water affairs
Department:
Water Affairs
REPUBLIC OF SOUTH AFRICA

CONTRACT NO. WP 10276

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

LEVUVHU GOVERNMENT WATER SCHEME MANAGEMENT PLAN

FINAL REPORT

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NOVEMBER 2012

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Scheme Manager

Accepted on behalf of Luvuvhu GWS

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EXECUTIVE SUMMARY

Background

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

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

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

Project Objectives and approach taken

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

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

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

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[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 Government Water Schemes (GWSs), Irrigation Boards (IBs) and Water User Associations (WUAs) to implement the identified opportunities to improve irrigation water use efficiency

Overview of the Luvuvhu Irrigation Scheme

The Luvuvhu Irrigation Scheme was established in the late 1940's with the construction of the Albasini Dam (which has a storage capacity of 23.7 million m^3 and historic yield of approximately 5 million m^3/a). **Figure 1** below provides a schematic layout of the Luvuvhu Irrigation Scheme.

Schedule of rateable area

The Luvuvhu Irrigation Scheme has a total schedule of rateable area of 1 854.5 hectares, which is supplied by the Luvuvhu canal system, Lutonyanda canal system as well as some directly from the river as river irrigators. The Luvuvhu Irrigation Scheme has a total scheduled quota of 15.5 million m^3/a at 8 400 m^3 per ha per annum scheduled allocation. However approximately 871.4 hectares was irrigated from Albasini Dam canal system. This area is currently dependent on groundwater as the dam level has been consistently been very low to divert water into the Albasini canal system.

The irrigators in the scheme are growing diverse crops which include Avocados, Mangoes, Guavas and Macadamias. There are a wide variety of other crops that are irrigated in the Luvuvhu Scheme area but all these crops are mainly annual crops.

Conveyance and delivery infrastructure

Water to the water users in the Luvuvhu Irrigation Scheme is delivered through a system of canal infrastructure comprising of the three main canals namely the Albasini Canal which is currently not operational because the dam level is always low for water to be diverted, the Luvuvhu canal system which is above the Albasini canal, and the Latonyanda canal. There are branch canals on the Luvuvhu and Latonyanda canals which deliver water to the sluice gates at the irrigators' farms.

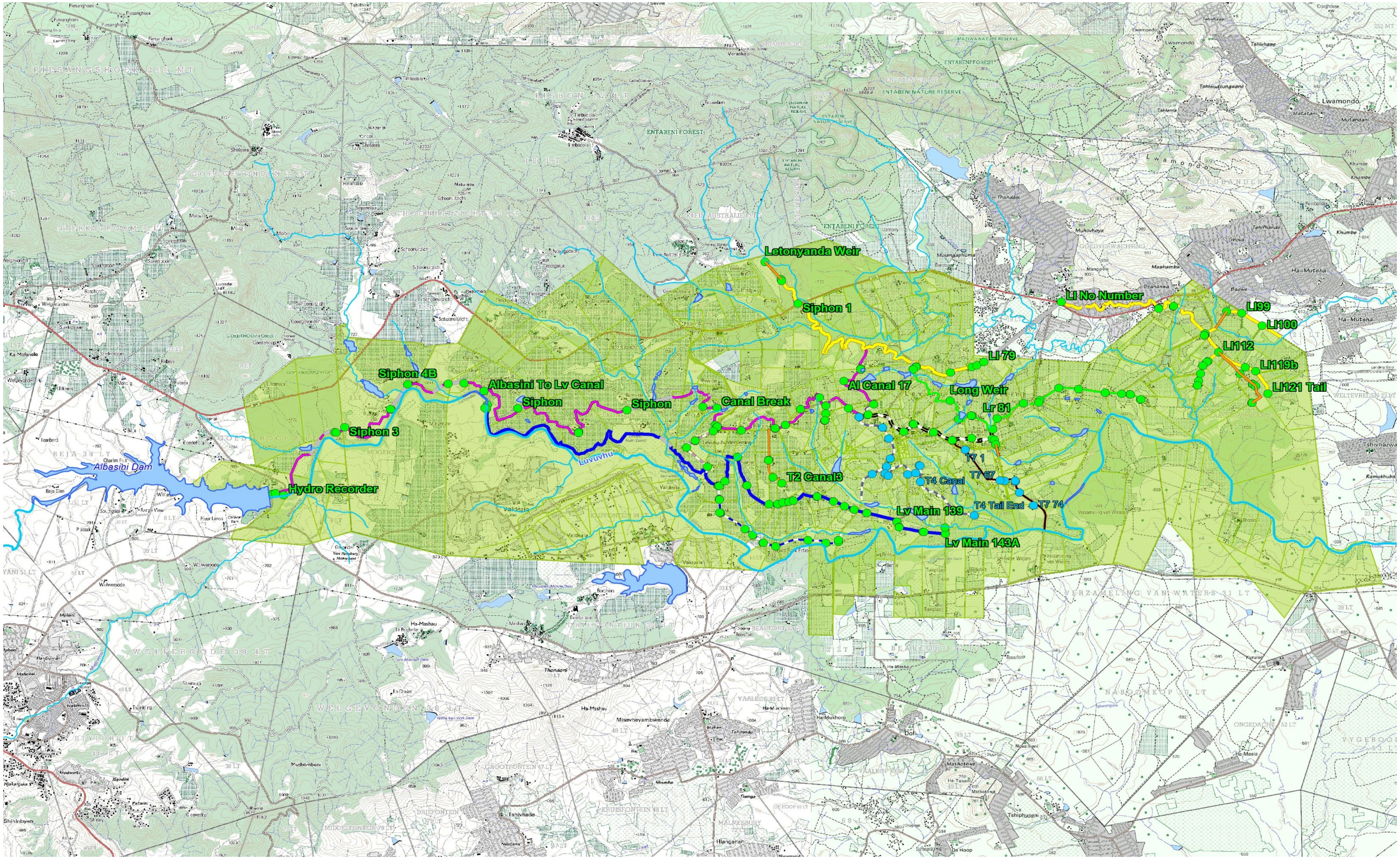

Figure 1: Luvuvhu Irrigation Scheme Layout

The total length of the canal infrastructure excluding drainage canals is 90.17 km with all the canals concrete lined. There is approximately 8.38 km of siphons in the scheme area. The condition of the canals was found to be generally fair to very poor in some sections particularly in the Albasini canal were some panels have shifted because of non-use.

Besides the canal infrastructure there are sluice gates, Parshall Flumes and V-notch weirs which are used to measure the volume of water taken by each water user in the canal. There are 75 sluice gates in the Luvuvhu canal system.

Irrigation storage and regulation

There is one balancing dam known as Albasini Balancing Dam in the Luvuvhu Irrigation Scheme which was intended to provide the balancing and regulation of flow to downstream water users as well as supplement the other two canals, Luvuvhu and Latonyanda canals.

Currently the balancing dam is not in operation as the Albasini sub-scheme does not have sufficient water to provide irrigation water to the scheme.

Findings of the situation assessments

A situation assessment of the Luvuvhu 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 could not be conducted at sub-scheme level, because the application for each branch canal was not available.

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 Luvuvhu canal system. The analysis indicated that the unavoidable water losses due to evaporation losses and seepage due to the expected hydraulic conductivity of lined canals excluding the Albasini canals which are not operational is 0.09 million m^3/a, and 0.6 million m^3/a respectively making a total unavoidable water loss of 0.69 million m^3/a. This translates into 10% of the total volume of water diverted into the canal systems currently in operation which are the Luvuvhu and Latonyanda canals.

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

Based on the evaluation of the unavoidable water losses and the expected operational inefficiencies for the Luvuvhu Irrigation Scheme, the water delivery Best Management Practice (BMP) should be based on the allowable water losses of approximately 20 % of the total inflow into the Luvuvhu irrigation canals.

Water balance assessment

A water balance assessment that was conducted for the Luvuvhu irrigation scheme indicated that the water losses in the government water scheme exceeded the minimum expected seepage and evaporation losses. The average water losses based on the historic water use records was determined to be 53% of the total water diverted in the Luvuvhu canal system (see **Table 1** below). The estimated avoidable water losses was determined to be 2.91 million m^3/a or 43% of inflows into the irrigation scheme.

Table 1: Summary of water losses for the Luvuvhu Government Water Scheme

<table>
<tr><th>Description</th><th>Unavoidable losses (m^3*10^6)</th><th>BMP for operation & distribution (m^3*10^6)</th><th>Avoidable losses (m^3*10^6)</th><th>Total losses (m^3*10^6)</th><th>% of total losses</th></tr>
<tr><td>Seepages</td><td>0.6</td><td></td><td></td><td></td><td>16.5%</td></tr>
<tr><td>Evaporation</td><td>0.09</td><td></td><td></td><td></td><td>2.5%</td></tr>
<tr><td>Filling losses</td><td></td><td rowspan="6">0.67</td><td rowspan="6">2.24</td><td rowspan="6">2.91</td><td>0%</td></tr>
<tr><td>Leakages</td><td></td><td>81%</td></tr>
<tr><td>Spills</td><td></td><td>0%</td></tr>
<tr><td>Operational Losses</td><td></td><td>0%</td></tr>
<tr><td>Over delivery to users</td><td></td><td>0%</td></tr>
<tr><td>Canal end returns</td><td></td><td>0%</td></tr>
<tr><td>Total</td><td>0.69</td><td>0.67</td><td>2.24</td><td>3.60</td><td></td></tr>
<tr><td>% of total losses</td><td>19%</td><td>19%</td><td>62%</td><td>100%</td><td></td></tr>
</table>

Description	Unavoidable losses (m^3*10^6)	BMP for operation & distribution (m^3*10^6)	Avoidable losses (m^3*10^6)	Total losses (m^3*10^6)	% of total losses
% of total volume released into system	10%	10%	33%	53%	

The equivalent depth of water diverted per actual unit area irrigated was determined. In the Luvuvhu Irrigation Scheme, the trendline indicates a decrease in the diversion per unit of irrigated areas from 2005 to 2011 water years for the Luvuvhu and Latonyanda canal systems (see **Figure 2** below).

The decreasing diversions per unit of irrigated land are a clear indication that there has been an improvement in irrigation water use efficiency during the period when the records were available. The lack of sufficient water within the scheme under permanent restrictions from about 2005 may have contributed significantly to the improvements in irrigation water conveyance.

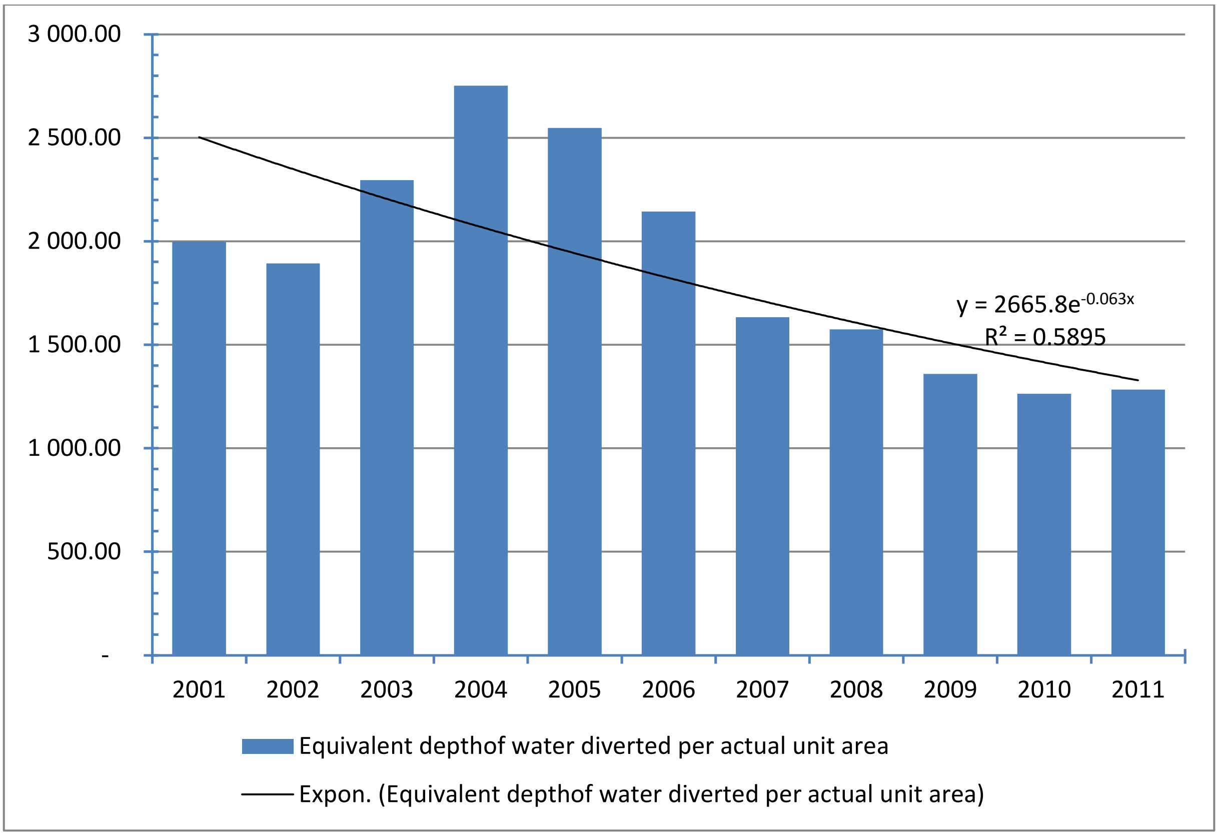

Figure 2: irrigation water diversion expressed as an equivalent depth of water diverted per actual unit area irrigated for the Luvuvhu canals

However any improvements over time for example due to improved operational efficiency maybe likely to be offset with the increase in water losses due to the poor condition of the canal infrastructure. 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.

Water Management Issues

A number of water management issues affecting the effective and efficient use of water in the Luvuvhu 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 flow measurement at some of the critical points in the scheme for a comprehensive water balance assessment to be conducted. These include the canal tail ends as well as the balancing dams. The spills at the canal tail ends are considered losses and can be avoided if regular flow measurements were taken.

Therefore the current water balances are not accurate as they are based on estimates.

(ii) Although there are sufficient flow measurements, the accuracy of some of the measuring system such as Parshall Flumes is problematic. A number of the existing Parshall Flumes were found to exhibit submergence conditions although the free flow measurement calibration is used to measure flows which is not accurate.

(iii) There is a lack of continuous flow monitoring to enable quick responses to operational problems have resulted in the low water use efficiency levels in the Luvuvhu Irrigation Scheme.

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

(v) The conditions of the canal infrastructure particularly in the Luvuvhu canal system were found to be poor. There are sections of the canal which will require complete renewal as some of the concrete panel sections have moved. This is attributed to some flooding but mainly the drainage due to irrigation of lands above the canal system.

(vi) The capacity of the Luvuvhu WUA to conduct full maintenance of the canal infrastructure including refurbishment is limited while the current water charge by the DWA for the Return on Assets (ROA) does not appear to cover for this.

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

Water Management Plan for the Luvuvhu Irrigation Scheme

Establishment of water saving targets at sub-scheme level

The implementation of a Water Management Plan for the Luvuvhu Irrigation Scheme to reduce water losses will imply reducing the water diverted per unit of the land area irrigated in the scheme. As is expected this will not affect the yields of the wheat, potatoes and maize crops 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 Luvuvhu Irrigation Scheme assuming the scheduled quota of 8 400 m^3/ha/a remains constant.

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

The priority water management measures to improve irrigation water use efficiency on the Luvuvhu 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) Installation of more accurate flow measurements such as crump weirs compared to the existing Parshall Flumes which are normally submerged.

(3) Preparation of more detailed water balance assessments for the Luvuvhu irrigation scheme, as well as the sub-schemes which include the Luvuvhu canal and its branches and the Latonyanda canals.

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

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

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

(7) 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.

Table 2: Estimated water saving targets for the Luvuvhu Irrigation (million m^3/a)

<table>
<tr><th rowspan="2">Description</th><th rowspan="2">System Inflow</th><th colspan="5">Present Situation - Losses</th><th colspan="2">Acceptable Water Losses</th><th colspan="3">Target Water Savings</th></tr>
<tr><th>Unavoidable losses</th><th>BMP for distribution losses</th><th>Avoidable losses</th><th>Total losses</th><th>% of Total Volume Released</th><th>Annual Volume</th><th>% of Total Volume Released</th><th>Annual Volume</th><th>% of Total Volume Released</th><th>Intervention measure</th></tr>
<tr><td>Seepages</td><td></td><td>0.6</td><td></td><td></td><td>0.6</td><td>8.9%</td><td>0.6</td><td>8.9%</td><td>0</td><td>0%</td><td>None</td></tr>
<tr><td>Evaporation</td><td></td><td>0.09</td><td></td><td></td><td>0.09</td><td>1.3%</td><td>0.09</td><td>1.3%</td><td>0</td><td>0%</td><td>None</td></tr>
<tr><td>Filling losses</td><td></td><td></td><td rowspan="7">0.67</td><td rowspan="7">2.24</td><td rowspan="7">2.91</td><td rowspan="7">43.2%</td><td rowspan="7">0.67</td><td rowspan="7">10.3%</td><td></td><td>0%</td><td></td></tr>
<tr><td>Over delivery to users</td><td></td><td></td><td></td><td>0%</td><td></td></tr>
<tr><td>Leakages</td><td></td><td></td><td rowspan="2">0.86</td><td rowspan="2">13%</td><td rowspan="2">Refurbishment & resealing</td></tr>
<tr><td>Infrastructure condition</td><td></td><td></td></tr>
<tr><td rowspan="3">Operational Losses</td><td rowspan="3"></td><td rowspan="3"></td><td>0.30</td><td>5%</td><td>Removal of aquatic weeds & water grass</td></tr>
<tr><td>0.54</td><td>8%</td><td>Flow measurement & monitoring</td></tr>
</table>

Description	System Inflow	Present Situation - Losses					Acceptable Water Losses		Target Water Savings		
		Unavoidable losses	BMP for distribution losses	Avoidable losses	Total losses	% of Total Volume Released	Annual Volume	% of Total Volume Released	Annual Volume	% of Total Volume Released	Intervention measure
										0%	Recalibration of Parshall flumes
Canal end returns									0.54	8%	Canal tail ends
										0%	Operational spills
Other					0.00	0.0%				0%	
Total		0.69	0.67	2.24	3.60	53.5%	1.36	20.5%	2.24	33%	
Loss as a % of total losses		19%	19%	62%	100%						
Loss as a % of total volume released into system		10%	10%	33%	53.5%						
Total releases into Scheme	6.73										

Conclusions and Recommendations

A water management plan for the Luvuvhu 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 53% to 20% of the total inflow into the irrigation scheme include the following:

(i) *Reduce operational losses at canal tail ends* - This measure has highest benefit with estimated water savings of 0.51 million m^3/a. This can be achieve at the least cost as no capital investment requirements is necessary to change the current operating procedures which ensures minimal or nor flows take place at the canal tail ends

(ii) *Improving water measurement system and flow monitoring* - This measure is the main driver for the above intervention. The direct estimated water savings of 0.54 million m^3/a, can be achieved by calibration of the Parshall Flumes and taking flow measurements consistently at the identified critical points. It is also easier to implement and should be considered a priority as all other measures are dependent on availability of sufficient water measurements in the Luvuvhu Irrigation Scheme.

(iii) *Chemical management of aquatic weeds and algae growth in canals* - This measure has the second most benefit with estimated water savings of 0.3 million m^3/a. It should be carried out at the same time as the first intervention measures because of its impact on the hydraulic capacity of the canals.

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

(v) *Refurbishment of the canals and siphons* - The capital investment requirements for this measure is very high and requires a long lead time to implement. However it has the highest water saving target with approximately 0.86 million m^3/a being able to be achieved over a 10 year period.

(vi) *Incentive based water pricing structure*- This measure has the third most benefit with estimated water savings of 0.22 million m^3/a. However there are legislative and administrative matters that need to be in place to enable incentive based pricing to be implemented effectively. Therefore a long lead time is required to implement this intervention measure.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF PHOTOGRAPHS

ABBREVIATIONS

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

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

GLOSSARY OF TERMS

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

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

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

	functions for which they were created.
Modernisation	This is the process of upgrading (replacing) an existing asset in order to meet enhanced technical capacity and level of service objectives.
On-farm:	Activities (especially growing crops and applying irrigation water) that occur within the legal boundaries of private property.
On-farm irrigation efficiency:	The ratio of the volume of water used for consumptive use and leaching requirements in cropped areas to the volume of water delivered to a farm (applied water).
Operational losses:	Losses at the tail ends, sluices not opened or closed on time or opened to big and spills
Operational waste:	Water that is lost or otherwise discarded from an irrigation system after having been diverted into it as part of normal operations.
Pan evaporation:	Evaporative water losses from a standardized pan. Pan evaporation is sometimes used to estimate crop evapo-transpiration and assist in irrigation scheduling.
Parshall flume:	A calibrated channel-like device, based on the principle of critical flow, used to measure the flow of water in open conduits. Formerly termed the Improved Venturi Flume.
Percolation:	Downward movement of water through the soil profile or other porous media.
Rehabilitation	This is the process of renovating an existing asset whose performance is failing to meet its original objective to its original design specifications. This may also be referred to as asset reproduction.
Reservoir:	Body of water, such as a natural or constructed lake, in which water is collected and stored for use.
Return flow:	That portion of the water diverted from a stream which finds its way back to the stream channel, either as surface or underground flow.

Return-flow system: A system of pipelines or ditches to collect and convey surface or subsurface runoff from an irrigated field for reuse. Sometimes called a "reuse system or “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, accounting for approximately 62% of the current water use nationally. With the increasing competition between existing water use sectors, the available water cannot meet the demand under current water use practices and operating conditions in all water use sectors. It is therefore imperative to ensure that available water supplies are used efficiently and effectively to avoid supply shortages and intermittent water supplies, which would have a major impact on the socio-economic growth and development of the country.

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

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

[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

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

Following the meetings with DWA Directorate: Water Use Efficiency, the Scheme Managers and the DWA Regional Office, this report provides the following:

- Overview of the water allocation and irrigation water use situation in the irrigation scheme 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 to improve water use efficiency and reduce water losses in the agricultural sector (See **Figure 1.1).** 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 based on the irrigation scheme characteristics;
- Determination of the irrigation water balances and establishing water use baseline for each irrigation scheme;
- Determination of the irrigation water management issues based on the situation assessment and water budgets prepared for each irrigation scheme;
- Identification of opportunities to improve water use efficiency in the agricultural sector;
- Benchmarking of irrigation water use efficiency and setting irrigation water use efficiency targets for each scheme;
- Preparation of an irrigation water management plan for each irrigation scheme;
- Capacity building of the irrigation schemes 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 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, irrigators and the users in the catchment in general will include:

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

1.3 Structure of the report

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

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 Levuvhu River catchment in which the Levuvhu Irrigation Scheme is situated.

Chapter 3 describes the history of the Levuvhu 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 and 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 Levuvhu 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 any available information.

Chapter 6 of this report describes how the scheme is currently being operated to provide water to the irrigators and any other users. 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 this 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, availability of balancing dams, flow monitoring to reduce operational losses if any, canal maintenance during the dry periods; etc.

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

Chapter 11 of the report provides an assessment of the identified water management measures that can be implemented to achieved the goals and objectives set in chapter 10. This is the strategic WC/WDM business plan for irrigation agriculture. The chapter also provides an estimate of the capital investment required to implement the strategy. It also provides the performance indicators for monitoring and controlling the implementation of the measures.

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

Chapter 13 provides conclusions and recommendations for the Irrigation Scheme.

2 CATCHMENT CHARACTERISTICS OF LUVUVHU RIVER CATCHMENT

2.1 Overview

The Luvuvhu Government Water Scheme (GWS) is situated in the Luvuvhu and Letaba Water Management Area which is located in the Limpopo Province. It is in the Vhembe District Municipality with the nearest main town to the Luvuvhu GWS being Elim. This is located approximately 30 km upstream of the government water supply scheme area. **Figure 2.1** presents the locality map of the Luvuvhu Irrigation Scheme area.

The Luvuvhu has its headwaters in the Soutpansberg Mountains upstream of Albasini Dam. There is one major storage dam in the Luvuvhu catchment, namely the Albasini Dam. The Albasini Dam is located just downstream of the headwaters of the Luvuvhu River. The Albasini Dam has a storage capacity of 23.7 million m^3. The dam was constructed in 1952 and was raised (by means of spillway gates) in 1970/71, to meet the irrigation water requirements of the lands downstream of the Albasini Dam in the Luvuvhu River catchment. However the yield available for irrigation agriculture is very limited as discussed in the later chapters of the report.

2.1.1 Climate and rainfall distribution

2.1.1.1 Precipitation

The climate and temperature variations of the Luvuvhu 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 catchment in which the Luvuvhu Government Water Scheme (GWS) is located is characterised by the mean annual precipitation (MAP) ranging from 800 mm to 899 mm in the majority of the scheme area (see **Figure 2.2** below).

There is a small area of the GWS where the MAP ranges from 700 mm to 799 mm of rainfall. The low MAP indicates the need for irrigating the lands because of low rainfall in the Luvuvhu Irrigation Scheme area.

