above identified measures.

Two sources of funding were identified and is recommended based on the beneficiaries of the intervention measures. The recommendation is that

(i) Impala WUA should look at financing the measures which will benefit and improve the operation and monitoring of irrigation water in the scheme. These measures will also allow Impala to fulfil it legal requirements in terms of the National Water Act on reporting and efficient management of irrigation water. These include updating the flow measurements, installation of the telemetry system and to implement the WAS programme on sub-schemes. Some of these actions have already been implemented by the WUA.

(ii) The DWA owns the infrastructure in Impala Irrigation Scheme. The refurbishment of the canal infrastructure requires significant funding which cannot be met with the maintenance balance assessment of Impala. Therefore the capital investment required for the total construction of sections of the Impala canal and the relining of sections of the canals should be provided by the DWA. This also includes the implementation of incentive based pricing which will improve the on-farm irrigation efficiency while the savings will benefit downstream users unless Impala WUA can use the water to expand.

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