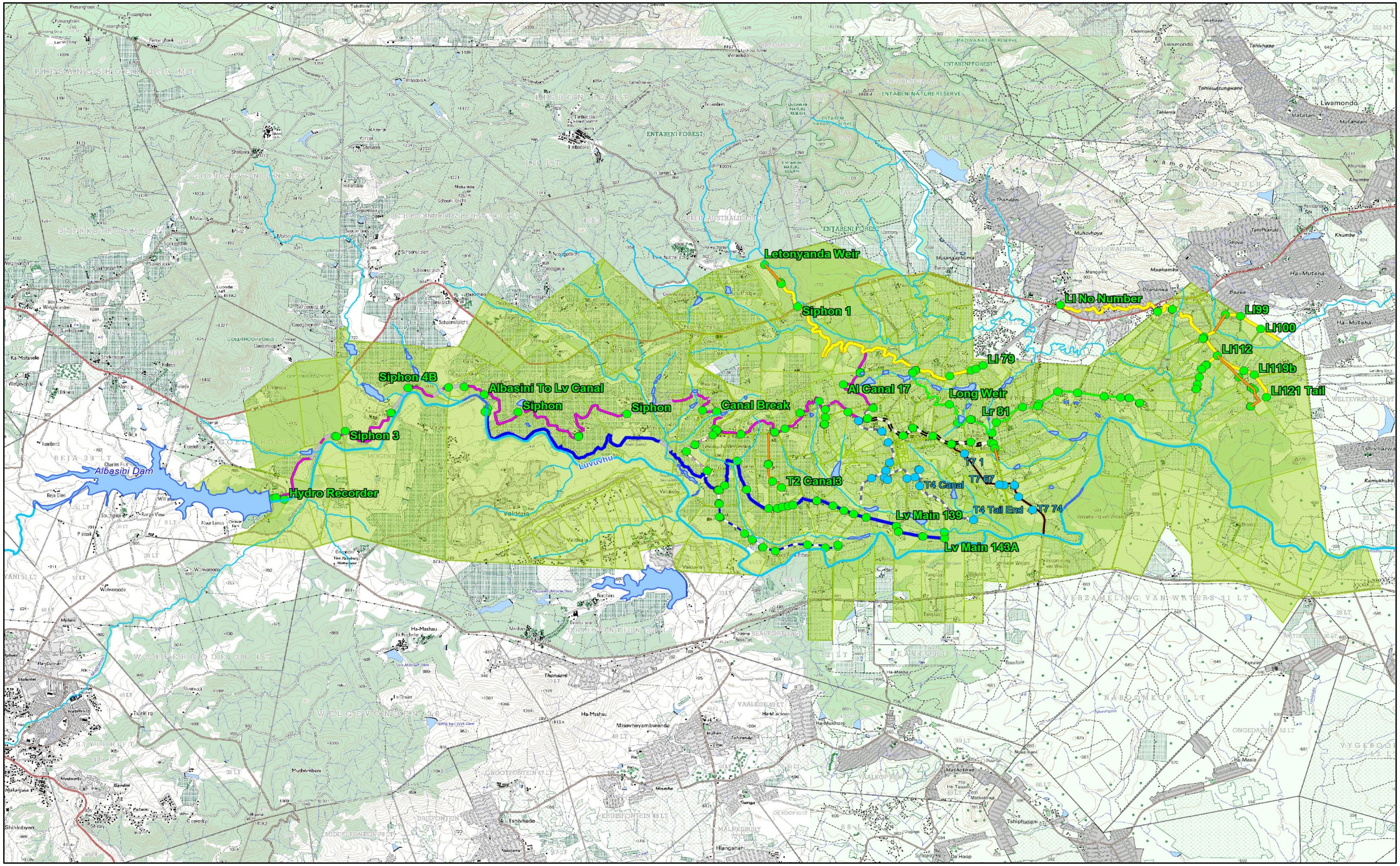

Figure 2.1: Locality Map of Luvuvhu Government Water Scheme

Figure 2.2: Precipitation Map of the Luvuvhu Irrigation Scheme

2.1.1.2 Evaporation

The Luvuvhu Irrigation Scheme is located in two evaporation zones. The extreme Albasini area has the evaporation ranging between 1400 mm to 1500 mm. However, the evaporation in the area in which the irrigation scheme is mainly located, ranges between 1500 mm and 1600 mm. The high evaporation rate has a direct correlation with the irrigation water use requirements.

2.1.2 Geology and soils of the catchment

As a result of the predominant geological strata as well as the climate, the soils of the Luvuvhu Irrigation Scheme can be categorised as moderate to deep clayey loam soils on steep terrain (see **Figure 2.3** below). The average soil depth in the scheme area is 1050 mm. These Luvuvhu soils are fine textured soils where the water and plant nutrient losses may not be as great. However the timing and quantity of chemical and water applications is considered important on these soils.

There are four important levels of soil moisture content that reflect the availability of water in the soil. These levels are commonly referred to as: 1) saturation, 2) field capacity, 3) wilting point and 4) oven dry. The water held between field capacity and the wilting point is available for plant use and is known as water holding capacity. The water holding capacity of the Luvuvhu soils ranges between 120 -270 mm per m depth of available water for the crop to (J.L. Schoeman and M. van der Walt.) Therefore in order to meet this water holding capacity and because the Luvuvhu soils possess a good characteristic and ability for draining water, supplemental irrigation water is required to meet the soil moisture requirements of these Luvuvhu soils.

Figure 2.3: Luvuvhu Irrigation Scheme Soil Map

3 OVERVIEW OF THE LUVUVHU IRRIGATION SCHEME

3.1 Overview of the Luvuvhu Government Water Scheme

Figure 3.1 below indicates the Luvuvhu Government Water Scheme. The scheme is located in the Makhado Local Municipality. It initially used to receive its water for irrigation purposes from the Albasini Dam in the Luvuvhu River. However the yield of Albasini Dam has been affected severely by upstream developments including a lack of sufficient catchment for the dam. Therefore the capacity of the Albasini Dam is unlikely to supply the irrigation scheme in the near future.

The other sources of irrigation water supply for the Luvuvhu Government Water are tributary inflows into the Luvuvhu River. These tributaries join the Luvuvhu River downstream of Albasini Dam as indicated in **Figure 3.1** below. These include the Lutanyanda River and Tshipane River. Furthermore because of the fact that no irrigation water is supplied from the Albasini Dam, the irrigators are now dependent on groundwater which is now a major source of supply to supplement the irrigation water from the tributaries.

The main irrigation canals were constructed from the Albasini Dam as well as from a weir in the Luvuvhu River downstream of Albasini Dam as well as a weir in the Lutanyanda River to supply irrigators on the left bank of the Luvuvhu River as discussed in the latter sections. These canals convey the irrigation water to the irrigated farms located downstream of the dam and the weir along the Luvuvhu as indicated **in Figure 3.1** below.

The Luvuvhu Government Water Scheme (GWS) comprises a total of 1 854ha supplying 138 Parshall Flumes in the scheme although not all of them are operational as Albasini canal is closed while the Luvuvhu and Lutanyanda canals are on restrictions. The irrigation area is all below the Albasini Dam and stretches for approximately 23 km until Mangwele.

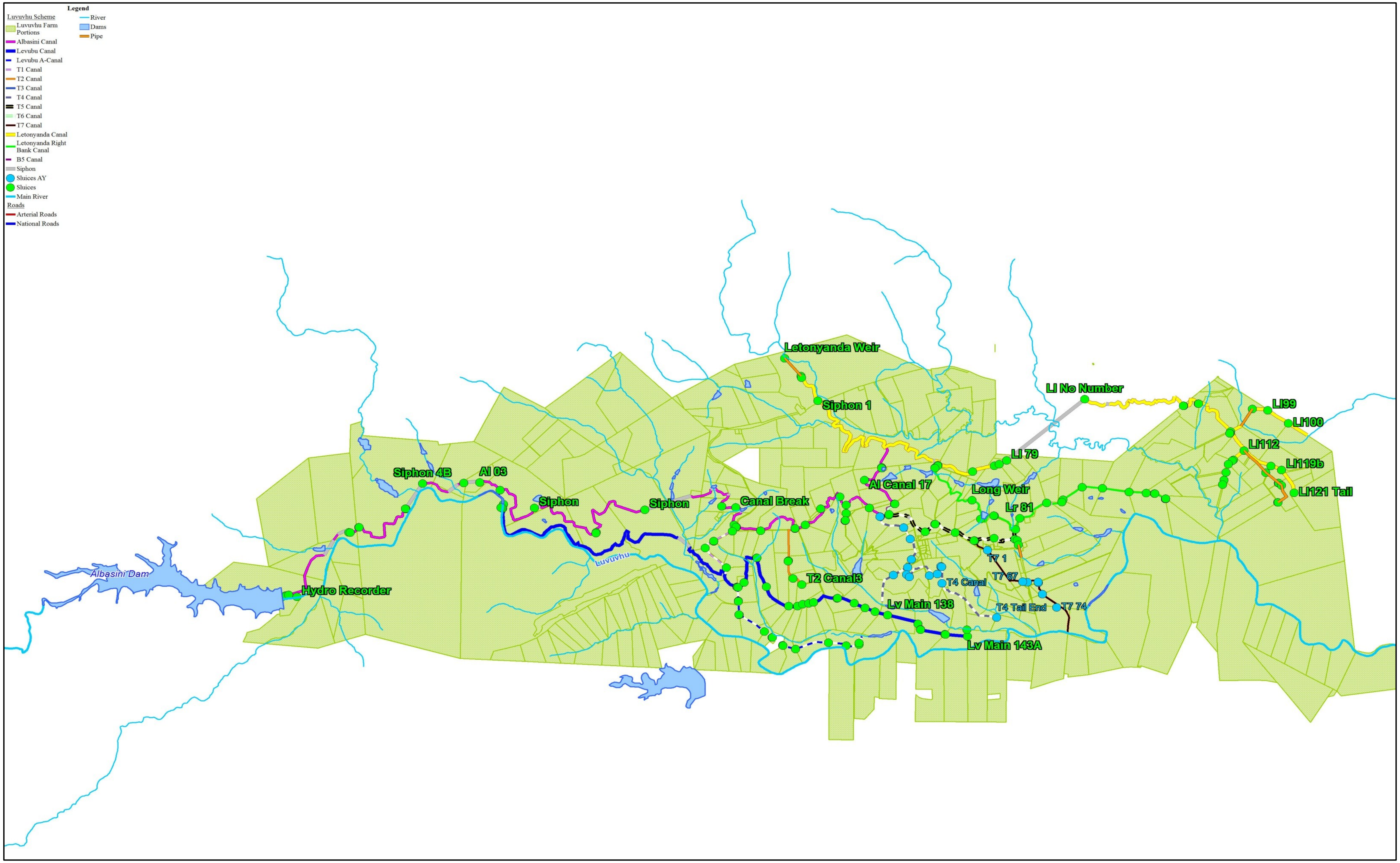

Figure 3.1: Luvuvhu Government Water Scheme

3.2 Organisational arrangements

The Luvuvhu Irrigation Scheme is a government water scheme (GWS) since it was established. The DWA, through its Infrastructure Branch is responsible for the operation and maintenance of the scheme. As part of the operation of the irrigation scheme, the Infrastructure Branch supplies water not only to the irrigators in the Luvuvhu Government Water Scheme but also provides the water requirements for municipal water use through the canal infrastructure to the surrounding areas.

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

3.2.1 Water distribution Section

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

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

There are three levels in the water distribution section which include, the Chief Water Control Officer, the Water Control Officer and the Water control aids or canal guards. Their responsibilities are discussed in the following sections.

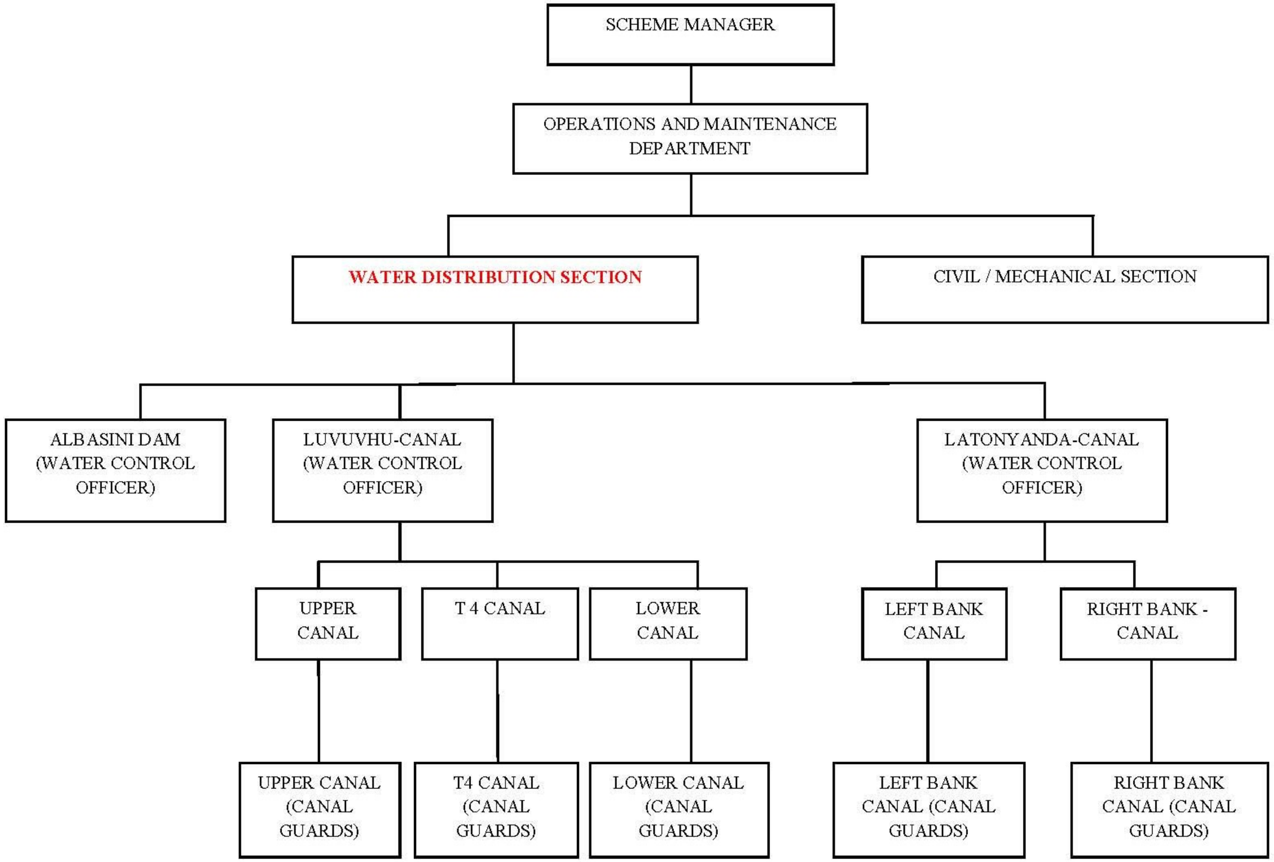

Figure 3.2: Organisational structure for water distribution in the Luvuvhu Government Water Scheme

3.2.1.1 Chief Water Control Officer

The Luvuvhu GWS has an Chief Water Control Officer who is responsible for the operation of the whole irrigation. His main function is to collect the information provided by the Water Control Officers, process it and issue the operational orders to be executed. These include the amount and timing of releases from the Luvuvhu Dam, the setting of the sluice gates and structures to deliver the amount and timing of irrigation water requested by the irrigator on a weekly basis

The job description of the Chief Water Control Officer ideally is mainly to carry out the following tasks:

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

3.2.1.2 Water Control Officers

The Luvuvhu Government Water Scheme is sub-divided into three (3) sections, each with a Water Control Officer (WCO) who is responsible for managing the section. The job description of the WCO is mainly to carry out the following tasks:

(i) Read the water levels in the canal off takes, river and balancing dams in those sections they are available;
(ii) Transmit the data to the Water control aids (WCAs) responsible for the different sections;
(iii) Manipulate or set the sluice gates and structures as indicated by the Luvuvhu GWS main office;
(iv) Receive data from the WCAs as to the required amount of water, and transfer the data to the main office;

(v) Report to the Chief Water Control Officer of any malfunctioning of sluice gates and structures and any water thefts;

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

Manpower requirements

Data from several projects indicate that one Water Control Officer can cover 10 - 15km depending on the number of hydraulic structures in the canal. The main intake works which is at the Luvuvhu Dam requires one or two people depending on the complexity of operation. The operation of the dam gates requires one person.

In the Luvuvhu GWS, there are three WCOs with one of the WCOs responsible for operation of the Luvuvhu Dam outlet gates. Given the fact that the Luvuvhu canal system has approximately 75 km of canal, each WCO is responsible for 25 km of canal.

3.2.1.3 Water control aids

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

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

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

(ii) Open and close sluice gates and valves;

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

(iv) Communication to the WCO of the requests for water;

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

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

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

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

Manpower requirements

Given the local circumstances such as transport facilities, ease of access and the configuration of the irrigation canal scheme layout, there are four WCA for the nearly 3 000 ha of the scheduled area. This is considered more than sufficient when the size of the farms is determined to be of medium size.

As illustrated in the **Figure 3.1** above the Luvuvhu GWS has sufficient resources to carry out the water distribution to its constituents, the irrigators in all the sections.

3.2.2 Civil / Mechanical Maintenance Section

The maintenance section is entrusted with the overall responsibility for keeping the irrigation and drainage infrastructure working in a satisfactory manner, within the limitations imposed by the limited design.

The main functions of the Civil/Mechanical Maintenance Section to be undertaken include the following:

(i) Planning the maintenance activities;

(ii) Implementing the maintenance activities planned and those unforeseen. Maintenance activities can be easily undertaken during the dry periods in the off-season;

(iii) Monitoring the abovementioned activities - a maintenance service requires data for good planning which can be obtained by regular monitoring. Without reliable data on costs for the different units of work and on productivity no realistic planning can be done.

The existing organisation structure for the Civil/Mechanical Maintenance section is provided in **Figure 3.3** below.

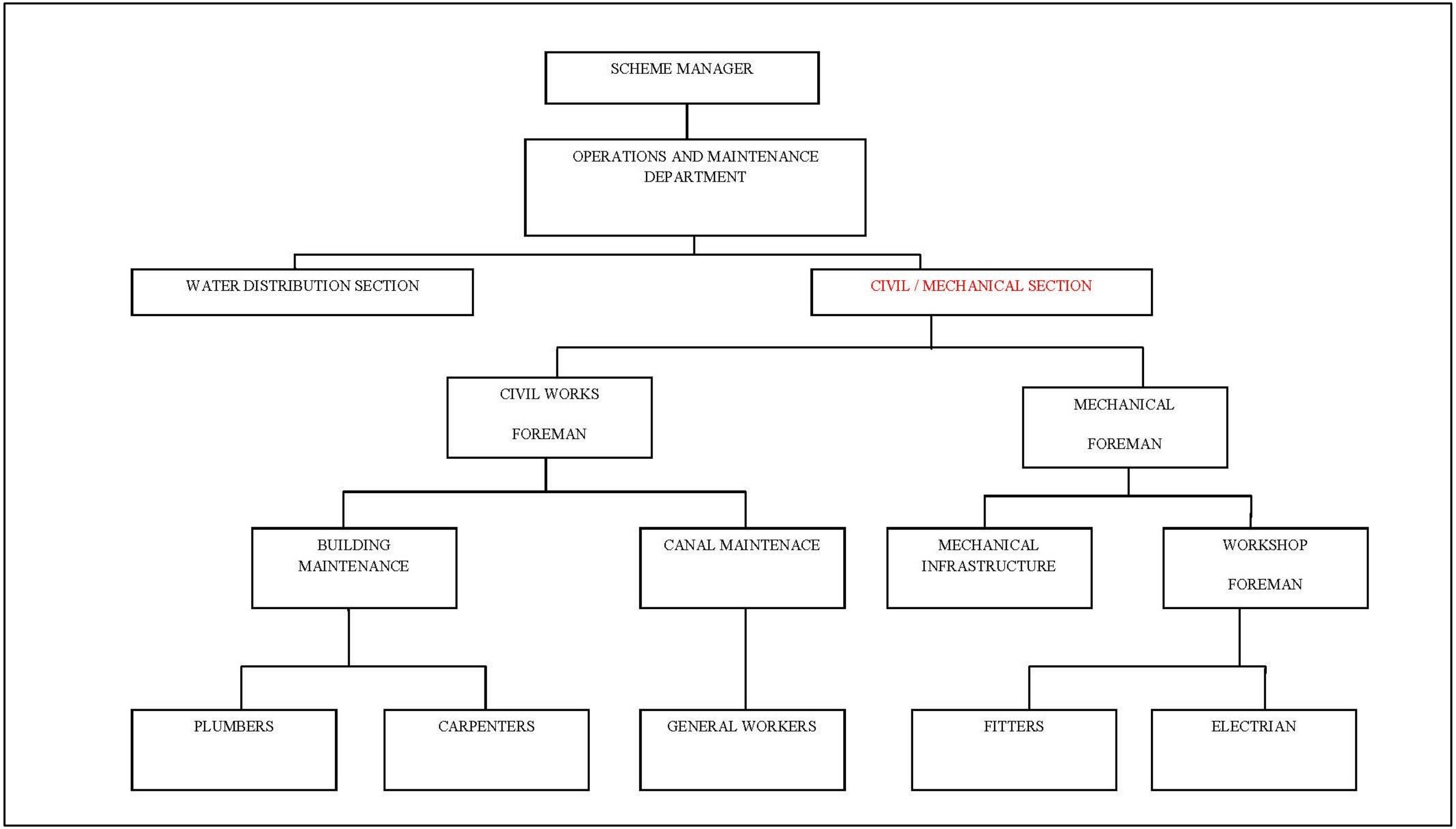

Figure 3.3: Organisational structure for the maintenance of the Luvuvhu Government Water Scheme

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

3.3 Irrigation water use charge

3.3.1 Water User Charge

The irrigators in the Luvuvhu Government Water Scheme are charged a water use charge of 22.87 c/m^3, which is equivalent of R1 875.34 per ha/a, while the river irrigators are charged at 16.42 c/m^3 which is equivalent of R1 346.44 per ha/a for the 2009/10 financial year. Compared to other irrigation schemes these costs can be considered to be comparable and reasonable to ensure irrigation agriculture is a viable option.

No Water Resource Infrastructure (WRI) charge has been provided in the Government Gazette to be paid by the domestic and industrial users from the Albasini Dam although there is an allocation from the dam to supply the town of Louis Trichardt or Makhado as it is likely to be known in future. If provided it would be higher than irrigation agriculture because of the high assurance provided to the domestic and industries. This would have indicated that the WRI charge for irrigation agriculture is currently heavily subsidised when compared to the water use charged for domestic users and industries from the same scheme.

Each irrigator is responsible for the payment of the WRI charge to the Department of Water Affairs (DWA). The collection of the water use charge is also carried out by the DWA.

3.3.2 Water Resource Management Charge

Besides paying for the use of the water released from the Albasini Dam, the irrigators in the Luvuvhu Irrigation Scheme also pay for the water resource management charge of the catchments. The current WRM charge for the Luvuvhu and Letaba WMA in which the Luvuvhu GWS is located, is 1.57 c/m^3 or R 128.74 per ha/a.

The WRM charge is different for different user sectors in the Luvuvhu and Letaba Water Management Area (WMA) in which the Luvuvhu Irrigation Scheme is situated. The domestic and industrial users pay a WMA of 2.65c per m^3.

The purpose of the WRM charge is to cover all management activities that are undertaken by a Catchment Management Agency (CMA) or a proto-CMA where one has not been established and to ensure the sustainable water resource management to ensure all users in the WMA have fair and equitable share of the available water. The activities that are covered by the WRM include the following:

(i) water abstraction control to ensure that all get their fair share of water,
(ii) monitoring and pollution control to keep the rivers healthy,
(iii) planning for development of new schemes and to extend existing schemes,
(iv) clearing of invading alien plants which consume water that should be available for use.

For the canal irrigators in the Luvuvhu Government Water Scheme, the total cost of irrigation water including the management charge amounts to R 2 004.08 per ha/a. This is comparable to a number of other irrigation schemes.

3.4 Water use permits / licenses and contracts

The authorisation for the water use, within the Luvuvhu Government Water Scheme (GWS) area of jurisdiction, lies in the Schedule, for 1 845.4 ha, drawn up in terms of section 88 of the 1956 Water Act, and approved by the Department in 1999. This scheduled use is deemed to be an Existing Lawful Water Use under section 32 of the National Water Act, 1998 and as such, does not require a Licence, but does need to be registered. The irrigators have permission to continue irrigating this scheduled area until licensing takes place, provided they pay all charges due to Luvuvhu Government Water Scheme.

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

The total allocation for the scheme is 15.6 million m^3/a, at 8 400 m^3/ha/a. This does not include irrigators supplied directly from the dam through the Luvuvhu River. A review of the Water Allocation Registration Management System (WARMS) database indicates that the total registered water use in the scheme area is much higher than the scheduled area, which is supplied from the canal infrastructure.

3.5 Irrigated areas and types of crops

The current irrigated area is 1 854 hectares, which comprises the following:

(i) 871.4 hectares is the irrigated area directly supplied from Albasini Dam. This area is currently dependent on groundwater as the dam level has been consistently very low to divert water into the Albasini canal system.

(ii) 605.6 hectares is the area irrigated from the Lutanyanda weir and the canal system.

(iii) 325.9 hectares is the area irrigated from the Luvuvhu canal system with the irrigation water diverted from the Luvuvhu River downstream of Albasini Dam

Each of the irrigators in the Luvuvhu Irrigation Scheme area is registered individually and the Registration certificates reflect the enlisted area as well as the non-scheduled areas.

The irrigators in the scheme are growing diverse crops which include Avocados, Mangoes, Guavas and Macadamias. There are a wide variety of other crops that are irrigated in the Luvuvhu Scheme area but all these crops are mainly annual crops.

3.6 Historic water use

In order to evaluate the water use of the Luvuvhu Irrigation Scheme, it was intended to treat the scheme as having two sub-schemes namely the Albasini Main Bank and the Luvuvhu Main Bank canal system. However there was no data available to distinguish between the Luvuvhu canal and the Albasini canal system because of lack of flow measurements.

The historic water use of whole scheme is provided in the **Table 3.1** below.

3.6.1 Historic water use - Luvuvhu Government Water Scheme

The historic water use for the Luvuvhu GWS was prepared based on the information provided from the WUEARs from the 2001/02 water year to 2011/12 water year. The historical information was available to determine the annual average inflows and water use (see **Table 3.1** below).

Water use for irrigation has averaged approximately 2.97 million m^3/a, for the 11 years of records. The records include the wet periods of 2001/02 to the dry periods of 2005/06. When compared to the scheduled quota for the scheme, this is approximately only 19% of the scheduled water allocation for the Luvuvhu GWS of 15.58 million m^3/a. This clearly indicates that over the 11 year period the Luvuvhu GWS has been on irrigation water restriction with the Albasini canal not operational.

Table 3.1: Historic water use levels (thousand m^3/a) for the whole of the Luvuvhu GWS

User	2001/02	2002/03	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	11 year average
Irrigation	4 207.00	6 044.00	3 951.00	3 022.00	1 184.00	2 540.00	1 889.00	2 217.00	2 802.00	1 736.00	3 037.00	2 966.27
Household		-	-	-	-	-	-	-	-	-	-	-
Industrial use		-	-	-	-	-	-	-	-	-	-	-
Municipal use	263.00	305.00	94.00	-	-	-	-	-	-	-	-	220.67
Total	4 470.00	6 349.00	4 045.00	3 022.00	1 184.00	2 540.00	1 889.00	2 217.00	2 802.00	1 736.00	3 037.00	3 186.94
Inflow into the Scheme	10 006.00	13 626.00	10 796.00	9 902.00	3 590.00	6 484.00	3 671.00	4 154.00	4 533.00	2 612.00	4 639.00	6 728.45
Water Losses	5 536.00	7 277.00	6 751.00	6 880.00	2 406.00	3 944.00	1 782.00	1 937.00	1 731.00	876.00	1 602.00	3 702.00
% water losses	55%	53%	63%	69%	67%	61%	49%	47%	38%	34%	35%	53%

The scheme also provided municipal water for the town of Makhado until 2003/04. No records are available of the domestic and industrial water use from the irrigation canals. The consumption until 2003/04 was 0.22 million m^3/a.

The flows at the canal tail ends which are currently being measured are not reflected in the water balance assessment as discussed in the later sections of this report.

The historical information provided by the hydrological section on the diversion at the hydro station at Lutanyanda and Luvuvhu weirs indicated that the average inflow into the irrigation scheme for the 11 year period for which flow records were available was 6.7 million m^3/a.

When this is compared to the applications from the canal infrastructure, the average additional water required to deliver the irrigation water applications (which comprises canal seepage losses, leakage, evaporation and spills at canal tail ends) is 53% of the total irrigation water diverted into the canal system. This is considered to be extremely high.

4 INVENTORY OF THE EXISTING WATER INFRASTRUCTURE

4.1 Overview

The Luvuvhu Irrigation Scheme comprises a dam from which irrigation water originally used to be supplied; two weirs on the Luvuvhu and Lutanyanda rivers where irrigation water is diverted into the scheme, primary and second canal infrastructure to convey the irrigation water to the farms, drainage canals to drain water from the irrigation fields back to the Luvuvhu River as well as canal turnouts.

The primary and secondary irrigation canal system delivers the water ordered to the irrigators at their farm turnouts through a number of sluice gates where flow measurement is done using Parshall flumes.

4.2 Water Supply Sources

4.2.1 Albasini Dam

The source of water supply for irrigation is from the Albasini Dam which is located in the headwaters of the Luvuvhu. The dam was built and commissioned in 1952 and has a storage capacity of 23.7 million m^3. The historical yield of the dam is 5 million m^3/a. Water used to be diverted into the Albasini main irrigation canal from the Albasini Dam.

4.2.2 Lutanyanda River weir

The Lutanyanda River is a tributary of the Luvuvhu River which has its headwaters in the Soutpansberg Mountains. There is a weir in the headwaters which is used to divert irrigation water into the Lutanyanda canal system. The storage capacity of the weir is not known. However the Lutanyanda River is a perennial river with sufficient yield to supply irrigators dependent on the canals from the River.

4.2.3 Luvuvhu River weir

The Luvuvhu River downstream of the Albasini Dam has significant run-off due to the tributary inflows from the mountains taking place downstream of the dam. A weir was constructed in the Luvuvhu River which is used to divert irrigation water into the Luvuvhu canal system. It is not known what the storage capacity of the Luvuvhu River weir is.

4.3 Irrigation conveyance infrastructure

Figure 4.1 below, illustrates the conveyance and distribution infrastructure of the Luvuvhu Irrigation Scheme. As discussed above there are three sources of supply for the Luvuvhu Government Water Scheme.

Irrigation water is diverted into the three main canal systems supplying the irrigation scheme. There are three primary canals in the Luvuvhu Irrigation Scheme known as the Albasini Main canal, Luvuvhu main canal as well as the Lutanyanda main canal system. There are several branch canals from the primary canals which supply the irrigators in the scheme area. The total length of the main canal including the branch canals and pipelines was measured to be 98.55 km, all of which is concrete lined.

The canal information including the geometry where available is discussed in the following sections of the report.

4.3.1 Albasini Dam main canal system

Table 4.1 below provides a summary of the canal infrastructure in the Luvuvhu Government Water Scheme.

4.3.1.1 Albasini main canal

This is the primary canal from the Albasini Dam which traverses the government water scheme with the intent to supply irrigators on the left bank of the Luvuvhu River. It comprises approximately 24.6 km of concrete lined canal as well as 3.5 km of siphons.

The Albasini canal is the largest canal based on the canal geometry, with a maximum design capacity of 4 300 m^3/h or 1.2 m^3/s. Any excess water not taken up by irrigators will flow back to the Luvuvhu River at the canal tail end.

Because the level of water in Albasini Dam has consistently been very low for a number of years, the Albasini irrigation canals have not been operational. Currently no water is diverted from the dam into the canals because the dam does not have sufficient water. This has been the case for a number of years. The Albasini canal was intended to supply 871.4 ha of the scheduled area. This area is now dependent on groundwater as its main source of irrigation water.

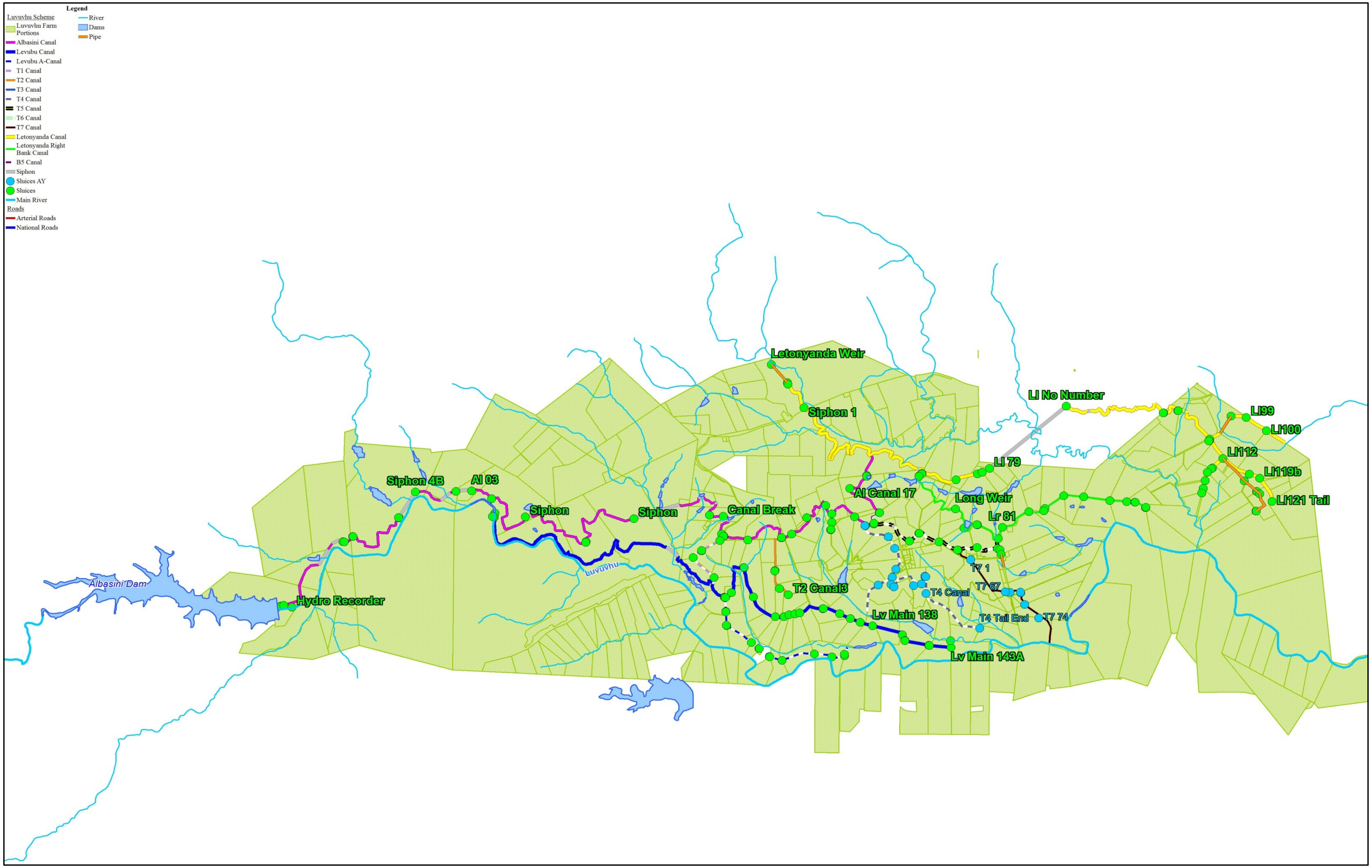

Figure 4.1: Luvuvhu Irrigation Scheme -Infrastructure

4.3.1.2 Albasini Branch canals

The Albasini main canal comprises seven (7) branch canals which was intended to supply the irrigators located upstream of the Luvuvhu River canal system. The characteristics of the branch canal system are as follows:

(i) *T1 branch canal*: This is the first branch canal which was intended to convey the irrigation water for the farmers between the Luvuvhu canal and the Albasini canal. It is estimated that there is 2.2 km of concrete lined canal. The maximum hydraulic capacity of the branch canal is 1 000 m^3/h of 0.28 m^3/s. The T1 branch canal links to the Luvuvhu canal. Therefore any operational spills would have been taken into account in the Luvuvhu canals.

(ii) *T2 branch canal*: The T2 branch canal is a concrete line canal which was intended to supply between the Luvuvhu canal and the Albasini canal. It is estimated that there is 3.0 km of concrete lined canal and 1km of siphons. The maximum hydraulic capacity of the branch canal is 400 m^3/h of 0.11 m^3/s. The T2 branch canal ends at the irrigator's farm dam. Therefore any operational spills are measured at the irrigators Parshall Flume.

(iii) *T3 branch canal*: The T3 branch canal also conveys the irrigation water for the farmers between the Albasini canal and Luvuvhu canal. It is a short canal and comprises approximately 0.6 km of concrete lined canal and 0.4 km of siphons. The maximum hydraulic capacity of the branch canal is 300 m^3/h of 0.08 m^3/s. The T3 canal ends at an irrigator's farm dam. Therefore any operational spills are measured at the irrigators Parshall Flumes.

(iv) *T4 branch canal*: The T4 branch canal also conveys the irrigation water for the farmers between the Albasini canal and Luvuvhu canal. It comprises of approximately 7.1 km of concrete lined canal. The maximum hydraulic capacity of the branch canal is 600 m^3/h of 0.17 m^3/s. The T3 canal bifurcates into two smaller branch canal which end at an irrigator's farm dam. Therefore any operational spills would be measured at the irrigators Parshall Flumes.

(v) *T5 branch canal*: The T5 branch canal also conveys the irrigation water for the farmers between the Lutanyanda canal and Luvuvhu canal. It comprises approximately 4.0 km of concrete lined canal. The maximum hydraulic capacity of the branch canal is 1 050 m^3/h of 0.29 m^3/s. The T5 canal bifurcates into the T6 and T7 branch canals. The canal ends flow back to the Luvuvhu River. Therefore any operational spills would need to be measured.

Table 4.1: Canal Infrastructure on the Luvuvhu Irrigation Scheme

Item No	Canal Name	Type of canal	Total Length of canal (km)	Total length of siphons (km)	Canal capacity (m^3/h)	Canal capacity (m^3/s)
1	Albasini Main Canal	Concrete lined	24.60	3.50	4 300.00	1.19
	T1 Branch canal	Concrete lined	2.20		1 000.00	0.28
	T2 Branch canal	Concrete lined	3.00	1.00	400.00	0.11
	T3 Branch canal	Concrete lined	0.60	0.40	300.00	0.08
	T4 Branch canal	Concrete lined	7.10		600.00	0.17
	T5 Branch canal	Concrete lined	4.00		1 050.00	0.29
	T6 Branch canal	Concrete lined	0.70		300.00	0.08
	T7 Branch canal	Concrete lined	2.60		500.00	0.14
			44.80	**4.90**		
2	Luvuvhu Main Canal	Concrete lined	15.20		1 600.00	0.44

Item No	Canal Name	Type of canal	Total Length of canal (km)	Total length of siphons (km)	Canal capacity (m^3/h)	Canal capacity (m^3/s)
	Luvuvhu 1 Branch Canal	Concrete lined	4.00		500.00	0.14
			19.20			-
3	Lutanyanda Main Canal	Concrete lined	6.74	0.58		-
	Lutanyanda Left Bank Canal	Concrete lined	9.02	2.40	1 200.00	0.33
	Lutanyanda Left Bank A canal	Concrete lined	1.76	0.50	300.00	0.08
	Lutanyanda Left Bank B Canal		1.08			-
	Lutanyanda Right Bank Canal		7.57		1 500.00	0.42
			26.17			
Total length of canal system (km)			90.17	8.38		

(vi) *T6 branch canal*: The T6 branch canal also conveys the irrigation water for the farmers between the Albasini canal and Luvuvhu canal. It is a short canal and comprises approximately 0.7 km of concrete lined. The maximum hydraulic capacity of the branch canal is 300 m^3/h of 0.08 m^3/s. The T3 canal ends at an irrigator's farm dam. Therefore any operational spills are measured at the irrigators Parshall Flume.

(vii) *T7 branch canal*: The T7 branch canal branches off from the T5 canal and conveys the irrigation water for the farmers between the T5 branch canal and Luvuvhu River. It comprises approximately 2.6 km of concrete lined canal. The maximum hydraulic capacity of the branch canal is 500 m^3/h of 0.14 m^3/s. The canal ends flow back to the Luvuvhu River. Therefore any operational spills would need to be measured. Any excess water not taken up by irrigators will flow back to the Luvuvhu River at the canal tail end.

4.3.2 Luvuvhu main canal system

As illustrated in **Table 4.2** below, the Luvuvhu main canal starts from the Luvuvhu River weir downstream of the Albasini Dam and supplies irrigators between the Albasini main canal and the Luvuvhu River on the left bank. There is also a branch canal supplying water to the farms. The total length of the Luvuvhu canal systems is 19.2 km and serves 325.9 ha of the scheduled allocation at 8 400 m^3/ha (i.e. total scheduled allocation of 2.7 million m^3/a). The two canals are as follows:

4.3.2.1 Luvuvhu main canal

This main canal originates from the Luvuvhu weir and traverses the government water scheme supplying irrigators on the left bank of the Luvuvhu River between the Albasini canal and the Luvuvhu River. It comprises approximately 15.2 km of concrete lined canal infrastructure. The maximum design capacity of the main canal is 1 600 m^3/h or 0.33 m^3/s. The canal tail end flows back into a tributary of the Luvuvhu River. Any excess water not taken up by irrigators will flow back to the Luvuvhu River at the canal tail end.

4.3.2.2 Luvuvhu A Branch canal:

This is the canal which conveys the irrigation water for the farmers who are closer to the Luvuvhu River between the river and the Luvuvhu main canal. It is estimated that there is 4.0 km of concrete lined canal infrastructure with a maximum hydraulic capacity of 300 m^3/h of 0.08 m^3/s. The canal tail end returns any excess water to a tributary of the Luvuvhu River canal.

4.3.3 Lutanyanda main canal system

As illustrated in **Table 4.2** below, the Lutanyanda canal starts from the Lutanyanda River and supplies irrigators above the Albasini main canal. The total length of the Lutanyanda canal system is 26.17 km and 3.48 km of siphons. The canals serve approximately 605 ha of the scheduled allocation at 8 400 m^3/ha (i.e. total scheduled allocation of 5.08 million m^3/a). The Lutanyanda canals are as follows:

4.3.3.1 Lutanyanda main canal

This main canal originates from the Lutanyanda weir and traverses the government water scheme supplying irrigators above the the Albasini canal on the left bank of the Luvuvhu River. It comprises approximately 6.7 km of concrete lined canal infrastructure and 0.58 km of siphons. The maximum design capacity of is estimated to be 5 000 m^3/hr or 1.4 m^3/s

The Lutanyanda main canal bifurcates into the two branch canals with the left bank canal supplying irrigators on the left bank of the Lutanyanda River while the right bank supplies irrigators on the right bank of the Lutanyanda River.

4.3.3.2 Lutanyanda left bank canal:

This is the branch canal which conveys the irrigation water for the farmers who are situated on the left bank of the Lutanyanda River. It is estimated that there is 9.0 km of concrete lined canal infrastructure and 2.4 km of siphon across the Lutanyanda River. The left bank canal has a maximum hydraulic capacity of 1 200m^3/h of 0.33 m^3/s. There are three branch canals on the canal with three canal tail ends which end at the irrigators' farm dams. Therefore any excess water is included as irrigation water ordered by the farmer and is taken out of his scheduled quota.

4.3.3.3 Lutanyanda right bank canal:

This is the branch canal which conveys the irrigation water for the farmers who are situated on the right bank of the Lutanyanda River. It is estimated that there is 7.6 km of concrete lined canal infrastructure. The right bank canal has a maximum hydraulic capacity of 1 500 m^3/h of 0.42 m^3/s. There is one canal tail end which returns any excess water or operational spills back to the river. Therefore any excess water has to be measured at the canal tail end.

4.4 Irrigation storage and regulation system

4.4.1 General

Besides the main dam, the two weirs and the canal system for conveyance of the irrigation water to the irrigators' farms, the Luvuvhu Irrigation Scheme also has a balancing dam, to reduce the time of delivery to downstream irrigators. The balancing dam is indicated in **Figure 4.1** above and is discussed in the following sections.

4.4.2 Albasini canal Balancing Dam

The Albasini canal Balancing Dam is the balancing dam in the Albasini sub-scheme area of the Luvuvhu Irrigation Scheme. It was intended to supplement irrigation water to irrigators supplied by the Lutanyanda canal. However since the Albasini Dam is not operational the balancing dam is not being used at present.

The Albasini Balancing dam was intended to provide significant operational flexibilities to the Luvuvhu GWS depending on the distribution of users requesting water for the week in the Lutanyanda canal system downstream of the balancing dam. It was also likely to not only reduce the delivery time for the downstream irrigators supplied from the balancing dam, but also provide additional water to the Lutanyanda canal system.

However the storage capacity of Albasini Balancing Dam is not known which makes it difficult to determine the extent of its benefit to irrigation water management. Furthermore during the dry periods when the irrigation canals are emptied to carry out maintenance, it can provide water to the downstream irrigators thereby providing sufficient downtime for the canals to be properly maintained.

4.4.3 Irrigation Farm Dams

A number of irrigators have farm dams which they use to provide balancing storage. Any water ordered by the irrigators and not utilised directly for crop water irrigation is stored in the farm dams and used when the soil moisture levels are low before irrigators put in their water applications.

The farm dams are also important to store any excess water which irrigators do not use after ordering their water for the week.

4.4.4 Irrigation infrastructure distribution system

As illustrated in **Figure 4.1** and **Table 4.1** above, there are several kilometres of branch canals in the Luvuvhu irrigation scheme which distribute the irrigation water to approximately 138 sluices which are measured using the Parshall flumes.

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

4.5 Flow Measurement and telemetry system

4.5.1 Measurement of flow into the scheme area

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

As illustrated, the first measurement of the water diverted at the Lutanyanda weir into the main canal system is located on the right bank of the weir. This comprises a flow recorder as well as the 3 ft Parshall flume. There is a telemetry system linked to the flow measurement at the Lutanyanda weir which is operated by the Hydrological Branch of the Department of Water Affairs (DWA).

There is also a flow recorder as well as the 4ft Parshall flume at the Luvuvhu weir which serves the Luvuvhu canal system, the other canal which is operational at present. There is a telemetry system linked to the flow measurement at the Luvuvhu weir which is operated by the Hydrological Branch of the Department of Water Affairs (DWA).

4.5.2 Measurement into the various canal systems

The Luvuvhu Government Water Scheme has two main irrigation canals which are currently operational. These are the Lutanyanda main canal which serve the irrigators above the Albasini canal and Luvuvhu main canal which supply irrigators below the Albasini Dam on the left bank of the Luvuvhu River. These two canals have been the focus of this water management plan. The Albasini main canal is currently not operational due lack of water in the Albasini Dam.

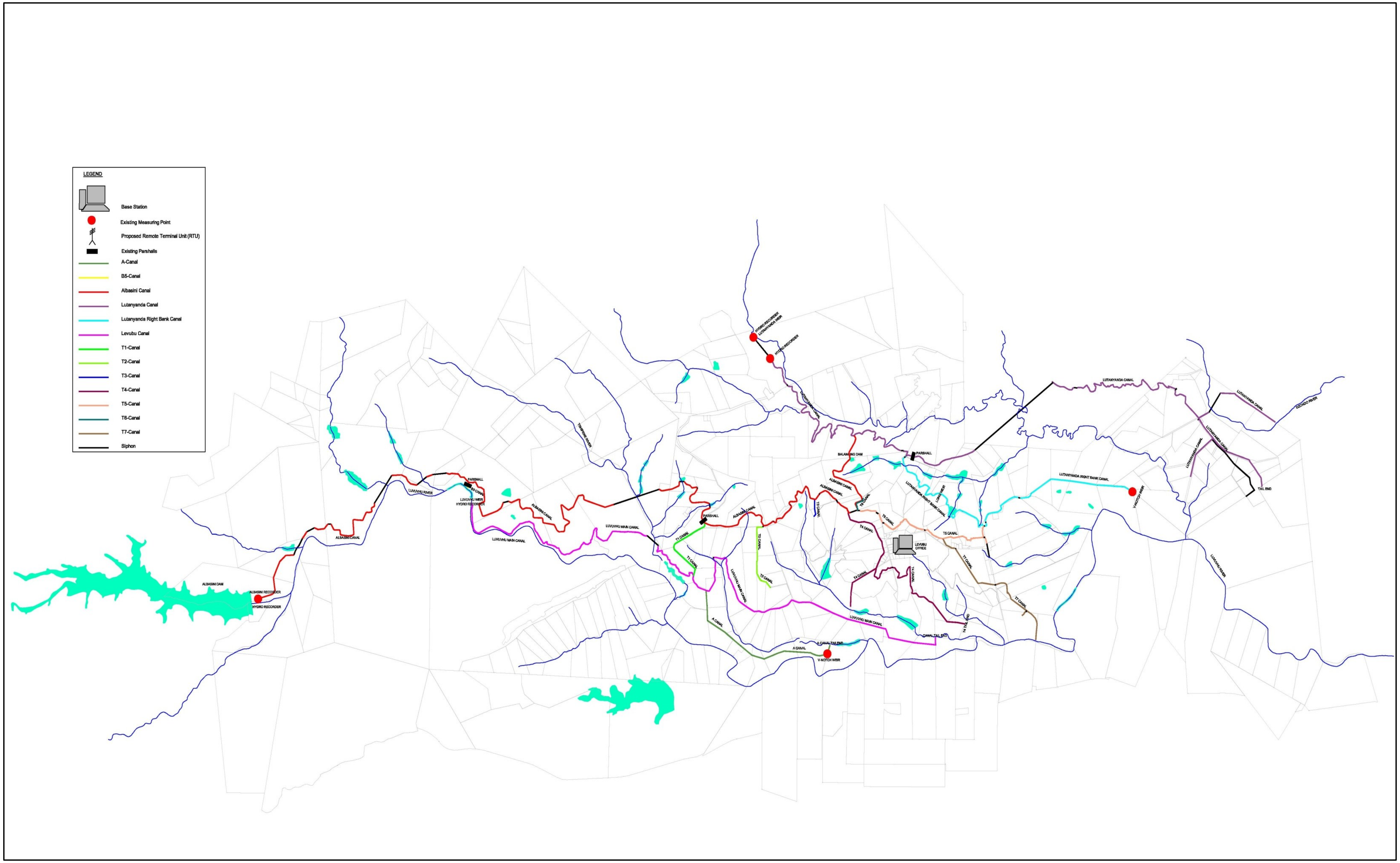

Figure 4.2: Schematic layout of the Luvuvhu State Water Scheme with the existing water measurement system

The preliminary survey of the aerial photographs and the site visits identified that there are flow measurement structures in both the Lutanyanda and Luvuvhu main canals. In the Lutanyanda and Luvuvhu main canals the flow measurements include Parshall Flumes at some of the critical points.

4.5.2.1 Flow measurements in the Lutanyanda canal system

There is a Parshall flume which measures flows at the inlet of the Lutanyanda Left Bank canal (see **Photo 4.1** below). The canal tail of the left bank canal ends at the irrigators' sluices. Therefore the water measurements downstream of the sluices where there are V-Notch weirs to measure the irrigator's water also includes the excess water at the canal tailend if any.

Photo 4.1: Parshall Flume to measure flow rates into the Lutanyanda Left bank canal

There was no flow measurement into the Lutanyanda right bank canal. However measurement into the right bank canal can be determined as the difference between the flow into the main canal and the left bank canal measurement.

There is a flow measurement at the canal tail end of the Lutanyanda right bank canal (see **Photo 4.2** below). Therefore the water balance for the left bank and right bank can be calculated

Photo 4.2: Flow measurement structure at the Lutanyanda right bank canal

4.5.2.2 Flow measurement structures in the Luvuvhu canal system

There is a Parshall flume which measures the volume of water diverted into the Luvuvhu main canal. The other flow measurement is at the Luvuvhu A branch canal where there is a V-notch weir to measure any excess water back into the river system. There is no flow measurement at the canal tail end of the Luvuvhu main canal. The tail ends returns any operational spills back to a tributary of the Luvuvhu River. If there are any operational spills these would not be able to be measured.

4.5.3 Measurement at irrigators' outlets

The Luvuvhu Government Water Scheme (GWS) measures the weekly volume of water delivered to the water users at the farm gate by setting the sluice gates located off the main canal. It was identified that there were no flow measurements on a number of the sluice gates (see **Photo 4.3** below). The scheme appears to rely on the manual settings at the sluice gates to determine the weekly irrigation application.

The sluice gates are adjusted depending on the water application by the irrigators. There are five streams which can be delivered to the irrigator by adjusting the pressure controlled sluice gates. These are 30 m^3/h, 50 m^3/h; 100 m^3/h; 150 m^3/h and 200 m^3/h. The minimum time period for each stream is 12 hours.

Photo 4.3: No flow measurement downstream of the sluice gates

4.5.4 Telemetry system

The Luvuvhu Irrigation Scheme has no telemetry system directly linked to the GWS. There is however telemetry infrastructure that is used by the hydrological branch to measure real time flows at Lutanyanda weir and the Luvuvhu weir in the irrigation canals serving the irrigation scheme. These are currently not easily accessible for use by the scheme operators.

5 INFRASTRUCTURE CONDITION ASSESSMENT

5.1 Overview

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

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

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

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

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

5.2 Canal Condition Evaluation

Although it was not possible to undertake condition assessment of the irrigation canals of the Luvuvhu Irrigation Scheme, because at the time of developing the WMP, there were no dry periods to inspect the canals, the results of the preliminary investigations carried by our project team as part of the data capture have been used to provide a situation assessment of the condition of the infrastructure.

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

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

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

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

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

Table 5.1: General Condition rating

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

Table 5.2: Criteria for hairline, pencil size and large cracks

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

Table 5.3: Noticeable amounts of maintenance and repair (patchwork

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

Table 5.4: Vegetation growing in canal lining

Rating	Definition
0	None
1	Sparse
2	Moderate
3	Dense

Table 5.5: Vegetation in drainage canals and along the outer embankment of the levee

Rating	Definition
1	Normal; rain-fed weeds only
2	Canal fed grass or small weeds only
3	Moderate; bushes & some small trees with no water near levee or drain
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 Luvuvhu irrigation scheme was done for the three main canals as well as the branch canal from source to the canal tail ends. The findings of the condition of the infrastructure are discussed in the following sections.

5.3.2 Condition assessment of the Albasini main canal

5.3.2.1 Condition of the concrete lining

An assessment of the condition of the Albasini main canal and its branch canals was conducted by driving along the canal and using the RAT to determine the structural defects and any visual leaks that could be observed. This could be done because the Albasini canal system is currently not operational because of lack of sufficient water in the Albasini Dam.

It was observed through the visual assessment that in some sections of the Albasini canal, the condition of the canal had deteriorated. This could be attributed to lack of maintenance and neglect as the canal system is not operational (see **Photo 5.1** below). There has been significant vegetation growth between the concrete panels which may be widening the concrete joints as illustrated in **Photo 5.2** below.

The condition of this section is considered to be in a poor condition and was given a condition rating of 4. This will require attention in future if the Albasini canal is to become operational.

Besides visible cracks as illustrated in **Photo 5.1 and Photo 5.2** below, there were some sections of the concrete canals which are still in very good condition as illustrated in **Photo 5.3** below.

Photo 5.1: Major cracks in concrete panels of the Albasini Main canal

Photo 5.2: Vegetation growth in the canal

Photo 5.3: Sections of the Albasini canal in good condition

5.3.2.2 Condition of the siphons

No visual inspections were conducted on the canal siphons. Therefore the condition of the Albasini canal siphons could not be determined.

5.3.3 Condition assessment of the Lutanyanda main canal

5.3.3.1 Condition of the concrete lined canal

An assessment of the condition of the Lutanyanda main canal was conducted by driving along the main canal and using the RAT to determine the structural defects and any visual leaks that could be observed bearing in mind that at the time the canal was operational.

There are cracks and vegetation growth that was identified in the Lutanyanda main canal from the site survey. As illustrated in **Photo 5.4 and Photo 5.5** below, the soils behind the concrete panels have eroded which has resulted in the concrete joints shifting.

Photo 5.4: Open joints between the concrete panels as well as growth in the canal

The condition of the Lutanyanda left bank canal section is considered to be in a poor condition and was given a condition rating of 4. This will require attention because the scheme is losing significant volumes of water through leakage.

Besides the structural condition of the concrete panels, one of the problems that were identified was the presence of algae in the main Lutanyanda canal (see **Photo 5.6** below). This has had the effect of reducing the hydraulic performance and capacity of the canal. This has meant that more water is diverted to address the increased flow resistance in the canals.

Photo 5.5: Vegetation growth in the Lutanyanda canal

Photo 5.6: Algae and vegetation in the Lutanyanda canal

5.3.3.2 Condition of the siphons

During the site visit the Lutanyanda canal was not running. As a result the condition of the siphons could not be determined. However discussions with the scheme operators concluded that there were problems with the major siphon that crosses the Lutanyanda River to supply the irrigators on the left of the river.

However this could not be verified during the site visit.

Because the conditions of the pipes on the above canal siphons are in a poor state, there is a strong likelihood that there is a need to replace some of the pipes besides flashing and cleaning of the siphons.

5.3.4 Condition assessment of the Luvuvhu canal system

An assessment of the condition of the Luvuvhu canal was conducted by driving along the main canal and using the RAT to determine the structural defects and any visual leaks that can be observed.

The major problem that was identified on the Luvuvhu canal was the major cracks in the concrete. There was also significant growth of vegetation inside the canals. The vegetation growth in the canal and the cracks in the canals is a clear indication that there is significant leakage taking place in the canals. This is illustrated in **Photo 5.7** below.

The condition of the branch canal is considered to be poor and was given a condition rating of 4. This will require urgent attention because the scheme is losing significant volumes of water through overtopping while at the same time damaging the canal.

Photo 5.7: Cracks in the concrete panels of the Luvuvhu canal and vegetation growth

5.3.5 Condition assessment of the A branch canal

An assessment of the condition of the A branch canal was conducted by driving along the main canal and using the RAT to determine the structural defects and any visual leaks that can be observed.

The major problem that was identified on the A branch canal was major cracks in the concrete lining (see **Photo 5.8** below). Because of the cracks; this has resulted in the significant loss of irrigation water in the A branch canal system.

Photo 5.8: Major breaks in the A branch canal linings

The condition of the branch canal is considered to be poor and was given a condition rating of 5. This will require urgent attention because the scheme is losing significant volumes of water through the damaged canal.

Figure 5.3 below indicates the general condition rating of the different segments of the Luvuvhu Irrigation Scheme canal system. This will form the basis for prioritisation of the canal segments for maintenance including any canal section renewals that will be required.

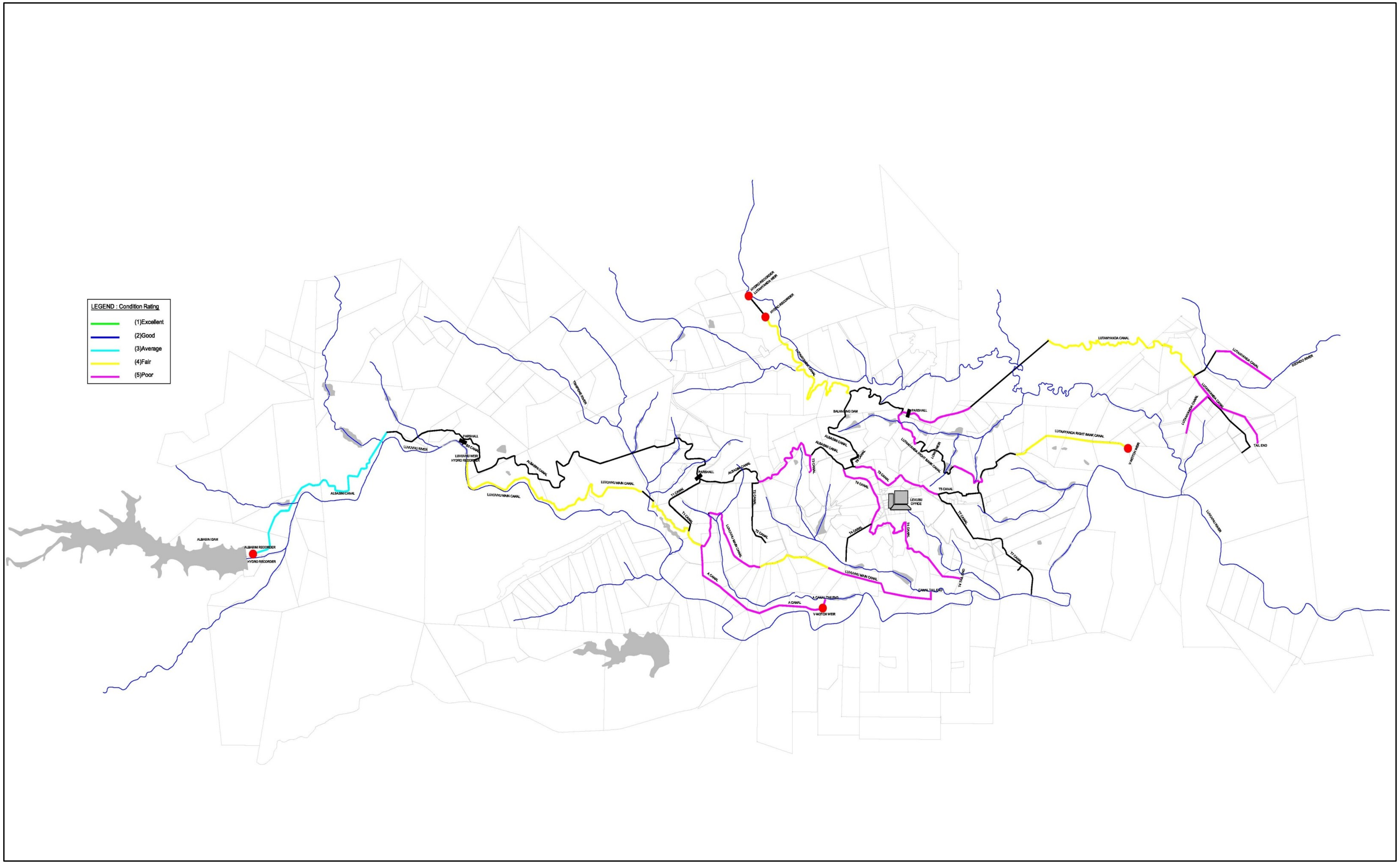

Figure 5.1: General Condition Rating of the surveyed canal segments

6 SCHEME OPERATIONS AND OPERATING PROCEDURES

6.1 General scheme options

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

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

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

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

The Luvuvhu Government Water Scheme is currently dependent on the run-of-river diversion from the Luvuvhu River downstream of the Albasini Dam and the Lutanyanda River with diversions from the weirs at the two rivers into the Luvuvhu canal and the Lutanyanda canals. Therefore only a fraction of the scheduled allocation that can be supplied from these two sources is supplied by the scheme. The remainder of the scheduled allocation which is 871 ha does not benefit from the Albasini Government Water Scheme because the available water from Albasini Dam cannot supply the irrigation water demands.

Since the Luvuvhu Government Water Scheme became operational, the irrigation scheme has experienced significant water restrictions, where the scheduled quotas have not been delivered to the farmers even to the areas currently being supplied from Lutanyanda and Luvuvhu rivers.

The irrigation water from the Lutanyanda and Luvuvhu River weirs is abstracted at the sluice gates by irrigators according to their water applications provided to the scheme operators during the week based on the restricted number of days per week that the two canals can provide.

The Luvuvhu GWS is owned and operated by the Department of Water Affairs (DWA). Water is only released from the weirs to meet the restricted irrigation water requirements as well as domestic water use, based on the weekly requested demands from users in the scheme area. Any excess water, particularly during the wet periods spills into the river and therefore helps in meeting the compensation requirements for downstream water users. Currently no managed flow releases to supply the ecological water requirements (EWR) of the downstream Luvuvhu and Lutanyanda Rivers are being made.

6.2 Water ordering and delivery procedures

6.2.1 Overview

In order to ensure that the irrigators receive their scheduled quota as and when required, the Luvuvhu GWS operates the irrigation scheme based on "delivery on request" where each water user (irrigator) must submit a written request on a weekly basis and the water is delivered to the abstraction point along the canal system. There are written scheme operating procedures in place. However the scheme operators and irrigators understand the water ordering and delivery procedures as discussed below.

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 as well as their scheduled quota.

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

(3) The management at the Luvuvhu GWS 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 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 does not exceed the hydraulic capacity of the canal system, including the expected canal losses.

(4) The above process is repeated from the branch canals up to the main canal to determine how much water needs to be diverted from the Luvuvhu River weir and the Lutanyanda weir which are downstream of Albasini Dam. This includes the total transmission and evaporation losses required to deliver the requested water.

(5) The requested water, including the transmission losses are then reconciled with the available water at the weir and the volume of water required to be released from the weir. Water is then diverted into the Luvuvhu and Lutanyanda main canals in time to meet the requested water for the following week.

(6) Because of water restrictions the scheme provides the irrigators for 72 hours only during the week instead of the normal 120 hours weekly supply. That is water is released at the sluice gates on Tuesday and is closed on Friday.

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

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

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

(10) Based on the availability and priorities, decisions are then made to release from Lutanyanda and Levuvhu weirs into the main canals based on the calculated volumes for the week to be delivered continuously during the week. The cycle commences on the Tuesday morning and ends on the Friday evenings, when the cycle is completed. This is because of restrictions.

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

The above water ordering and delivery procedures have not been formally documented. This is required as a service level agreement (SLA) between the irrigators and the scheme operators. This will enable all irrigators as well as the water control officers to be aware of the responsibilities of each stakeholder in ensuring effective and efficient delivery of water to the consumers. This will be useful particularly for new irrigators and WCOs to understand the process.

The water is supplied through pressure control sluice gates to the irrigators with measurements taken as part of the monitoring to ensure that each irrigator does not exceed his/her schedule quota. Approximately 138 of the individual offtakes are installed with sluice gates and some have Parshall flumes to measure the flows.

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

Due to the pressure variance in the canal system 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

6.3.1 General Procedure

There have been frequent water shortages since the construction of the Albasini Dam because the historic yield of the dam is 5 million m^3 and 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 Albasini Dam that can be supplied to irrigators is reconciled with the scheduled quota. Where it is envisaged that less water is available, as has been the case for the past several years, no irrigation water is diverted into the Albasini main canal to supply irrigators.

(ii) However if the dam level is such that a portion of the scheduled quota can be supplied then the allocations to irrigators are reduced equitably regardless of the types of crops irrigated.

(iii) Priority is given to supply domestic water users in the event of water shortages. This has been the case from the Albasini Dam which is only supplying domestic water users.

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

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

6.4 Water trading - Temporary water transfers

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

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

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

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

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

Currently the GWS 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 Setting of the irrigation pricing

6.5.1.1 Water Use Charge

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 the case with Luvuvhu Government Water Scheme. The irrigators pay two sets of charges. The first charge is known as the water use charge which is the cost to recover the capital investment which was used by DWA to develop the irrigation canals as well as Albasini Dam.

The Water User Charge for the Luvuvhu Irrigation Scheme for the 2009/10 financial year was 22.87 cents per m^3. Based on the schedule quota of 8 400 m^3/ha/a, irrigators are therefore paying R 1 875.34 per hectare per annum.

6.5.1.2 Operation and Maintenance Charge

The second charge is the cost for the operation and maintenance based on the annual budgeted operation and maintenance costs of the scheme. This charge is not applicable to the Luvuvhu Irrigation Scheme as it is a government water scheme and the O&M charge is included in the water use charge discussed in the previous section.

6.5.1.3 Water Resource Management Charge

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 Luvuvhu and Letaba Water Management Area in which the Luvuvhu Irrigation Scheme is located for the 2009/10 financial year, is 1.57 c per m^3 or R 128.74 per ha/a, while the WRM charge for domestic and industrial users is 2.65 c/m^3 which is different from irrigation agriculture.

6.5.2 Collection of the irrigation water use charges

The Luvuvhu GWS scheme operators, which is the DWA Infrastructure Branch is responsible for collection of the water use charges on behalf of the Department of Water Affairs (DWA) which includes the money which it uses to pay for the operation and maintenance of the irrigation scheme. Irrigators, domestic and industrial users are also billed directly by DWA for the WRM charges.

7 BEST MANAGEMENT PRACTICES FOR WATER MANAGEMENT IN LUVUVHU IRRIGATION SCHEME

7.1 OVERVIEW

Before determining the irrigation water use efficiency of the Luvuvhu Government Water Scheme, it was important to assess the expected seepage and evaporation losses if the irrigation scheme infrastructure is well maintained while taking into account the useful life of the canal system infrastructure. This establishes the Best Management Practice (BMP) for irrigation water management in the government water scheme.

This is discussed in the following sections of this chapter.

7.2 Water Use Efficient Best Management Practice for irrigation water management

7.2.1 Overview

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

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

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

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

7.2.2 Best Management Practice for seepage losses

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 Luvuvhu Government Water Scheme. A perfect canal lining which is well maintained reduces significantly the amount of seepage through the lining although the canal lining deteriorates with time and becomes ineffective in controlling the seepage.

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

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

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

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

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

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

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

Where

T = top width of the channel at the water surface, (m);

Y = flow depth of water (m); and

G = 0.915965594, known as Catalan's Constant.

The seepage loss per unit length was then calculated using the hydraulic conductivity of the concrete lining; the canal geometry and the seepage rate based on the wetted perimeter. However because there was not sufficient information on the canal geometry, the seepage losses were estimated based on some of the measurements taken during the site visit. The expected seepage losses for the different canal sections in the Luvuvhu Government Water Scheme are indicated in **Table 7.1** below.

As illustrated in **Table 7.1** below, the minimum seepage losses expected in the Luvuvhu GWS canal system is 1.53 million m^3/a if the Albasini Dam main canal is included. This is the amount of seepage losses required in order to deliver the scheduled allocation of 15.58 million m^3/a. As a percentage of the scheduled allocation, the minimum seepage losses that should be provided as additional to the scheduled allocation are 9.8% of the scheduled allocation.

Table 7.1: Expected seepage losses in the Luvuvhu River canal system

Item No	Canal Name	Canal capacity (m^3/h)	Seepage Loss, Qs*(m^3/d per unit length)	Canal Length (km)	Expected Seepage losses (million m^3/a)
1	Albasini Main Canal	4 300.00	0.08489	24.60	0.70
	T1 Branch canal	1 000.00	0.03302	2.20	0.02
	T2 Branch canal	400.00	0.03302	3.00	0.03
	T3 Branch canal	300.00	0.03302	0.60	0.01
	T4 Branch canal	600.00	0.03302	7.10	0.08
	T5 Branch canal	1 050.00	0.03302	4.00	0.04
	T6 Branch canal	300.00	0.03302	0.70	0.01
	T7 Branch canal	500.00	0.03302	2.60	0.03
				44.80	0.93
2	Luvuvhu Main Canal	1 600.00	0.04646	15.20	0.24

Item No	Canal Name	Canal capacity (m^3/h)	Seepage Loss, Qs*(m^3/d per unit length)	Canal Length (km)	Expected Seepage losses (million m^3/a)
	Luvuvhu 1 Branch Canal	500.00	0.03302	4.00	0.04
				19.20	0.28
3	Lutanyanda Main Canal	2 500.00	0.04646	6.74	0.11
	Lutanyanda Left Bank Canal	1 200.00	0.03302	9.02	0.10
	Lutanyanda Left Bank A canal	300.00	0.03302	1.76	0.02
	Lutanyanda Left Bank B Canal		0.03302	1.08	0.01
	Lutanyanda Right Bank Canal	1 500.00	0.03302	7.57	0.08
				26.17	0.32
	Total Seepage Losses Luvuvhu Canal			90.17	1.53

* Seepage rate estimated where canal geometry was not available

The seepage losses of the Albasini Dam main canal were excluded because it is not operational. Therefore the expected seepage losses of the Lutanyanda and Luvuvhu canals is 0.6 million m^3/a, to deliver the scheduled allocation from the two canals of 7.82 million m^3/a. As a percentage of the scheduled allocation, the minimum seepage losses that should be provided as additional to the scheduled allocation are 7.7% of the scheduled allocation.

When the above percentage seepage losses are compared with the best management practices, canal seepage would be approximately 5% of the input volume (Streutker, 1981 and Muller, 1984). Other factors that have an effect on seepage losses are, *inter alia*, soil characteristics, water depth in the canal, flow speed, soil capillary tension, amount of sediment, etc.

The minimum seepage losses as calculated above have been compared with the water losses of each canal system in the Luvuvhu 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 unavoidable water losses.

7.2.3 Best Management Practices for evaporation losses

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 S-pan evaporation figure for the 1970 - 1979 hydrological record from the station at the Albasini Dam. The MAE in the Luvuvhu GWS taken as the measurement taken at the evaporation station at Luvuvhu was 1 868 mm per year.

Table 7.2 below provides the estimated evaporation losses for the different canals based on the average width of the canal and the total length of the canals.

The total annual evaporation from the irrigation canal surface area was determined to be 0.27 million m^3/a. This was taken as the average over the seven years records. Based on the calculated evaporation losses, the evaporation losses as a percentage of the total inflows was determined to be 1.7%. This is much higher than the estimated evaporation losses at approximately 0.3% of total inflow volume (Reid, Davidson and Kotze; 1986).

Table 7.2: Expected evaporation losses in the Luvuvhu Government Water Scheme

Item No	Canal Name	Canal capacity (m^3/h)	Average Surface width	Canal Length (m)	Pan evaporation	Expected Evaporation losses
			m		m	(million m^3/a)
1	Albasini Main Canal	4 300.00	3.7500	24 600.00	1.63	0.1500
	T1 Branch canal	1 000.00	1.3500	2 200.00	1.63	0.0048
	T2 Branch canal	400.00	1.2500	3 000.00	1.63	0.0061
	T3 Branch canal	300.00	1.5000	600.00	1.63	0.0015
	T4 Branch canal	600.00	0.5000	7 100.00	1.63	0.0058
	T5 Branch canal	1 050.00	1.5000	4 000.00	1.63	0.0098
	T6 Branch canal	300.00	0.5000	700.00	1.63	0.0006
	T7 Branch canal	500.00	0.5000	2 600.00	1.63	0.0021
	Evaporation losses					0.18

Item No	Canal Name	Canal capacity (m^3/h)	Average Surface width	Canal Length (m)	Pan evaporation	Expected Evaporation losses
			m		m	(million m^3/a)
2	Luvuvhu Main Canal	1 600.00	1.5000	15 200.00	1.63	0.0371
	Luvuvhu 1 Branch Canal	500.00	0.5000	4 000.00	1.63	0.0033
						0.04
3	Lutanyanda Main Canal	2 500.00	1.3500	6 740.00	1.63	0.0148
	Lutanyanda Left Bank Canal	1 200.00	1.2500	9 020.00	1.63	0.0183
	Lutanyanda Left Bank A canal	300.00	0.5000	1 760.00	1.63	0.0014
	Lutanyanda Left Bank B Canal		0.5000	1 080.00	1.63	0.0009
	Lutanyanda Right Bank Canal	1 500.00	1.2500	7 570.00	1.63	0.0154
						0.05
	Evaporation losses			90 170.00		0.27

Therefore the BMP evaporation loss in the Luvuvhu Irrigation Scheme area that was used was 1.7% 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.

8 LUVUVHU GOVERNMENT WATER SCHEME - WATER BALANCE ASSESSMENT

8.1 Overview

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

- how much water is diverted 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 budget to account for any inefficiency in irrigation water management in the scheme. The Luvuvhu GWS uses the Water Administration System (WAS) to account for the water used by the scheme and the water use efficiency accounting report (WUEAR) for reporting on matching irrigation supply and demand (MISD).

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

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

The irrigation water budget for the Luvuvhu Irrigation Scheme was intended to be undertaken at two levels. The first level was to determine the overall water budget, with a view to determine the extent of water losses at an irrigation scheme level.

The second level, which could not be conducted because of lack of information at sub-scheme level, was intended to determine the water balance for two sub-schemes of the Luvuvhu GWS, namely the Luvuvhu Main Canal and Lutanyanda main canal. This is one of the recommendations that in future water use efficiency accounting reporting should be conducted at sub-scheme level.

8.2 Quality and integrity of the available information

8.2.1 Sources of information

It is important to note the available records from the WUEARs that were used to conduct the water budget for the Luvuvhu irrigation scheme are for the period from 2001/02 water year to the 2011/12 water year. There were sufficient records at scheme level to carry out an assessment of the water use and to determine the water balance during the wet periods as well as during the dry periods as discussed in the following sections.

There was a need for long period of records in order to take into account the drought periods when water restrictions were imposed as well as wet periods in order to review whether there have been any significant changes in the irrigation scheme water use efficiency. This has also assisted in determining a longer term average BMP based on dry years and wet years.

Another source of information for the volume of water diverted from the dam was from the DWA, hydrological branch. This was used to compare with the inflows into the Luvuvhu irrigation scheme.

8.2.2 Integrity of the available data and information

The data and information used to date to carry out the water budgets for the Luvuvhu irrigation scheme was from the available WUEARs prepared by the scheme operators and submitted to the DWA Directorate of Water Use Efficiency. The data used to prepare the WUEARs were based on measured data of the inflows into the canals; measured data on the outlet of the weir downstream of Albasini Dam at the beginning of the irrigation cycle; data from the water applications and supplied at the sluices of each irrigator. All other information was estimated in the WUEAR and therefore not necessarily used.

It would appear that no canal tail ends are being measured, however this needs to be investigated. There may also have been canal tail ends which end at the irrigator's dam which would have been measured at the Parshall for the water delivered to the irrigator through the sluice.

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

There were gaps in yearly records from the WUEARs. In order to evaluate the full year's records a process of patching using average monthly records for the year was conducted This has resulted in patching some of the records to determine the total annual inflow and outflow records in some of the years.

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. These were used to estimate the seepage and deep percolation of irrigation water.

8.3.2 Determination of the water losses

An irrigation water balance was prepared for the Luvuvhu Government Water Scheme. The water balance assessment was based on information from the WUEARs, where records of inflows and water applications were provided as well as the inflow records from the hydro section. The records of inflows which consist of all the sources of water supply to the Luvuvhu Irrigation Scheme were provided on a weekly basis. These flows were converted to monthly records.

The water demand consists of all the water that was order and delivered by the scheme operators at the farm turnouts as well as for other uses who are provided from the canals.

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

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

8.4 Overall scheme level Water Balance Assessment - Luvuvhu Irrigation Scheme

8.4.1 Overview

The Luvuvhu irrigation scheme was analysed on the basis that although it comprises three irrigation sub-schemes, namely the Albasini Dam canal, the Luvuvhu weir canal system and the Lutanyanda canal system, the scheme level water balance analysis was the only one which could be carried out.

The Albasini main canal system is excluded in the water balance assessment because it has not been in operation for a very long time. This has been due to the consistently low dam level. The Albasini Dam has a very small catchment area and with the development upstream, this has limited the run-off into the dam. As a result the Albasini Dam main canal has not been operational since 2005.

Therefore the findings of the scheme level water balance assessment is for the Luvuvhu and Lutanyanda canal system which are discussed in the following section.

8.4.2 Diversions into the Luvuvhu scheme

There are two areas where water is diverted into the Luvuvhu Irrigation Scheme canal at present. There is the diversion at the Luvuvhu River weir downstream of the Albasini Dam. The irrigation water is diverted into the Luvuvhu main canal which is located below the Albasini main canal.

The second source of irrigation water is Lutanyanda weir which is located above the Albasini Dam main canal. Irrigation water is diverted to supply the irrigators on the left bank and right bank of the Lutanyanda River.

There are flow measurements taken immediately downstream of the two weirs where there are flow recorders to measure the flow into the two main canals. The monthly flows diverted into the Luvuvhu and Lutanyanda canals were used to determine the total inflow into the Luvuvhu irrigation scheme canals at present.

There is also another source of irrigation water. Because Albasini Dam cannot supply irrigators, the irrigators who were supplied from the Albasini main canal are currently dependent on groundwater. These are private boreholes and there is however no records of the extent of groundwater usage for irrigation. It would appear that there is significant groundwater being used for irrigation in the Luvuvhu Government Water Scheme.

No other inflows take place in the scheme area. Individual groundwater abstraction data was not taken into account as this was not available.

The monthly flow records of the inflows into the main canal were taken and used to determine the total annual water diverted into the Luvuvhu Government Scheme canal system. The records were aggregated into monthly records. Monthly records from 2001/02 water year to the 2011/12 water year were generated as illustrated in **Table 8.1** below.

The total average annual diversion into the Luvuvhu Scheme for the 11 years of records, was determined to be 6.7 million m^3/a. A further analysis of the diversions into the Luvuvhu scheme indicated that before the drought of 2005/06, the average annual diversion was 11.08 million m^3/a. This reduced to 4.24 million m^3/a, from 2005/06 to the 2011/12 water year.

The water allocation for 1 854 ha of enlisted areas for irrigation is 15.58 million m^3/a (excluding water losses). The scheduled allocation without the Albasini Dam is 831.5 ha at 8 400 m^3/ha or 7.8 million m^3/a. The high diversion is based on matching the demand for irrigation water use and domestic use taking into account the water losses required to deliver the water demand.

No data was available for the monthly rainfall as well as for the groundwater abstraction records for the Luvuvhu Irrigation Scheme area for the same period. Therefore the precipitation and groundwater records were not included as an input into the water balance.

The balancing dam in the Luvuvhu irrigation scheme, is dependent on the Albasini dam and is therefore currently not in operation. Therefore there are no net inflows or outflows to include from the balancing dam.

8.4.3 Water Demands from Luvuvhu scheme

The supply to individual water users is measured (or rather administered) through the head and hence the variable water pressure at different adjustable sluice gates at each of the farm turnout that has an allocation from this section on the scheme. The scheme operators measure the head and the resultant pressure is then related to a specific volume of water (e.g. 30 m^3/h, 50 m^3/h, 100 m^3/h, 150 m^3/h and 200 m^3/h). The sluices are adjusted by hand in increments based on the irrigation application for the week.

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

This was taken as the crop evapo-transpiration (ET). The monthly records of water deliveries to other water users namely for household consumption was included in the water demand from the canal system.

Table 8.1: Luvuvhu Irrigation Scheme - Water Balance

		INFLOWS					DEMANDS								GROSS WATER LOSSES			NON BENEFICIAL WATER LOSSES			BENEFICIAL WATER LOSSES			UTILISATION
WATER YEAR	MONTH	Latonyanda & Luvuvhu weirs	Other Supplements	Balancing Dam	Precipitation	Total inflows	Irrigation water application	Households/Stock Consumption	Industrial	Municipality	Government	Free Water	Other Canals	Total Outflows	Total water losses	% of inflow	Water Use Index	Evaporation	Seepage	Unavoidable water losses	Canal End Point	Seepage & Leakage	% avoidable water losses	% of scheduled volume
2001/02																								
	April	240.00				240.00	83.00			89.00				172.00	68.00	28.3%	1.40	8.64	23.54	32.18		35.82	14.9%	
	May	719.00				719.00	262.00			86.00				348.00	371.00	51.6%	2.07	25.88	70.54	96.42		274.58	38.2%	
	June	968.00				968.00	428.00			88.00				516.00	452.00	46.7%	1.88	34.85	94.96	129.81		322.19	33.3%	
	July	1 288.00				1 288.00	520.00							520.00	768.00	59.6%	2.48	46.37	126.36	172.73		595.27	46.2%	
	August	986.00				986.00	430.00			-				430.00	556.00	56.4%	2.29	35.50	96.73	132.23		423.77	43.0%	
	September	1 158.00				1 158.00	528.00							528.00	630.00	54.4%	2.19	41.69	113.60	155.29		474.71	41.0%	
	October	891.00				891.00	404.00							404.00	487.00	54.7%	2.21	32.08	87.41	119.49		367.51	41.2%	
	November	664.00				664.00	292.00							292.00	372.00	56.0%	2.27	23.90	65.14	89.04		282.96	42.6%	
	December	0				-	0							-	-	#DIV/0!	#DIV/0!	-	-	-		-	#DIV/0!	
	January	790.00				790.00	326.00							326.00	464.00	58.7%	2.42	28.44	77.50	105.94		358.06	45.3%	
	February	668.00				668.00	284.00							284.00	384.00	57.5%	2.35	24.05	65.53	89.58		294.42	44.1%	
	March	1 634.00				1 634.00	650.00							650.00	984.00	60.2%	2.51	58.82	160.30	219.13		764.87	46.8%	
Sub-total		10 006.00	-	-	-	10 006.00	4 207.00	-	-	263.00	-	-	-	4 470.00	5 536.00	55.3%	2.24	360.22	981.63	1 341.84	-	4 194.16	41.9%	0%
2002/03																								
	April	1 053.00				1 053.00	415.00			112.00				527.00	526.00	50.0%	2.00	18.37	103.30	121.68		404.32	38.4%	
	May	1 408.00				1 408.00	603.00			96.00				699.00	709.00	50.4%	2.01	24.57	138.13	162.70		546.30	38.8%	
	June	882.00				882.00	301.00			97.00				398.00	484.00	54.9%	2.22	15.39	86.53	101.92		382.08	43.3%	
	July	1 265.00				1 265.00	586.00							586.00	679.00	53.7%	2.16	22.07	124.10	146.17		532.83	42.1%	
	August	1 279.00				1 279.00	578.00							578.00	701.00	54.8%	2.21	22.32	125.47	147.79		553.21	43.3%	
	September	1 573.00				1 573.00	751.00							751.00	822.00	52.3%	2.09	27.45	154.32	181.76		640.24	40.7%	
	October	1 026.00				1 026.00	481.00							481.00	545.00	53.1%	2.13	17.90	100.65	118.56		426.44	41.6%	
	November	592.00				592.00	281.00							281.00	311.00	52.5%	2.11	10.33	58.08	68.41		242.59	41.0%	
	December	1 804.00				1 804.00	838.00							838.00	966.00	53.5%	2.15	31.48	176.98	208.45		757.55	42.0%	
	January	689.00				689.00	291.00							291.00	398.00	57.8%	2.37	12.02	67.59	79.61		318.39	46.2%	
	February	1 172.00				1 172.00	572.00							572.00	600.00	51.2%	2.05	20.45	114.98	135.43		464.57	39.6%	
	March	883.00				883.00	347.00							347.00	536.00	60.7%	2.54	15.41	86.63	102.03		433.97	49.1%	
Sub-total		13 626.00	-	-	-	13 626.00	6 044.00	-	-	305.00	-	-	-	6 349.00	7 277.00	53.4%	2.15	237.74	1 336.76	1 574.50	-	5 702.50	41.9%	0%
2003/04																								
	April	1 647.00				1 647.00	664.00			32.00				696.00	951.00	57.7%	2.37	28.74	161.58	190.31		760.69	46.2%	
	May	1 840.00				1 840.00	666.00			62.00				728.00	1 112.00	60.4%	2.53	32.10	180.51	212.61		899.39	48.9%	
	June	1 268.00				1 268.00	378.00							378.00	890.00	70.2%	3.35	22.12	124.40	146.52		743.48	58.6%	
	July	572.00				572.00	247.00							247.00	325.00	56.8%	2.32	9.98	56.12	66.10		258.90	45.3%	
	August	1 251.00				1 251.00	502.00							502.00	749.00	59.9%	2.49	21.83	122.73	144.55		604.45	48.3%	
	September	797.00				797.00	357.00							357.00	440.00	55.2%	2.23	13.91	78.19	92.09		347.91	43.7%	
	October	1 043.00				1 043.00	354.00							354.00	689.00	66.1%	2.95	18.20	102.32	120.52		568.48	54.5%	
	November	632.00				632.00	222.00							222.00	410.00	64.9%	2.85	11.03	62.00	73.03		336.97	53.3%	
	December	1 057.00				1 057.00	313.00							313.00	744.00	70.4%	3.38	18.44	103.70	122.14		621.86	58.8%	
	January	447.00				447.00	153.00							153.00	294.00	65.8%	2.92	7.80	43.85	51.65		242.35	54.2%	
	February	242.00				242.00	95.00							95.00	147.00	60.7%	2.55	4.22	23.74	27.96		119.04	49.2%	
	March	-				-	-							-	-	#DIV/0!	#DIV/0!	-	-	-		-	#DIV/0!	
Sub-total		10 796.00	-	-	-	10 796.00	3 951.00	-	-	94.00	-	-	-	4 045.00	6 751.00	62.5%	2.67	188.37	1 059.13	1 247.49	-	5 503.51	51.0%	0%
2004/05																								
	April	-				-	-							-	-	#DIV/0!	#DIV/0!	-	-	-		-	#DIV/0!	
	May	1 184.00				1 184.00	332.00							332.00	852.00	72.0%	3.57	20.66	116.15	136.81		715.19	60.4%	
	June	965.00				965.00	316.00							316.00	649.00	67.3%	3.05	16.84	94.67	111.51		537.49	55.7%	
	July	1 135.00				1 135.00	357.00							357.00	778.00	68.5%	3.18	19.80	111.35	131.15		646.85	57.0%	
	August	738.00				738.00	243.00							243.00	495.00	67.1%	3.04	12.88	72.40	85.28		409.72	55.5%	
	September	1 167.00				1 167.00	420.00							420.00	747.00	64.0%	2.78	20.36	114.49	134.85		612.15	52.5%	
	October	1 295.00				1 295.00	440.00							440.00	855.00	66.0%	2.94	22.59	127.04	149.64		705.36	54.5%	
	November	1 251.00				1 251.00	388.00							388.00	863.00	69.0%	3.22	21.83	122.73	144.55		718.45	57.4%	
	December	457.00				457.00	149.00							149.00	308.00	67.4%	3.07	7.97	44.83	52.81		255.19	55.8%	
	January	649.00				649.00	174.00							174.00	475.00	73.2%	3.73	11.32	63.67	74.99		400.01	61.6%	
	February	643.00				643.00	119.00							119.00	524.00	81.5%	5.40	11.22	63.08	74.30		449.70	69.9%	
	March	418.00				418.00	84.00							84.00	334.00	79.9%	4.98	7.29	41.01	48.30		285.70	68.3%	
Sub-total		9 902.00	-	-	-	9 902.00	3 022.00	-	-	-	-	-	-	3 022.00	6 880.00	69.5%	3.28	172.77	971.42	1 144.19	-	5 735.81	57.9%	0%
2005/06																								
	April	238.00				238.00	73.00							73.00	165.00	69.3%	3.26	4.15	23.35	27.50		137.50	57.8%	
	May	204.00				204.00	90.00							90.00	114.00	55.9%	2.27	3.56	20.01	23.57		90.43	44.3%	
	June	234.00				234.00	98.00							98.00	136.00	58.1%	2.39	4.08	22.96	27.04		108.96	46.6%	
	July	237.00				237.00	94.00							94.00	143.00	60.3%	2.52	4.14	23.25	27.39		115.61	48.8%	
	August	691.00				691.00	212.00							212.00	479.00	69.3%	3.26	12.06	67.79	79.85		399.15	57.8%	
	September	898.00				898.00	249.00							249.00	649.00	72.3%	3.61	15.67	88.10	103.77		545.23	60.7%	
	October	943.00				943.00	306.00							306.00	637.00	67.6%	3.08	16.45	92.51	108.97		528.03	56.0%	
	November	75.00				75.00	31.00							31.00	44.00	58.7%	2.42	1.31	7.36	8.67		35.33	47.1%	
	December	30.00				30.00	17.00							17.00	13.00	43.3%	1.76	0.52	2.94	3.47		9.53	31.8%	
	January					-								-	-	#DIV/0!	#DIV/0!	-	-	-		-	#DIV/0!	
	February	29.00				29.00	11.00							11.00	18.00	62.1%	2.64	0.51	2.85	3.35		14.65	50.5%	
	March	11.00				11.00	3.00							3.00	8.00	72.7%	3.67	0.19	1.08	1.27		6.73	61.2%	
Sub-total		3 590.00	-	-	-	3 590.00	1 184.00	-	-	-	-	-	-	1 184.00	2 406.00	67.0%	3.03	62.64	352.19	414.83	-	1 991.17	55.5%	0%
2006/07																								
	April	-				-	-							-	-	#DIV/0!	#DIV/0!	-	-	-		-	#DIV/0!	
	May	84.00				84.00	28.00							28.00	56.00	66.7%	3.00	1.47	8.24	9.71		46.29	55.1%	
	June	342.00				342.00	106.00							106.00	236.00	69.0%	3.23	5.97	33.55	39.52		196.48	57.5%	
	July	641.00				641.00	177.00							177.00	464.00	72.4%	3.62	11.18	62.88	74.07		389.93	60.8%	
	August	723.00				723.00	271.00							271.00	452.00	62.5%	2.67	12.61	70.93	83.54		368.46	51.0%	
	September	896.00				896.00	394.00							394.00	502.00	56.0%	2.27	15.63	87.90	103.53		398.47	44.5%	
	October	1 053.00				1 053.00	451.00							451.00	602.00	57.2%	2.33	18.37	103.30	121.68		480.32	45.6%	
	November	563.00				563.00	240.00							240.00	323.00	57.4%	2.35	9.82	55.23	65.06		257.94	45.8%	
	December	788.00				788.00	303.00							303.00	485.00	61.5%	2.60	13.75	77.31	91.05		393.95	50.0%	
	January	667.00				667.00	296.00							296.00	371.00	55.6%	2.25	11.64	65.44	77.07		293.93	44.1%	
	February	399.00				399.00	155.00							155.00	244.00	61.2%	2.57	6.96	39.14	46.11		197.89	49.6%	
	March	328.00				328.00	119.00							119.00	209.00	63.7%	2.76	5.72	32.18	37.90		171.10	52.2%	
Sub-total		6 484.00	-	-	-	6 484.00	2 540.00	-	-	-	-	-	-	2 540.00	3 944.00	60.8%	2.55	113.13	636.10	749.24	-	3 194.76	49.3%	0%
2007/08																								
	April	-				-	-							-	-	#DIV/0!	#DIV/0!	-	-	-		-	#DIV/0!	
	May	498.00				498.00	243.00							243.00	255.00	51.2%	2.05	8.69	48.86	57.54		197.46	39.6%	
	June	393.00				393.00	190.00							190.00	203.00	51.7%	2.07	6.86	38.55	45.41		157.59	40.1%	
	July	448.00				448.00	222.00							222.00	226.00	50.4%	2.02	7.82	43.95	51.77		174.23	38.9%	
	August	489.00				489.00	298.00							298.00	191.00	39.1%	1.64	8.53	47.97	56.50		134.50	27.5%	
	September	782.00				782.00	418.00							418.00	364.00	46.5%	1.87	13.64	76.72	90.36		273.64	35.0%	
	October	77.00				77.00	53.00							53.00	24.00	31.2%	1.45	1.34	7.55	8.90		15.10	19.6%	
	November	353.00				353.00	201.00							201.00	152.00	43.1%	1.76	6.16	34.63	40.79		111.21	31.5%	

Table 8.2: Luvuvhu Irrigation Scheme - Water Balance (continued)

		INFLOWS					DEMANDS								GROSS WATER LOSSES			NON BENEFICIAL WATER LOSSES			BENEFICIAL WATER LOSSES			UTILISATION
WATER YEAR	MONTH	Latonyanda & Luvuvhu weirs	Other Supplements	Balancing Dam	Precipitation	Total inflows	Irrigation water application	Households/Stock Consumption	Industrial	Municipality	Government	Free Water	Other Canals	Total Outflows	Total water losses	% of inflow	Water Use Index	Evaporation	Seepage	Unavoidable water losses	Canal End Point	Seepage & Leakage	% avoidable water losses	% of scheduled volume
	December	209.00				209.00	109.00							109.00	100.00	47.8%	1.92	3.65	20.50	24.15		75.85	36.3%	
	January					-								-	-	#DIV/0!	#DIV/0!	-	-	-		-	#DIV/0!	
	February	345.00				345.00	116.00							116.00	229.00	66.4%	2.97	6.02	33.85	39.87		189.13	54.8%	
	March	77.00				77.00	39.00							39.00	38.00	49.4%	1.97	1.34	7.55	8.90		29.10	37.8%	
Sub-total		3 671.00	-	-	-	3 671.00	1 889.00	-	-	-	-	-	-	1 889.00	1 782.00	48.5%	1.94	64.05	360.14	424.19	-	1 357.81	37.0%	0%
2008/09																								
	April	264.00				264.00	202.00							202.00	62.00	23.5%	1.31	4.61	25.90	30.51		31.49	11.9%	
	May	479.00				479.00	239.00							239.00	240.00	50.1%	2.00	8.36	46.99	55.35		184.65	38.5%	
	June	449.00				449.00	232.00							232.00	217.00	48.3%	1.94	7.83	44.05	51.88		165.12	36.8%	
	July	364.00				364.00	197.00							197.00	167.00	45.9%	1.85	6.35	35.71	42.06		124.94	34.3%	
	August	391.00				391.00	212.00							212.00	179.00	45.8%	1.84	6.82	38.36	45.18		133.82	34.2%	
	September	380.00				380.00	255.00							255.00	125.00	32.9%	1.49	6.63	37.28	43.91		81.09	21.3%	
	October	588.00				588.00	314.00							314.00	274.00	46.6%	1.87	10.26	57.69	67.94		206.06	35.0%	
	November	167.00				167.00	92.00							92.00	75.00	44.9%	1.82	2.91	16.38	19.30		55.70	33.4%	
	December	477.00				477.00	209.00							209.00	268.00	56.2%	2.28	8.32	46.80	55.12		212.88	44.6%	
	January	166.00				166.00	82.00							82.00	84.00	50.6%	2.02	2.90	16.29	19.18		64.82	39.0%	
	February	166.00				166.00	68.00							68.00	98.00	59.0%	2.44	2.90	16.29	19.18		78.82	47.5%	
	March	263.00				263.00	115.00							115.00	148.00	56.3%	2.29	4.59	25.80	30.39		117.61	44.7%	
Sub-total		4 154.00	-	-	-	4 154.00	2 217.00	-	-	-	-	-	-	2 217.00	1 937.00	46.6%	1.87	72.48	407.52	480.00	-	1 457.00	35.1%	0%
2009/10																								
	April	286.00				286.00	174.00							174.00	112.00	39.2%	1.64	4.99	28.06	33.05		78.95	27.6%	
	May	482.00				482.00	259.00							259.00	223.00	46.3%	1.86	8.41	47.29	55.70		167.30	34.7%	
	June	355.00				355.00	199.00							199.00	156.00	43.9%	1.78	6.19	34.83	41.02		114.98	32.4%	
	July	384.00				384.00	240.00							240.00	144.00	37.5%	1.60	6.70	37.67	44.37		99.63	25.9%	
	August	520.00				520.00	351.00							351.00	169.00	32.5%	1.48	9.07	51.01	60.09		108.91	20.9%	
	September	471.00				471.00	317.00							317.00	154.00	32.7%	1.49	8.22	46.21	54.42		99.58	21.1%	
	October	507.00				507.00	307.00							307.00	200.00	39.4%	1.65	8.85	49.74	58.58		141.42	27.9%	
	November	416.00				416.00	264.00							264.00	152.00	36.5%	1.58	7.26	40.81	48.07		103.93	25.0%	
	December	169.00				169.00	97.00							97.00	72.00	42.6%	1.74	2.95	16.58	19.53		52.47	31.0%	
	January	318.00				318.00	200.00							200.00	118.00	37.1%	1.59	5.55	31.20	36.75		81.25	25.6%	
	February	334.00				334.00	208.00							208.00	126.00	37.7%	1.61	5.83	32.77	38.59		87.41	26.2%	
	March	291.00				291.00	186.00							186.00	105.00	36.1%	1.56	5.08	28.55	33.63		71.37	24.5%	
Sub-total		4 533.00	-	-	-	4 533.00	2 802.00	-	-	-	-	-	-	2 802.00	1 731.00	38.2%	1.62	79.09	444.70	523.79	-	1 207.21	26.6%	0%
2010/11																								
	April	54.00				54.00	44.00							44.00	10.00	18.5%	1.23	0.94	5.30	6.24		3.76	7.0%	
	May	150.00				150.00	100.00							100.00	50.00	33.3%	1.50	2.62	14.72	17.33		32.67	21.8%	
	June	224.00				224.00	158.00							158.00	66.00	29.5%	1.42	3.91	21.98	25.88		40.12	17.9%	
	July	279.00				279.00	180.00							180.00	99.00	35.5%	1.55	4.87	27.37	32.24		66.76	23.9%	
	August	361.00				361.00	238.00							238.00	123.00	34.1%	1.52	6.30	35.42	41.71		81.29	22.5%	
	September	399.00				399.00	269.00							269.00	130.00	32.6%	1.48	6.96	39.14	46.11		83.89	21.0%	
	October	556.00				556.00	376.00							376.00	180.00	32.4%	1.48	9.70	54.55	64.25		115.75	20.8%	
	November	80.00				80.00	39.00							39.00	41.00	51.3%	2.05	1.40	7.85	9.24		31.76	39.7%	
	December					-								-	-	#DIV/0!	#DIV/0!	-	-	-		-	#DIV/0!	
	January					-								-	-	#DIV/0!	#DIV/0!	-	-	-		-	#DIV/0!	
	February	120.00				120.00	80.00							80.00	40.00	33.3%	1.50	2.09	11.77	13.87		26.13	21.8%	
	March	389.00				389.00	252.00							252.00	137.00	35.2%	1.54	6.79	38.16	44.95		92.05	23.7%	
Sub-total		2 612.00	-	-	-	2 612.00	1 736.00	-	-	-	-	-	-	1 736.00	876.00	33.5%	1.50	45.57	256.25	301.82	-	574.18	22.0%	0%
2011/12																								
	April	243.00				243.00	151.00							151.00	92.00	37.9%	1.61	4.24	23.84	28.08		63.92	26.3%	
	May	354.00				354.00	226.00							226.00	128.00	36.2%	1.57	6.18	34.73	40.91		87.09	24.6%	
	June	402.00				402.00	269.00							269.00	133.00	33.1%	1.49	7.01	39.44	46.45		86.55	21.5%	
	July	414.00				414.00	275.00							275.00	139.00	33.6%	1.51	7.22	40.61	47.84		91.16	22.0%	
	August	475.00				475.00	303.00							303.00	172.00	36.2%	1.57	8.29	46.60	54.89		117.11	24.7%	
	September	391.00				391.00	256.00							256.00	135.00	34.5%	1.53	6.82	38.36	45.18		89.82	23.0%	
	October	587.00				587.00	392.00							392.00	195.00	33.2%	1.50	10.24	57.59	67.83		127.17	21.7%	
	November	488.00				488.00	326.00							326.00	162.00	33.2%	1.50	8.51	47.87	56.39		105.61	21.6%	
	December	337.00				337.00	216.00							216.00	121.00	35.9%	1.56	5.88	33.06	38.94		82.06	24.3%	
	January	401.00				401.00	261.00							261.00	140.00	34.9%	1.54	7.00	39.34	46.34		93.66	23.4%	
	February	309.00				309.00	195.00							195.00	114.00	36.9%	1.58	5.39	30.31	35.71		78.29	25.3%	
	March	238.00				238.00	167.00							167.00	71.00	29.8%	1.43	4.15	23.35	27.50		43.50	18.3%	
Sub-total		4 639.00	-	-	-	4 639.00	3 037.00	-	-	-	-	-	-	3 037.00	1 602.00	34.5%	1.53	80.94	455.10	536.04	-	1 065.96	23.0%	0%

8.4.3.1 Irrigation water demands

The volume of water requested by the irrigators in the Luvuvhu Irrigation Scheme area varies from week to week and from year to year, as does the cropping pattern for each year. There was 11 years of records available on the volume of water supplied for the irrigation water use. This has ranged from 1.18 million m^3/a in 2005/06 water year which was a drought year to 6.04 million m^3/a in 2002/03 which was a wet year.

The average irrigation water demands was 2.97 million m^3/a, for the 11 years of records and 2.2 million m^3/a for the period after the 2005 drought. When compared to the scheduled quota excluding Albasini Dam for canal irrigators this represents that on average approximately 28% of the scheduled area was irrigated over the period. This clearly indicates that there are water restrictions being imposed for irrigation water. The remainder of the scheduled allocation is being supplied by groundwater. However it is not known the extent of the scheduled allocation that is currently supplied from groundwater.

8.4.3.2 Other demands

Besides irrigation water demands, the Luvuvhu Irrigation Scheme used to supply water to the surrounding communities. This was reflected in the WUEARs for the first three of years of records. The average municipal water use was 0.22 million m^3/a.

It is not clear whether the domestic water demand from the irrigation canal infrastructure is still being supplied or not. This needs to be investigated.

8.4.3.3 Delivery to downstream canals

There are no downstream canals which are supplied from the Luvuvhu irrigation scheme canals.

8.4.4 Comparison of monthly diversions with monthly demands

There is some correlation between the monthly diversions in the Luvuvhu irrigation canals with the monthly demands as illustrated in **Figure 8.1** below. The irrigation water supplied is more than the water requested by irrigators and other water users in the scheme as the scheme has tried to match the irrigation supplies with the irrigation demands.

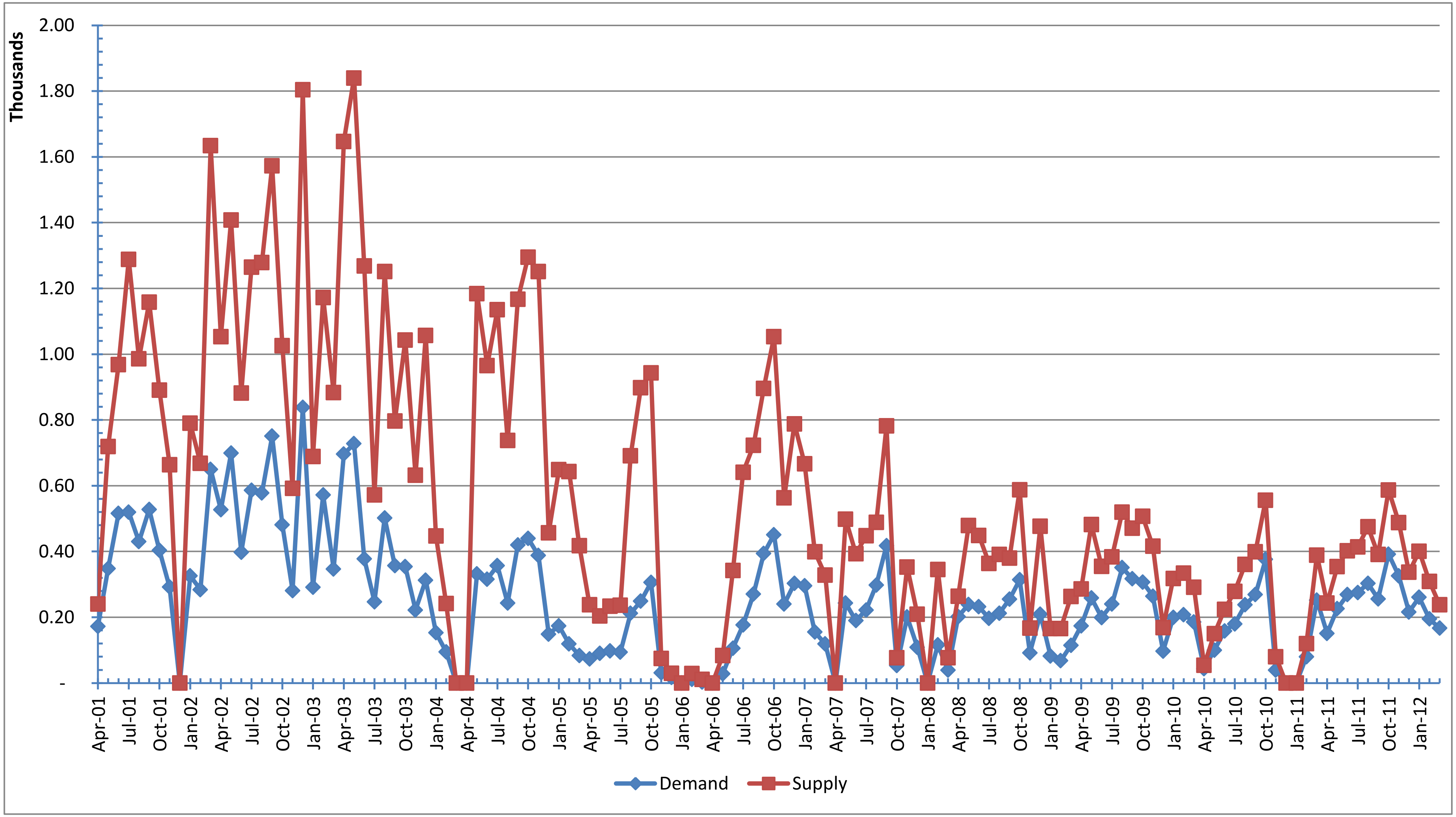

Figure 8.1: Comparison of deliveries and the demands (million m^3)

The difference in matching the supply to the demand is to take into account the losses needed to deliver the water required by the irrigators. There may also be excess water being delivered into the canals of the Luvuvhu government water scheme which is considered as operational spills at the canal tail ends. Without actual measurements of the amount of water flowing back at the canal tail ends the current operational regime may have an impact on the level of conveyance efficiency of the scheme.

As illustrated in **Figure 8.1** above, there is a significant difference in trying to match the irrigation supply to the irrigation water demands, as more water needs to be diverted to meet the irrigated water ordered. It is also important to note that during the drought period from 2005/06 to 2007/08, the water losses were very high with the water losses ranging from 61% to 69% of the total diverted into the scheme. The may be attributed to the water restrictions and the low flows in canals below the minimum threshold.

The 11 year average percentage of water losses in order to meet the irrigation demands and downstream canals was determined to be 53% of the total water diverted. The additional water can be attributed to irrigation water losses owing to seepage, operational losses, leakage losses in the irrigation canals, and evaporative losses from the open irrigation canal infrastructure and spills due to aquatic weeds.

The above average percentage has been benchmarked against best management practice (BMP) in order to determine the avoidable water losses that will need to be reduced in order to only supply the additional water based on the BMP for seepage losses in lined canals and the expected evaporation losses of the Luvuvhu Government Water Scheme.

8.5 Gross Water losses - Luvuvhu Irrigation Scheme section

8.5.1 Overview

Figure 8.2 below provides the monthly average gross water losses including the return flow, over the period.

A review of the monthly figures indicate that the difference between supply and demand is significantly more during the months of April/May as well as during September / October when the percentage additional water is much higher. This may be attributed to the fact that although the demand is lower during this period the amount of water diverted remains high to meet the low demands indicating that there is inconsistence in matching supply to the demand during this period.

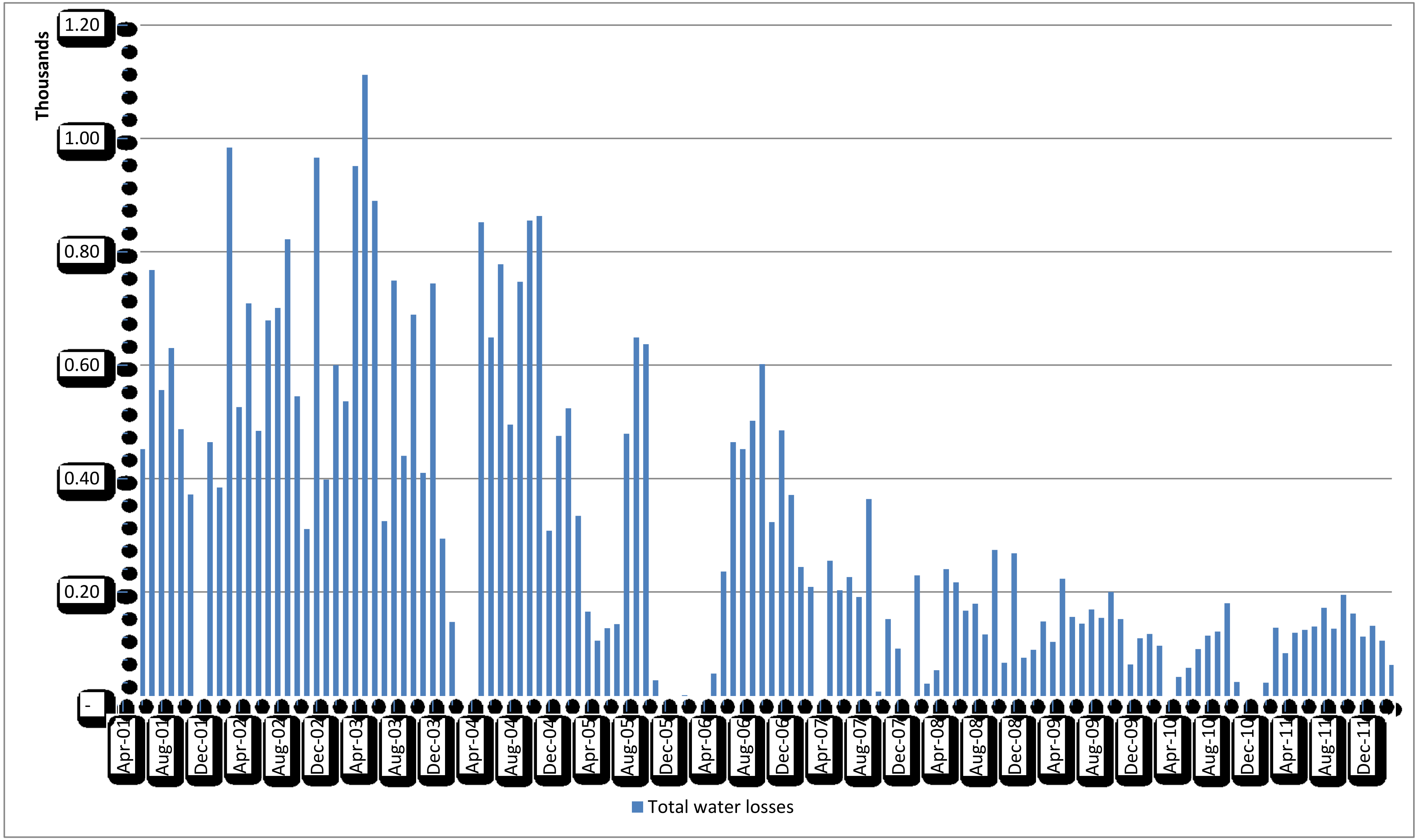

Figure 8.2: Water losses in Luvuvhu Irrigation Scheme area (million m^3)

The other reason may be due to the fact that the evaporation losses during the summer periods of September / October are generally higher than the average used in the BMP for evaporation losses in the Luvuvhu Government Water Scheme.

The water depth in the canals is high and there is potential for overflows because of the aquatic weeds found in the canals. Because of the high water depth 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.

8.5.2 Water losses - Luvuvhu Government Water Scheme

The average estimated water losses for the whole Luvuvhu GWS were calculated to be 54% of the net inflow over the eleven (11) years of records. The water losses are equivalent of 3.6 million m^3/a including any canal tail ends. This is illustrated in **Table 8.3** below.

When compared with the Best Management Practice (BMP) for evaporation losses, and expected seepage losses from lined canal infrastructure which was determined to be 10% (see **Table 8.3** below) of the net inflow into the Luvuvhu GWS, there is potential to reduce the water losses.

8.5.3 Unavoidable water losses

As illustrated in **Table 8.3** below, the minimum seepage losses as calculated in the previous chapter for the Luvuvhu canal system is 0.6 million m^3/a while the evaporation losses was calculated based on the canal surface area and the MAE as 0.09 million m^3/a. The total minimum unavoidable losses that has to be added to the irrigation water requirements or the schedule allocation is 0.69 million m^3/a, or 10% of the total diverted into the Luvuvhu canal system.

Based on the above Best Management Practice (BMP) for evaporation losses and expected seepage losses from lined canal infrastructure, the estimated unavoidable losses for the Luvuvhu irrigation canal is 10% of the net inflow.

Table 8.3: Summary of water losses in the Luvuvhu Government Water Scheme

Description	Unavoidable losses (m^3*10^6)	BMP for operation & distribution (m^3*10^6)	Avoidable losses (m^3*10^6)	Total losses (m^3*10^6)	% of total losses
Seepages	0.6				16.5%
Evaporation	0.09				2.5%
Filling losses		0.67	2.24	2.91	0%
Leakages					81%
Spills					0%
Operational Losses					0%
Over delivery to users					0%
Canal end returns					0%
Total	0.69	0.67	2.24	3.60	
% of total losses	19%	19%	62%	100%	
% of total volume released into system	10%	10%	33%	53%	

8.5.4 Avoidable water losses

8.5.4.1 Total avoidable water losses

The unavoidable losses calculated in the previous were based on the assumption that the condition of the Luvuvhu 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 Luvuvhu 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 Luvuvhu canal system was determined to be 2.91 million m^3/a, or 81% of the total water losses. The avoidable water losses include leakage and operational spills, particularly at canal tail ends.

8.5.4.2 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 17% of the irrigation water losses (Reid, Davidson and Kotze, 1986).

Because of lack of sufficient flow measurement data at present particularly at canal tail ends, it was not possible to disaggregate the avoidable losses into operational losses and leakage losses. However the preliminary estimates that were taken during the site visit of the operational losses at the canal tail end was estimated to be 0.75 million m^3/a (see **Photo 8.1** below). This is approximately 20% of the avoidable water losses. This is much higher than the norm which is a clear indication that there are operational problems in the operation of the Luvuvhu irrigation scheme.

Photo 8.1: Operational spills at the Lutanyanda right bank canal tail end

The operational losses at canal tail ends represent that either not all irrigators are taking up their water orders or more water is being diverted into the canal system than is required which could have been left in the river to meet environmental water requirements. In the Luvuvhu 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.

8.5.4.3 Leakage losses:

The determination of the volume of water that is wasted as a result of leakages is very difficult to calculate and can only really be determined through accurate 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 (see **Photo 8.2** below).

An important factor that has a marked effect on leakages is the water depth in a canal system. The leakage losses which can be avoided is due to the constant movement of water through the bottom and sides of the canal system due to small cracks including abnormally large cracks in the canal infrastructure which can be reduced through canal maintenance. 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.

As expected because of the age of the canal infrastructure and the condition of some sections of the canals as discussed in the previous chapter 4, the leaks due to the poor condition of the canal infrastructure are high. This is estimated to be 2.16 million m^3/a based on the difference between the total avoidable losses and the estimated operational losses.

The leakage losses were estimated to be more than the operational losses which is an indication that the condition of the concrete lined canal in the Luvuvhu Government Water Scheme is very poor. There are abnormally large cracks in the canal system due to a lack of renewal and refurbishment of the irrigation canals.

A review of the condition of the infrastructure (see **Photo 8.2** below) does seem to confirm that there are significant leakage losses due to the major cracks and vegetation growth in the Luvuvhu canal system. Furthermore there are hairline cracks resulting in seepage losses particularly with the changes in the capillary rise and fall due to the start and stop procedure of operating the scheme.

Photo 8.2: Broken section of concrete panels of canal system

8.5.4.4 Aquatic weeds and algae:

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

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

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

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

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

(v) Water logging of long-weirs.

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

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

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

It is likely that the high water losses can be attributed to algae growth in the Luvuvhu irrigation canals which is reducing the hydraulic capacity of the canal system and therefore more water is required to meet the applications.

9 EXISTING WATER MANAGEMENT MEASURES AND PROGRAMMES

9.1 Overview

Chapter 8 indicated that the water losses in the Luvuvhu Government Water Scheme (GWS) 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 Luvuvhu GWS.

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

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

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

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

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

9.2 Existing Water Management Measures

9.2.1 Flow measurements

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

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

The existing flow measurement can provide the overall gross water losses of the three sections of the Luvuvhu Irrigation Scheme. However this cannot provide what the operational losses are at canal tail ends as there are no flow measurements. If there are, then the flow measurements are not being read and included in the WUEARs.

9.2.2 Water ordering policy

The Luvuvhu Irrigation Scheme has a water ordering policy although not formalised which enables only the amount of water applied for plus the estimated water losses to be diverted into the main irrigation canals. The irrigators and other users put their water application for the following week by the Thursday to allow the scheme operators to plan how much water to be released to meet these demands only.

9.2.3 Implementation of water restriction measures

One of the measures that have affected water management of the Luvuvhu Government Water Scheme is the droughts in the area from 2005/06 when the irrigation water requirements were curtailed because of the limited yield of the Albasini Dam. Before 2005/06 water year, the average irrigation water requirements was 4.3 million m^3/a while the total water diverted was 11.08 million m^3/a. The water losses were 6.6 million m^3/a or 60% of the total system input volume for the period.

However after the drought of 2005/06, the average irrigation water requirements have reduced to 2.2 million m^3/a. However the total water diverted into the irrigation scheme averaged 4.2 million m^3/a. The water losses have reduced to 2.04 million m^3/a, or 48% of the total irrigation water diverted for the period. The reduction has been due to the implementation of water restrictions in the Luvuvhu Government Water Scheme.

9.2.4 Water Shortage Contingency Plan

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

(i) Hydrologic forecasting to predict water supply availability;
(ii) Definition of water allocation procedures to be used during drought periods;
(iii) Identification of alternative or supplemental water supplies such as groundwater in the scheme.

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

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

9.2.5 Operation and maintenance of the canal infrastructure

9.2.5.1 Maintenance of the canal system

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

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

9.2.5.2 Penalties for not taking up the requested water

According to the scheme operating rules, when an irrigator orders a certain volume of water and he/she does not take up their full water application, the scheme operators impose a penalty by deducting the full water demanded for the week from the scheduled quota of the irrigator. The irrigators must provide changes to their irrigation water application by a certain timeframe to enable the scheme operators to adjust the supplies to the scheme. Any losses due to changes in demand during this timeframe are to the account of the irrigator.

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

9.3 Impact of existing water management measures

9.3.1 Overview

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

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

10 WATER MANAGEMENT ISSUES AND GOALS

10.1 Overview the management issues

The water balance assessment discussed in the Chapter 8 together with discussions held with scheme operators of the Luvuvhu GWS, has helped to identify several key water management issues. First there are substantial losses taking place in the Luvuvhu Irrigation Scheme, as illustrated by the water balance. There is insufficient data to clearly determine where and how losses are occurring in the irrigation scheme. Currently there are no records as to how much water spills at the canal tail end which may be due to operational issues or due to over-irrigation.

The water balance assessment could also not determine which of the two sub-schemes, i.e. the Luvuvhu canal or the Lutanyanda canal has the highest water losses. There were no flow records into each canal system. This would have helped in determining which of the two sub-schemes, the scheme operators should prioritise in improving irrigation water use efficiency.

However, the total avoidable water losses amounted to 2.9 million m^3/a, or 43% of the total water released into the Luvuvhu GWS canal system. This includes the operational spills at the canal tail ends.

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

10.2 Water restrictions on the Albasini main canal system

10.2.1 Specific approach to Albasini main canal

With the historic yield of the Albasini Dam given as 5 million m^3/a, this has not been sufficient to supply the 871 ha of irrigation lands from the dam at the scheduled allocation of 8 400 m^3/ha/a during normal years. Therefore the scheme has generally been under permanent restrictions. Since 2005 until to date, approximately 20% of the scheduled allocation was diverted into the Albasini main canal only two times.

Because of the permanent water restrictions, the irrigators of the 871 ha of scheduled area have had to rely on groundwater to irrigate their lands. With the use of groundwater, this has limited the use of the Albasini canal infrastructure. Any water available in Albasini Dam has been allocated for the domestic water use in Makhado town and the surrounding area. Even then the Albasini Dam cannot meet the growing domestic water demands of the area. The DWA has initiated a project to supplement the domestic water supplies of Makhado and the surrounding areas from the Nondoni Dam. This will release the available water in Albasini Dam.

However with the historical yield of Albasini Dam having been only 5 million m^3/a, coupled with upstream catchment developments in the Luvuvhu River which has been and will likely continue to reduce the run-off into the dam, affecting the yield of the dam, the Albasini Dam may not be likely to provide irrigation water in future. Furthermore the irrigators have responded to the water shortages due to drought and capacity of Albasini Dam to meet their required irrigation water for the 871 ha by investing heavily in the development of groundwater which in most cases cannot be linked to the canal infrastructure. Therefore the situation of the 871 ha scheduled allocation being supplied from Albasini Dam is uncertain. The future of the Albasini canal infrastructure being used to supply the scheduled allocation is therefore also uncertain.

The above water management issue cannot be addressed in this assignment. This will need to be addressed in a separate study as discussed in the proposed water management plan for the Levuvhu Government Water Scheme.

10.3 Water Measurement and Accounting Systems

10.3.1 Lack of sufficient water measurement

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

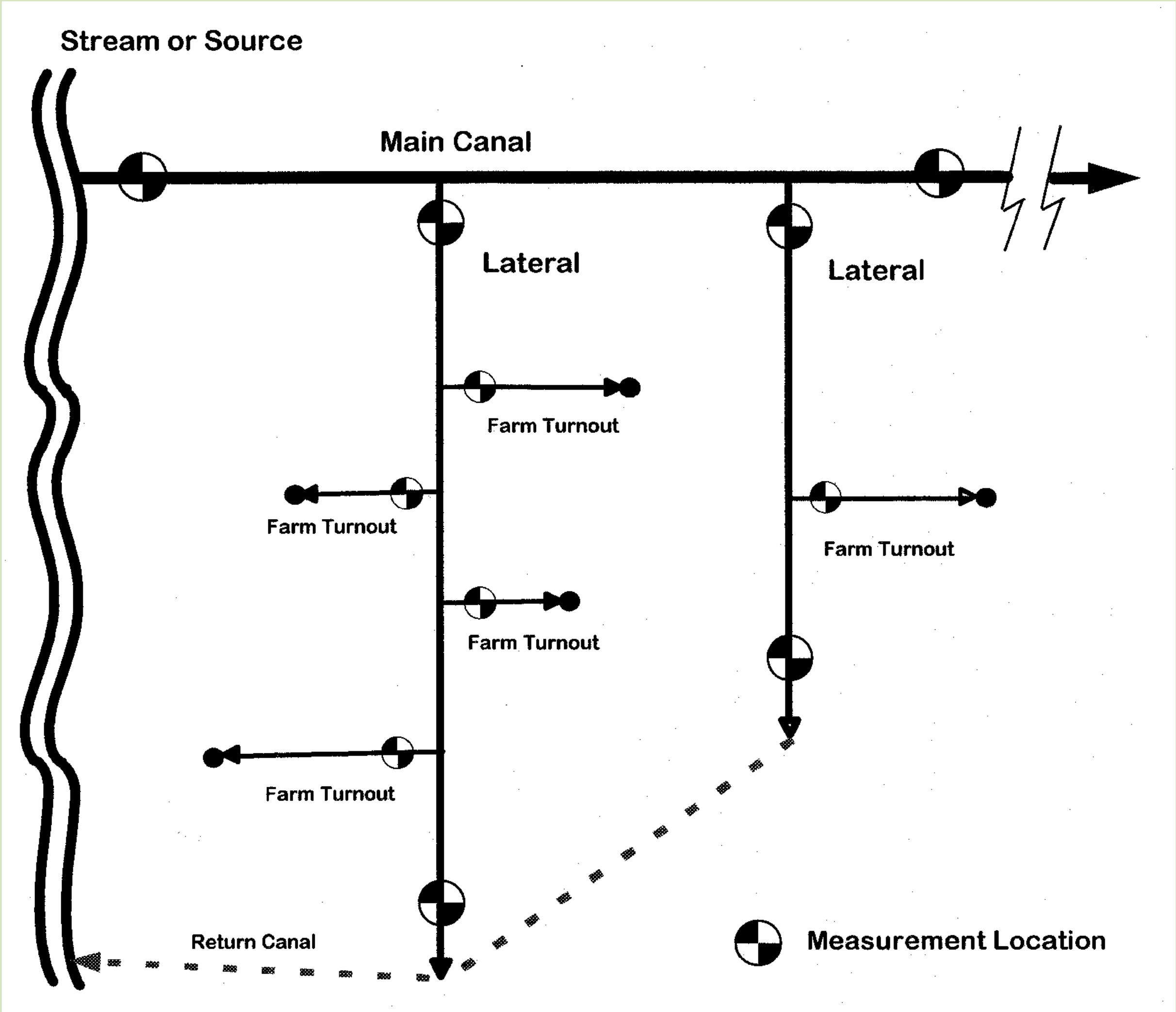

Figure 10.1: Irrigation Scheme with ideal water measurement system

Source: Bureau of Reclamation

There are two flow measurement structures at the inlet of the Lutanyanda main canal as well as at the weir for the Luvuvhu main canal. This is where accurate flow measurement is being taken. There is a flow measurement where the Lutanyanda main canal bifurcates into the right bank and the left bank canals. There is also one flow measurement at the canal tail end on the Lutanyanda left bank canal.

Based on the assessment of the WUEAR the following areas were identified either not to be having flow measurements or there are flow measurements which are not being read as there are no flow records being taken. There are no measurement structures or no flow measurement at the following canals

(i) Measurement of the diversion into the Lutanyanda right bank canal tail end.

(ii) *Measurement of the spills at the canal tail end of the Luvuvhu main canal system*: Either there are flow measurements structures which are currently not being used or there are no measurement structures making it difficult to accurately determine the actual spills at the canal tail end as well as determine the conveyance efficiency of the Luvuvhu canals.

(iii) *Measurement of diversions into the Lutanyanda right bank secondary canal system:* In order to determine the actual water delivered, and the seepage and leakage losses, flow measurement structures into the secondary canals are considered important. At present either there are no flow measurement structures or the scheme operators are not measuring the spills at the canal tail ends which would provide accurate information on the amount of water which can be saved if there will be no operational spills reflected at the canal tail ends

From the scheme operators' perspective, adequate water measurement will help with:

- Assembling information needed for a detailed water balance to be done at scheme and sub-scheme level. This provides the basis to implement measures to reduce water losses;
- Identifying areas where additional efficiency measures can be achieved and priority areas where maintenance is required given the limited time available during the dry period;
- Implementing a cost recovery system based on deliveries (this is available as deliveries to each irrigator is measured via the pressure sluices, however inaccurate).

10.3.2 Lack of continuous monitoring

The Luvuvhu Irrigation Scheme is a manually operated system with no continuous flow recording taking place as the existing flow recorders are not operational. There is no telemetry infrastructure linked to any of the existing flow measurements within the scheme area to carry out real time or near real time flow monitoring and control of deliveries. The only real time flow monitoring is being done at the canal headworks, at the Lutanyanda and Luvuvhu weirs were the Department of Water Affairs (DWA) Hydrological Branch has remote control flow measurements. These are currently not easily accessible to the scheme operators.

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

The lack of real time reduces the scheme operators' capacity and flexibility to respond to changes in demand by water users or operational spills at canal tail ends thereby improving the efficiency of irrigation water management.

However, with the installation of the Water Administration System (WAS) to undertake water accounting reports, it would be ideal to install a telemetry system that is compatible with the WAS programme to enable real time or near real time measurement and changes to be made. This will significantly improve the water use efficiency of the Luvuvhu Irrigation Scheme.

10.3.3 Management Goal 1

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

(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.

(iii) Planning for the installation of telemetry system infrastructure, so that the flow measurement data is sent via the telemetry to the Luvuvhu GWS office for direct input into the WAS programme. This should be with a view to have real time flow monitoring in order to reduce the time required to adjust flow rates, identify where losses are occurring and allow the Luvuvhu GWS to operate the scheme more efficiently.

In the meantime it is proposed that the scheme operators have access to the telemetry system operated by hydrological branch for continuous flow monitoring at the canal headworks.

10.4 Lack of flow measurements at sluice gates

10.4.1 Existence of flow measurement at the irrigators sluice gates

A survey of the sluice gates and Parshall Flumes where measurement of the irrigation water delivered to each irrigator was conducted to determine their locations and their existence. In the Lutanyanda and Luvuvhu canal systems, it was identified that there were a number of the sluice gates which did not have more accurate flow measurements, such as Parshalls or V-notch weirs (see **Photo 10.1** below).

Photo 10.1: Irrigator's sluice gate based on pressure controlled sluice gates

10.4.2 Condition of the flow measurements at the sluice gates

Besides the lack of flow measurements at some of the irrigator's sluice gates in the Luvuvhu Government Water Scheme, the condition of some of the Parshall Flumes and V-Notch weirs is very poor. The flow measurements at these sluice gates are likely to be inaccurate. Therefore the measurements provided in the water balance assessments are likely to be only estimates.

The need for accurate flow measurement is particularly critical in the Luvuvhu GWS because of water shortages. This will need to be addressed if accurate flow measurement is to be carried in the Luvuvhu Government Water Scheme particularly a scheme operating under severe water restrictions.

10.4.3 Management Goal 2

The management objective to address the above issues is to determine the number of flow measurements required in the Luvuvhu and Lutanyanda canals and plan for the installation of these flow measurements to enable effective irrigation water management in this water stressed irrigation scheme.

10.5 Irrigation water balance assessment

10.5.1 Irrigation water balance is not conducted in detail

Although a lot of measurement structures are available including the Parshall flumes at branch canals, at the balancing dams as well as at many canal tail ends in the Luvuvhu Irrigation Scheme, there are some components of the water balance that are not being measured, estimated or included in the water balance assessment. These include the following:

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

(ii) Measurement at the canal branches to enable sub-scheme water balance assessments to be conducted is currently not being done.

(iii) Measurement of operational losses at the tail ends, as well as at the rejects are currently not being measured, particularly at the Lutanyanda right bank canal tail end which has a flow measurement structure.

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

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

The irrigation water balance at scheme level for the Luvuvhu Irrigation Scheme, indicated that the scheme "water losses", comprising seepage losses, evaporative losses, operational spills, as well as the flows at the canal tail ends, was averaging approximately 3.6 million m^3/a. Not all of this volume can be considered avoidable water losses, as some is unavoidable losses, such as evaporation losses due to the exposed canal surface area and the seepage losses due to the hydraulic conductivity of the concrete lining as well as the water table in which the canal system was built.

It is currently difficult to disaggregate the avoidable losses into the different components of water losses. This is because no measurement is being taken at the canal tail ends although there are measuring structures. This would provide the operational losses at canal tail ends assuming there are no other demands downstream that are supplied by the scheme. At this stage, it is difficult to determine how much water is returned back to the Luvuvhu River and the tributaries. Therefore the available flow measurements can provide a more accurate water balance if the measurements are included in the WAS programme and as part of the water balance assessment.

As a result of the lack of sufficient flow measurement, the actual water losses are estimated, which would complicate the setting of water saving targets to implement different management intervention measures to reduce the avoidable water losses.

Although there are Parshall Flumes to measure the inflows into some of the branch canals as well as the canal end points in the Luvuvhu Irrigation Scheme, the measurements from these points are currently not being included in the determination of a comprehensive irrigation water balance at both scheme and sub-scheme level where they are read. This would assist the Luvuvhu GWS in determining which of the sub-schemes has the highest seepage losses and what measures are needed to reduce the losses.

10.5.3 Management Goal 3

The goal to address the above issue is as follows:

(i) Ensure that actual flow rates at the canal tail ends, into and out of the Luvuvhu branch canals are measured in the Luvuvhu Irrigation Scheme on a weekly basis;

(ii) Ensure that all measured data is included in determining water balance and calculating water losses within 1 year at scheme as well as sub-scheme level.

10.6 Full utilisation of the Water Administration System

10.6.1 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, WUAs and Government Water 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:

10.6.1.1 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.

10.6.1.2 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 Luvuvhu Irrigation Scheme has in responding to cancellations.

Currently there is reporting from this water order module.

10.6.1.3 Water release module

This module takes information from the water request module and calculates the volume of water to be diverted from the Albasini Dam at the Luvuvhu weir into the main canal and all its branches allowing for lag times and any water losses and accruals to supply the irrigation applications 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 gauge plate readings where needed, so that the sluice gates can be set to deliver the flow rates required to meet the water required for the week which is 72 hours. It is understood that there are no gauge plates at the sluice gates.

The Luvuvhu GWS is currently not utilising the water release module. Instead all the calculations are currently being done in a spreadsheet and the gauge plate settings provided to the scheme operators to set at the beginning of the week.

10.6.1.4 Measured data module

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

Currently the data that is measured manually is not being captured into the data module.

10.6.1.5 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. This module is currently in use at the scheme level.

At present the WAS is not being fully utilised by the scheme as the release module is not being utilised. There will be substantial benefit in utilising the WAS system to undertake Water Use Efficiency Accounting Reporting (WUEAR), with a view to determining which of the irrigation sub-schemes are experiencing significant water losses. This can provide priority areas, where issues need to be addressed in irrigation water management in the Luvuvhu 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 Luvuvhu Irrigation Scheme, the WAS programme has been installed for some time but the records indicate that these savings have not been achieved because the WAS programme has not been fully utilised.

10.6.2 Management Goal 4

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

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

10.7 Aquatic weeds and algae growth in the canals

10.7.1 Hydraulic capacity of the canals affected by the aquatic weeds

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

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

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

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

10.7.2 Management Goal 5

The management objective to address the above issues is to develop and implement an effective management of the aquatic weeds and algae proliferation as well as refurbishment programme to reduce irrigation canal losses within 5 years.

10.8 Condition of the conveyance and measurement facilities

10.8.1 General

In order to properly develop the Luvuvhu 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 5, a high level condition assessment together with discussions with the Luvuvhu GWS was undertaken. No assessment of the on-farm delivery systems was conducted. The main issues that were identified are discussed in the following sections.

10.8.2 Condition of canal infrastructure

Although there are no measurements to determine the actual avoidable water losses in the Luvuvhu Irrigation Scheme, the assessment carried out in the previous chapter together with the preliminary condition assessment in Chapter 5, has highlighted that there are likely to be very high water losses due to the condition of the canal infrastructure.

The condition of the Luvuvhu canal infrastructure was found to range between fair and poor condition. There were sections of the canals where the concrete joints had shifted creating holes for water to escape. There breaks in some sections of the concrete lining indicating that relining of the canal sections was required.

Based on the preliminary assessment the sections of the canals 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.

10.8.3 Limited resources available to undertake maintenance

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

Furthermore there are sections of the canals where complete renewal of these sections is required. This requires significant financial resources which given the fact that ownership of the canal infrastructure belongs to the Department of Water Affairs (DWA) the responsibility for conducting renewal of canal infrastructure would appear to lie with the DWA.

The lack of maintenance of the canals may be resulting in a rapid deterioration of the canal infrastructure.

10.8.4 Management Goal 6

The management objective to address the above issues is to undertake the following:

(i) Develop a maintenance schedule based on the priority sections of the canal system in order to improve the maintenance of the canal infrastructure within 2 years with a view to reducing the irrigation water leakage in the irrigation system.

(ii) Develop and implement a refurbishment programme to reduce irrigation canal losses within 5 years, in order to reduce the amount of water losses with the water saved stored in the weirs to provide security of water supply during drought periods.

10.9 Ownership of irrigation infrastructure

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

Although the Luvuvhu irrigation scheme is a government water scheme, it is likely to be transferred in future to a water user association. 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 Luvuvhu Irrigation Scheme, the Department of Water Affairs (DWA) still owns the irrigation infrastructure including the Albasini Dam, the main, primary and branch canals. However, the GWS operates the irrigation infrastructure as an agent of the DWA with a view to being transformed into a WUA and undertakes the normal maintenance of the irrigation infrastructure as part of the draft service level agreement.

The problems in the Luvuvhu irrigation scheme arise, when the major infrastructure needs replacement/total refurbishment, as is the case with the sections of the Luvuvhu canals. It is unlikely that the GWS has the financial capacity to undertake the refurbishment of the assets and need the support of the DWA Infrastructure Branch.

10.9.2 Management Goal 7

The broad objective to address this issue is to ensure that the levels of responsibility between the various DWA entities are refined, in order to enable the responsible party to refurbish the canals as a matter of urgency.

10.10 Institutional Water Management Issues

10.10.1 Lack of incentive in current irrigation water pricing structure

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

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

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

10.10.2 Management Goal 8

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

10.11 Summary of the water management issues

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

Table 10.1: Luvuvhu Irrigation Scheme: Identified water management issues

Item No.	Water Management Issue category	Issue description	Comments
1	Albasini Dam cannot supply 871 ha of scheduled area	The historic yield of Albasini Dam is not sufficient to meet the irrigation water requirements of the 871 ha scheduled to be supplied from the dam at 8 400 m3/ha/ because: (i) The historic yield is 5 million m^3/a compared to the scheduled allocation of 7.3 million m^3/a (ii) Catchment developments upstream including commercial forestry is reducing the yield of the dam (iii) The existing Albasini canal is not being used because of the water shortages (iv) Irrigators have responded by investing in groundwater as a source of supply	A detailed study needs to be conducted to determine the future of the existing infrastructure, the scheduled allocation given groundwater use compared to Albasini Dam
2	Water Measurement,	There is a lack of measurement of flows at the branch canals and canal tail ends (i) Although there are adequate flow measurement structures which can be used to measure flows at the canal tail ends these are not being read (ii) Measurements at the branch canals are not being measured to conduct detailed water balances	Encourage the scheme managers to ensure consistent reading of flow measurements at branch canals and canal tail ends

Item No.	Water Management Issue category	Issue description	Comments
3		There is not sufficient flow measurement at the irrigators take off points with only sluice gates provided to adjust for flow rates. In other cases the condition of the flow measurement such as Parshall Flumes and V-notch weir is in a poor state requiring to be upgraded. The scheme is therefore relying on irrigation applications as the water delivered to the irrigators which may not necessary be correct	Determine the number of flow measurements required downstream of the sluice gates and plan for the installation of accurate flow measurements
4	Water balance assessments	Current water balances being conducted at Luvuvhu are not accurate & comprehensive because they are based on assumptions. (i) The flows at canal tail ends are estimated instead of being measured (ii) The actual water delivered by the scheme to the irrigators is based on the current applications and not measures as some sluices do not have flow measurements (iii) 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 (iv) Water balances contain estimates of water losses - there are no measurements (v) Water budget does not include precipitation	Implement detailed water balance including measurement of canal tail ends, balancing dam in order to disaggregate the water losses by sub-scheme as well as whether operational or leakage

Item No.	Water Management Issue category	Issue description	Comments
5	Flow monitoring	There is a lack of continuous flow monitoring in the scheme: (i) The flow recorders at the canal tail ends are currently not operational (ii) No manual flow monitoring is taking place as measurements are not being taken at the critical points (iii) The manual reading of flow records, which is cumbersome and has high risk of errors (iv) There are no automated controls	Encourage flow monitoring either through installation of telemetry system in order to make improvement in irrigation water management
6	Water Accounting & Reporting	The water administration system to manage water use is not being fully utilised for sub-scheme water budgets (i) The water release module is currently not being fully utilised to improve water management (ii) It is not known how much and where water losses are occurring in the scheme area	Implement use of WAS to conduct detailed sub-scheme irrigation water budget within 1 year
7	Infrastructure related issues	***The condition of the canal infrastructure is in a very poor state:*** Gross water losses are substantially higher than the expected BMP for lined canal irrigation scheme (i) Condition of sections of the canal infrastructure is in a very poor condition (ii) Some of the major siphons are blocked resulting in the overtopping of the	Implement refurbishment of canals within 1 year

Item No.	Water Management Issue category	Issue description	Comments
		canal	
		Storages upstream of the Albasini Dam affecting the yield of the dam - There has been a proliferation of storage dams upstream of Albasini Dam it appears since the 2004/05 drought. This has resulted in the yield of dam being reduced significantly to the extent that the Albasini Dam main canal is no longer being utilised. This has reduced the irrigation water use to 2.2 million m^3/a. This appears to be the scheduled area.	Carry out a validation and verification of the storages upstream of Albasini Dam. Any illegal storages will need to be removed to improve the yield of the dam
		Aquatic weeds and algae growth in canal systems - The scheme has a serious problem of aquatic weeds and algae growth in the canals. This is reducing the hydraulic capacity of the canals meaning more water than is necessary is being released into the scheme. This is contributing to the high water losses of the scheme	Develop and implement a programme to eradicate aquatic weeds and algae
8	Water pricing & revenue management issues	Irrigators are paying the DWA 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	Financial incentives are necessary to encourage efficient water use

Item No.	Water Management Issue category	Issue description	Comments
		water costs between efficient and inefficient users.	
9	Institutional Management	The Levuvhu GWS is both owned and managed by DWA. However, there is still a disjuncture in ensuring the assets are maintained, resulting in deterioration of the infrastructure and increase in water losses. (i) The priorities between the two Directorates may differ in terms of when to undertake rehabilitation of the infrastructure.	There needs to be some form of Service Level Agreement between the DWA Infrastructure and Levuvhu GWS to ensure timeous rehabilitation of the infrastructure.

11 LUVUVHU GWS WATER MANAGEMENT PLAN

11.1 Identification and evaluation of water management measures

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

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

(i) 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.

(ii) Upgrade the flow measurement particularly at the sluice gates by installing flow measurements where these are not in place

(iii) Preparation of more detailed water balance assessments for Luvuvhu irrigation scheme, including at the sub-scheme level which include the branch canals

(iv) Implementation of the release module of the WAS programme to enable irrigation monitoring and control of water use to reduce operational losses such as canal tail ends spills to be carried out as well as undertaken water balance assessment at scheme as well as sub-scheme level,

(v) Removal of aquatic weeds and algae growth taking place in the irrigation canals to reduce water losses.

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

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

(viii) 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.

Besides the implementation of the above priority water management measures to improve irrigation water use efficiency in the Luvuvhu GWS, the future of the scheduled 871 ha from the Albasini Dam needs to be addressed. This is discussed in the last section of this chapter.

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

11.2.1 Gross (Total) water losses

The water losses in the Luvuvhu Irrigation Scheme are considered to be very high at 54% of the total system input volume of water diverted into the Lutonyanda and Luvuvhu irrigation canal. The total water losses were determined to be 3.6 million m^3/a based on the two years of available records.

11.2.2 Unavoidable water losses

It has been estimated that the unavoidable water losses due to evaporation losses and seepage due to the age and condition of the infrastructure is 0.69 million m^3/a, which translates into 10% of the total volume of water diverted into the Luvuvhu and Lutonyanda canal system.

Based on the evaluation of the unavoidable water losses for the Luvuvhu Irrigation Scheme, the water delivery Best Management Practice (BMP) should be based on the allowable water losses of approximately 10% of the total inflow into the irrigation canal systems.

The unavoidable water losses for the Luvuvhu Irrigation Scheme contribute to the determination of the Best Management Practice (BMP) for the allowable water Luvuvhu irrigation scheme.

11.2.3 Water losses due to operational and distribution inefficiencies

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

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

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

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

Therefore on the basis of the WRC study a BMP for operational and distribution efficiency has been taken as 10% of the inflow into the Luvuvhu irrigation canal systems. This amounts to 0.67 million m^3/a based on the average inflow into the canals. This together with the unavoidable losses has been used in setting the water savings and the target water losses of each of the two canal systems.

11.2.4 Acceptable water losses in the Luvuvhu Irrigation Scheme

The unavoidable water losses in the Luvuvhu irrigation scheme were determined to be 10% of the total releases into the Luvuvhu canal system. This water is additional to the irrigation water use required at the farm edge.

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

As illustrated in **Table 11.1** below, the expected average water losses taking into account the unavoidable water losses and the expected inefficiencies in the distribution of irrigation water due to problems of matching supply and delivery as well as metering errors and canal filling losses will be 20% of the total releases into the Luvuvhu canal system.

Therefore based on the 2 year average and taking into account the unavoidable water losses and expected operational inefficiencies, the expected water losses were determined to be 1.37 million m^3/a. When compared with the total losses of 3.6 million m^3/a for the same period, there is still potential to implement water saving measures to reduce the current water losses from 54% to the target water losses of 20% of the total releases into the Luvuvhu canal system.

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

<table>
<tr><th>Description</th><th>Unavoidable losses</th><th>BMP Distribution Efficiency</th><th>Acceptable water losses</th><th>Potential water savings</th><th>Total losses</th></tr>
<tr><td>Seepages</td><td>0.60</td><td></td><td>0.60</td><td></td><td>0.60</td></tr>
<tr><td>Evaporation</td><td>0.09</td><td></td><td>0.09</td><td></td><td>0.09</td></tr>
<tr><td>Filling losses</td><td></td><td rowspan="6">0.67</td><td rowspan="6">0.67</td><td rowspan="6">2.24</td><td rowspan="6">2.91</td></tr>
<tr><td>Over delivery to users</td><td></td></tr>
<tr><td>Leakages</td><td></td></tr>
<tr><td>Spills</td><td></td></tr>
<tr><td>Operational Losses</td><td></td></tr>
<tr><td>Canal end returns</td><td></td></tr>
<tr><td>Total</td><td>0.69</td><td>0.67</td><td>1.37</td><td>2.24</td><td>3.60</td></tr>
<tr><td>% of total volume released into system</td><td>10%</td><td>10%</td><td>20%</td><td>33%</td><td>54%</td></tr>
<tr><td>% of total losses</td><td>19%</td><td>19%</td><td>38%</td><td>62%</td><td>100%</td></tr>
<tr><td>Total releases</td><td></td><td></td><td></td><td></td><td>6.73</td></tr>
</table>

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

11.3.1 Regular measurement of flows at the branch canals and canal tail ends

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

Therefore with the existing measurement infrastructure, the Luvuvhu irrigation scheme should be taking weekly flow measurements at all the branch canals as well as the canal tail ends. As a matter of priority the Luvuvhu GWS should commence with electronic measurement 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 electronically 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 is no capital cost required for the Luvuvhu GWS to start taking flow measurements at the canal tail ends or at the branch canals, other than costs related to flow recorders. However the functions and responsibilities of the existing water control aids and WCOs will need to be updated. This can be done when the scheme operators go and set the sluice gates of the irrigators as well as close the gates at the end of the week.

11.3.3 Impact of the identified water management

Although it is difficult to determine exactly how much water will be saved by taking flow measurements, this will provide the Luvuvhu GWS with appropriate and relevant information on where the excess water is taking place and what measures to put in place to reduce water losses. For example by taking flow measurements at the canal tail ends, the Luvuvhu GWS will be able to determine by how much they can reduce the flow rate at the canal headworks.

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

Based on the preliminary work that was done during the site visit when flow measurements were taken at the Lutanyanda right bank canal tail end, the water that can potentially be saved by changing the current operational procedures by ensuring a no flow at the canal tail ends would be 0.51 million m^3/a.

11.4 Task 2: Installation of flow monitoring system

11.4.1 Installation of a telemetry system

The existing flow recorders are not operational. Therefore there is limited monitoring through manual operation of the irrigation 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 canal tail ends.

The total water losses in the Luvuvhu Irrigation Scheme over the 12 months of the past water year has averaged 3.60 million m^3/a, which is considered to be very high when the BMP for the scheme are taken into account. The likelihood of a significant portion of the gross water loss being due to operational losses is high. Therefore improving the monitoring of irrigation water in the scheme through the telemetry system will see significant water savings for the scheme.

The Hydrological branch of the DWA already has a telemetry system on two measurement structures in the scheme. Therefore the Luvuvhu Irrigation Scheme should consider on planning for installing a telemetry system to monitor the flows in the canal conveyance system. The first urgent action to be undertaken by the Luvuvhu GWS is to ensure that the proposed telemetry system is compatible with the WAS programme so that the flow measurements from the measurement structures can be monitored on a real time basis and the flow rate readings can be entered directly into the Water Administration System (WAS) for use by the release module.

In order to get the telemetry system operational, the Luvuvhu GWS needs to appoint a specialist telemetry expert to assess and carry out the design and installation of the telemetry system. This will also include ensuring that the software is compatible with the WAS programme. The telemetry system should be able to display current, last 24 hours flow rates and monthly water and flow level data of all the Remote Telemetry Unit (RTU). It will also store all engineering and conversion data necessary for converting flow levels into flow rates and volumes. This will be done to ensure compatibility with the WAS so that all flow records can be read directly into the WAS programme. This will provide data on a real time basis and provide the tracking and accounting of water use in the irrigation scheme.

The installation of the telemetry system and ensuring compatibility is envisaged to take 2 years with an ensuing expected useful life of 15 years

11.4.2 Initial and O&M Costs

Table 11.1 below indicates that initial capital costs and related operation and maintenance costs.

The estimated initial capital investment is the cost of the telemetry expert and software requirements related to the compatibility issues. This has been estimated to be R565 000-00, comprising the supply and installation of the telemetry infrastructure, estimated at R377 000-00, which includes the time for the telemetry expert and the software link with the WAS estimated to cost about R188 000-00.

As indicated further in **Table 11.1** below, the expected water savings due to the flow monitoring as a result of installation of the telemetry that is aligned to the WAS programme including training of the WCOs, is estimated to be approximately 34% of the avoidable water losses as determined in the irrigation water budget. This has been estimated to be 0.77 million m^3/a allowing for an 80% success rate.

The water saved will be available for distribution to the irrigators who are currently not getting their scheduled allocation. This will improve the yield of the Luvuvhu river system with the scheme benefiting during the low flow periods or drought periods as there will be more water available to mitigate any drought.

The average incremental cost (AIC) of installing the telemetry system for realtime monitoring will be 11 c/m^3 which when compared with the current heavily subsidised water use charge of 22.87 c/m^3 would appear to be low. Therefore, the implementation of the realtime monitoring will be beneficial in the long term.

Table 11.2: Summary of the costs and potential savings - Telemetry system and flow monitoring system

Item	Description	Water Savings Million m^3/a	Cost Savings R per year	Sub-Total	Total
Telemetry	Install telemetry system which is compatible with WAS programme				
Installation period					12 months
Productive period					20 years
Initial Capital Investment Costs	Software			188 333.33	
	Telemetry infrastructure			376 666.67	565 000.00
Annual O&M Expenses	Software licence, replacement of parts, and batteries, etc			25 000.00	
Water Losses					
Estimated reduction in water losses due to flow monitoring	Flow monitoring	0.54	64 359.99		
Average Incremental Cost (AIC)					0.11

11.5 Task 3: Full implementation of WAS and alignment with the telemetry systems

11.5.1 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 Luvuvhu irrigation system runs in the order of nearly a hundred sluice gates 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.

11.5.1.1 Review the current use of WAS

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

The system includes the following seven modules:

Administration module -

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

Water 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 Luvuvhu Irrigation Scheme has in responding to cancellations.

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

Water release module

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

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

The Luvuvhu GWS is currently not utilising the water release module.

Measured data module

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

Other modules

The above four 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. This module is currently in use at the scheme level.

Therefore, the Luvuvhu Government Water Scheme (GWS) needs to review their water accounting system and incorporate the use of the WAS programme in undertaking it water accounting

11.5.2 Initial Capital Expenditure and O&M Costs

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

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

The estimated water savings has been included together with the installation of water measurements discussed in section 11.2 above. As mentioned above, it is estimated that 0.77 million m^3/a, could be saved, by undertaking the installation of water measurement devices and implementation of a water accounting system such as the WAS programme.

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

11.6 Task 4: Management of aquatic weeds and algae

11.6.1 Chemical aquatic weed management

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

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

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

Acrolein has been found to be effective in controlling submerged aquatic weeds and algae. It is used on a large scale in many countries in flowing canals and drainage ditches for quick control of aquatic vegetation. Being volatile, it evaporates from treated water within a short time of its application. It is effective at concentration varying from 4 -15 ppmv.

However Acrolein has pungent and foul smell and is a non-selective, contact herbicide for control of submerged weeds. Canals require regular treatment as the Acrolein is not translocated to the root systems of the plants but merely chemically mows the plants off at bed level. It also kills snails and mosquitoes.

The herbicides may be introduced over a time period of 30 min to 4 hrs in 3 m^3/s, to 8 hours to 4.8 hours in canals up to 56 m^3/s. Dosages are to be adjusted with water temperature, weed intensity and speed of water flow in system.

Acrolein is injected in water directly from the cylinder container through an injecting system. It is toxic to fish which may hinder its use in the branch canals as irrigators do not want its presence in their farm dams where there is fish. It is irritating to eyes and generally toxic to humans but can be applied without any problem when proper application equipment is used.

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

11.6.2 Initial Capital Costs and O&M Costs

The initial capital expenditure for the treating the aquatic weeds and algae with Acrolein is estimated to be R300 000. This is illustrated in **Table 11.2** below.

Table 11.3: Summary of the costs and potential savings - Chemical management of aquatic weeds and algae

Item	Description	Water Savings Million m^3/a	Cost Savings R per year	Sub-Total	Total
Chemical treatment of aquatic weeds	Inject acrolein to manage aquatic weeds and algae				
Installation period					Annually
Productive period					20 years
Initial Capital Investment Costs	Procurement of contractors			300 000.00	
	Chemical injection of acrolein				
				-	300 000.00
Annual O&M Expenses	Annual maintenance of aquatic weeds			60 000.00	
Water Losses					
Estimated reduction in water losses due to removal of aquatic weeds	Water loss reduction	0.3	108 233.93		
Average Incremental Cost (AIC)					0.18

The removal or management of the aquatic weeds and algae growth in the irrigation has the potential to save approximately 0.30 million m^3/a, while the average incremental cost of implementing the measure is only R 0.18 per m^3 or R 1 534.54 per ha per annum. This would be very prohibitive if the cost is to be borne by the irrigators. Hence the need for the DWA to cover the initial costs of the managing the aquatic weeds as this problem is external to the irrigation water management of Luvuvhu.

Based on the above capital cost estimates and the estimated water savings, this measure is considered to be justifiable for implementation by the DWA on the Luvuvhu GWS. The capital investment required to carry out this, is minimal compared to the significant benefit in not only reducing water losses in the Luvuvhu Irrigation Scheme but also ensuring the condition of the canals is not compromised due to canal overtopping which is taking place on the A branch canal. This should be considered a priority by the irrigation scheme.

11.7 Task 5: Conveyance infrastructure water management measures

11.7.1 General

The conveyance infrastructure rehabilitation programme is to carry out the refurbishment of the infrastructure in the conveyance system that was found to be causing significant leaks and seepage. The discussion with Luvuvhu Government Water Scheme indicated that the major problems currently, are the sections after the Luvuvhu irrigation canal where sections of the concrete panels have been damaged and shifted. This is discussed in the following section.

11.7.2 Conveyance infrastructure refurbishment and canal relining

The preliminary assessment conducted as well as the information supplied by the scheme operators of the Luvuvhu GWS on the infrastructure survey they conducted indicates that the condition of sections of the Luvuvhu canal system is very poor (see **Figure 5.1** in chapter 4).

Given the high water losses, due to structural failure of concrete lined irrigation canals caused by poor condition of canal, erosion on the canal banks, the age of the canal and to some extent drainage problems, there is significant scope for refurbishment of the existing canal infrastructure, in order to reduce the current water losses. This will provide the Luvuvhu GWS 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.

It was estimated that approximately 2.5 km of the canal in the Luvuvhu will require total construction and/or relining of the canal with concrete. Approximately 10 km of the canal will require sealing of the wetted perimeter with polyfelt and bitumen emulsion. This was based on the preliminary assessment of the canal.

The total cost estimate for relining of the canal sections with concrete and sealing of the wetted perimeter was determined to be R6.05 million while the operation and maintenance costs to maintain the infrastructure in good condition from thereon was calculated as R0.02 million per year (see **Table 11.3** below).

The potential savings from implementing the refurbishment of the Luvuvhu and Lutanyanda canals is estimated to be 1.01 million m^3/a which at 8 400 m^3/ha would mean an additional 120.64 hectares which are currently not being irrigated because of water shortages can be provided with irrigation water.

11.7.3 Repair the canal siphons that are leaking

Besides the leakages on the canals in the Luvuvhu Government Water Scheme, there are also leakage problems with the pipes on the canal siphons of the main canal as well as the branch canals. Although the extent of the water losses on these canal siphons could not be determined, the surrounding areas indicated that significant volume of water was being lost.

The refurbishment of the above siphons should be included with the refurbishment of the concrete lined canals in the Luvuvhu Government Water Scheme.

11.7.4 Recommendations

A more detailed condition assessment of the canal system is required in order to verify the sections requiring total construction of the canal, the sections requiring the relining of the concrete canal as well as the sections which require resealing of the canal. The above figures can then be refined and updated when the water management plan is revised in future. The findings of the condition assessment can then be used to develop a more detailed canal refurbishment and renewal programme for the Luvuvhu Irrigation Scheme.

Where the condition assessment has already been conducted the findings of these studies should be taken into account in the refinement and updating of this water management plan for the Luvuvhu Government Water Scheme.

Table 11.4: Summary of capital investment requirement & benefits - Rehabilitation of the canal infrastructure

Item	Description	Water Savings Million m^3/a	Cost Savings R per year	Sub-Total	Total
Refurbishment of 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			6 054 185.33	
	Sealing of canal with bitumen emulsion			1 305 686.69	7 359 872.01
Annual O&M Expenses	Repair & sealing of joints			15 951.52	
Water Losses					
Estimated reduction in water losses due to canal refurbishment	Leakage reduction	0.86	233 540.85		
Average Incremental Cost (AIC)					1.28

The capital cost requirements to enable the Luvuvhu irrigation scheme to carry out the refurbishment of the infrastructure is beyond the normal maintenance costs of the scheme. The total construction and relining of canals requires significant capital investment which the DWA will need to provide, since they own the assets. Priority in refurbishment of the Luvuvhu canal system should be on the very poor canal sections once a detailed condition assessment has been conducted.

Currently the refurbishment budget is with the DWA, who still own the infrastructure. Therefore the DWA should carry out the rehabilitation of the deteriorating conveyance infrastructure, by carrying out the rehabilitation of the infrastructure where this is identified.

11.8 Task 6: Incentive based water pricing

11.8.1 General

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

In order to encourage irrigators to use water efficiently, it is recommended that an incentive based water pricing structure for Luvuvhu Irrigation Scheme is considered, based on the optimal crop water requirements of the main crop which is citrus and grape fruit. 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.

11.8.2 Regulatory aspects for incentive pricing

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

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

11.8.3 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 Luvuvhu 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 Water Administration 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.

11.8.4 Economic aspects for incentive pricing

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

If the charging system is to have an impact on consumption, then the system of payment must be such as to induce the desired economic response. In the case of the Luvuvhu Government Water Scheme, 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 Luvuvhu GWS needs to undertake fixed operation and maintenance activities, the incentive based pricing should consider the potential effects on revenue generated through water sales. However any savings made from reduction in water use at field edge, can be sold to other users such as the domestic sector whose demand is growing. This will provide supplemental revenue that could be used to develop more improvements to the scheme.

11.8.5 Potential water savings

The potential water that can be saved from implementing incentive based pricing can vary depending on a number of on-farm irrigation and water management decisions that the irrigators take. The water saved from incentive based pricing is likely to range between 5% and 10% of the annual irrigation applications.

In order to achieve this target the measures above need to be put in place which will have financial implications as illustrated in **Table 11.4** below. The average incremental cost of implementing incentive based pricing (excluding metering if required) was calculated to be R0.17 per m^3 or R 1459.5 per ha per year. The cost of implementing incentive based pricing will likely be borne by the Department of Water as part of overall sustainable management of the country's water resources.

The water saved can be used by the irrigators to expand their irrigation areas where possible. With the additional 0.22 million m^3/a, of water saved an additional 26.5 hectares of avocadoes or mangoes can be put back into production in the Luvuvhu Government Water Scheme.

Table 11.5: Impact of implementing incentive based pricing

Item	Description	Water Savings Million m^3/a	Cost Savings R per year	Sub-Total	Total
Incentive based pricing					
Installation period					One year
Productive period					20 years
Initial Capital Investment Costs	Update regulation & administration system			250 000.00	
	Billing & measurement system			250 000.00	
	Communication				500 000.00
Annual O&M Expenses	Billing & measurement			50 000.00	
Water Use efficiency					
Estimated reduction irrigation water use	Irrigation water use reduction	0.22	50 878.99		
Average Incremental Cost (AIC)					0.17

11.9 Task 7: Initiate a study to address the future of the disused Albasini canal infrastructure and the scheduled allocation from the dam

11.9.1 Overview

As discussed in the previous chapter, the historic yield of Albasini Dam cannot meet the current scheduled allocation of 871 ha from the dam. Because the scheme cannot supply irrigation water requirements, the irrigators have developed groundwater to meet their irrigation water requirements.

This has resulted in the Albasini main canal infrastructure not being utilised and the future of the infrastructure together with the Albasini Dam is uncertain. The issue of what happens to the 871 ha scheduled from the dam has not been determined and cannot be addressed in this assignment.

11.9.2 Albasini Dam Study

It is recommended that a detailed study be commissioned by the DWA to address the following aspects:

(i) Conduct a surface water resource assessment of the Luvuvhu River system given the current catchment development and update the yield of Albasini Dam to determine how much surface water supplies are available from the dam

(ii) Conduct a hydrogeological assessment of the potential groundwater available in the Albasini Government Water Supply Scheme area and determine the potential for conjunctive use between groundwater and surface water

(iii) Undertake a validation and verification of the existing water use by conducting a review of the water demands from the Albasini Dam, including the Lutanyanda and Luvuvhu River weirs that can be sustainably supplied from the updated water resource available in the area taking into account the lawfulness of the water demands. This should be compared with the existing scheduled allocation and determine the extent of curtailment that may be required to ensure sustainable water supply to the area. This may require curtailment and/or compulsory licensing of the existing lawful water use in the area.

(iv) Conduct an assessment and make recommendations on the future of the existing irrigation infrastructure which include the Albasini Dam and the canal infrastructure.

12 LUVUVHU GOVERNMENT WATER SCHEME - IMPLEMENTATION PLAN

12.1 General

12.1.1 Legal provision for developing and implementing a WMP

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

Prevent water from any water resource being wasted;

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

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

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

b) relating to water management by:

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

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

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

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

12.2 Establishment of water saving targets for Luvuvhu Government Water Scheme

12.2.1 Introduction

The implementation of a Water Management Plan for the Luvuvhu Government Water 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 yield of the citrus or grape fruit 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 Luvuvhu Government Water Scheme.

In the Luvuvhu Government Water Scheme, the trendline indicates a lower diversion per unit of irrigated areas since 2006 water year (see **Figure 12.1** below). There have been dramatic changes in irrigation water use efficiency over the 5 years of records (excluding 2010). The decreasing diversions per unit of irrigated land are a clear indication that there have been major improvements in water use efficiency. With the irrigation water restrictions over the period from 2006 to 2011, the allocated water per unit has reduced over the same period. This may have been due to improvements for example in on-farm water use efficiency as the value of water increased because of shortages. This conclusion has however only been reached with very limited data as no other historical data was available and will need to be verified in time.

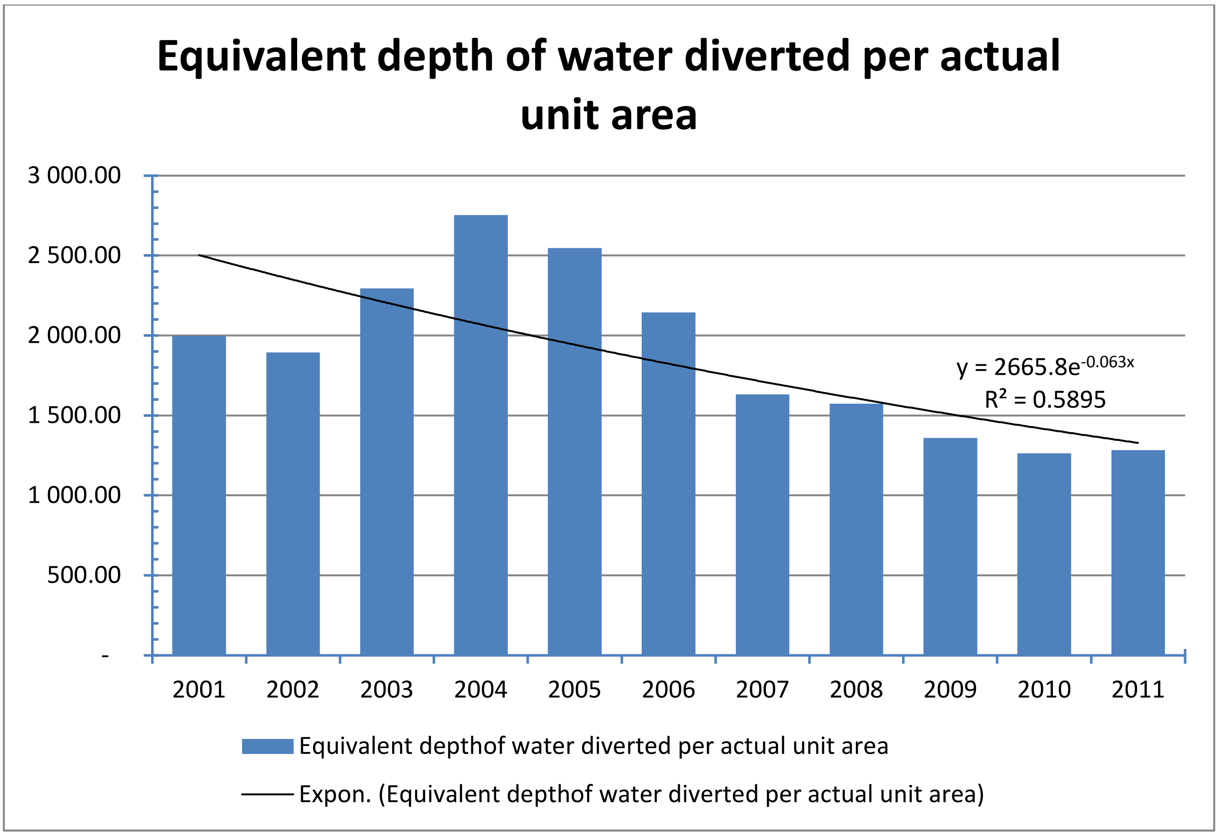

Figure 12.1: Trend line of slightly decreasing irrigation water diversion expressed as an equivalent depth of water diverted per actual unit area irrigated

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

12.2.2 Recommended water saving targets

Because there has not been a steep decline in the trendline of the diversions per unit area irrigated over the observed period, it would appear there is significant scope in implementing the irrigation management intervention measures discussed in the previous chapter. The water saving targets recommended for the Luvuvhu Government Water Scheme is provided in **Table 12.1** below. Based on the projected water saving targets, the Luvuvhu Government Water Scheme can achieve a 33% reduction in irrigation water losses relative to 2012 levels, by the end 2022 based on the components provided in **Table 12.1** below.

Table 12.1: Projected water saving targets for the Luvuvhu Government Water Scheme

Irrigation Component	Intervention	Estimated water savings	Percentage of irrigation diversion	Time frame for implementation
Conveyance Infrastructure	Refurbishment	0.86	13%	3-5 years
	Aquatic weeds removal	0.30	5%	3 years
Distribution infrastructure	Flow measurement		8%	2 years
	Recalibration of Parshall Flumes	0.54	0%	
Operational	Canal tail ends /		8%	1 year
	Operational spills	0.54	0%	
Sub-Total Scheme target		**2.24**	**33%**	
On Farm irrigation	Incentive pricing		3%	5 years
	Irrigation systems	0.22	0%	

12.2.2.1 Short term water saving targets

For the short term which has been taken as 3 years, the water savings from implementing the flow measurements; recalibration of Parshall Flumes will be 0.54 million m^3/a while monitoring of operational spills at the canal tail ends can reduce 0.51 million m^3/a. Furthermore the management of the aquatic weeds and water grass which is causing overtopping will potentially save an additional 0.30 million m^3/a, can be achieved. This is the water savings that has been targeted to be saved over a period of 3 years for the Luvuvhu Irrigation scheme until 2015.

Therefore a total of 1.35 million m^3/a can potentially be saved within the next 3 years, i.e. by 2015, if the above identified intervention measures are implemented.

12.2.2.2 Long term water saving targets

For the long term a further 0.86 million m^3/a, is envisaged to be saved by refurbishment of the canal infrastructure while another 0.22 million m^3/a, could potentially be saved through implementing incentive based pricing. This will require amendments to the current water pricing strategy which is currently being reviewed. It is unlikely that these water savings can be realised in the next three years. They are considered for the medium to long term in this water management plan. Therefore because of the complexities in implementing incentive based pricing and the timeline, it is recommended that this measure be implemented last.

The long term target is however to reduce the water losses from the current 54% of the total inflows to approximately 20% of the total inflow into the system. 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 Luvuvhu 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 Luvuvhu Government Water 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 which are required to ensure all flow measurements are taken by the Luvuvhu GWS and detailed water balance assessments are conducted on a monthly 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 Luvuvhu irrigation scheme has all the measurement structures to enable the GWS to take flow measurements at all critical points albeit by manually reading the flow levels and converting these levels to flow rates using the available calibration tables. This is because no electronic equipment for flow measurements are in place.

It is therefore considered a priority that the Luvuvhu GWS initiates the electronic reading of water levels at the following critical points. This should be conducted at all the three main canal tail ends of the Luvuvhu and Lutanyanda canals.

Furthermore the water measurement at the diversion points of Lutanyanda and Luvuvhu weirs should be measured separately as well as the diversion into the main branch canals. This will provide data to conduct sub-scheme water balance assessments.

Table 12.2: Luvuvhu Irrigation Scheme: Water Management Measures and action plan

Priority	Goal	Action Plan	Timeline	Responsible Authority
1	To measure all critical points in the Luvuvhu irrigation scheme	(i) Measure the 3 main canal tail ends on a weekly basis to determine the volume (loss) for the week.	March 2013	DWA / Luvuvhu GWS
		(ii) Measure the inflow and outflow at the balancing dam to determine weekly changes in storage	April 2013	
		(iii) Identify and incorporate measurement structures at the sluice gates without Parshall Flumes and V-notch weirs	March 2013	
		(iv) Calibrate the measurement structures as required	June 2013	
2	Undertake detailed water balance assessments of the scheme	(i) Split the Luvuvhu scheme into the different sub-schemes as per the branch canals and prepare water balance assessment and disposal reporting to DWA	March 2013	Luvuvhu GWS
		(ii) Prepare detailed water balance assessment for the sub-schemes and split the losses to reflect operational losses from canal tail ends	April 2013	
		(iii) Revise the water losses at scheme and sub-scheme and identify the nature of the water losses	April 2013	
		(iv) Set water saving targets based on new water balance assessment information	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	June 2013	Luvuvhu GWS
		(ii) Install new telemetry system infrastructure including software to ensure compatibility with WAS	Oct 2013	
		(iii) Calibrate the flow measurements such as flumes and sluices to improve the accuracy in flow measurement	April 2014	
		(iv) Prioritise areas of significant water losses	April 2014	
4	To fully implement the WAS programme	(i) Review current use of WAS programme modules	April. 2013	Luvuvhu GWS
		(ii) Implement the full use of the WAS ordering and release modules	June. 2013	
		(iii) Set up WAS programme to carry out water balances at scheme and sub-scheme level	July 2013	
		(iv) Implement full use of the WAS programme including reporting	July 2013	

Priority	Goal	Action Plan	Timeline	Responsible Authority
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	April 2013	`Luvuvhu GWS
		(ii) Prepare a motivation to DWA for refurbishment of the poor sections of the canals requiring total constructions as well as relining	Aug 2013	
		(iii) Engage with the DWA Infrastructure branch to motivate for refurbishment of the identified canal sections	Sept 2013	DWA / Luvuvhu GWS
		(iv) Prepare tender documents & specifications; Procure SP & undertake total construction of canal sections and relining of the canals with bitumen emulsion	Oct 2013	DWA
		(v) Assess water savings made from total construction of sections of the Levuvhu canal and relining of canal sections	May 2015	DWA
		(vi) Hand over the refurbished canals to Luvuvhu GWS for on-going maintenance in accordance with the formal service level agreement between the two parties		

Priority	Goal	Action Plan	Timeline	Responsible Authority
6	To implement incentive pricing structure for the WMA in 3 years	(i) Review current irrigation water pricing strategy and update administration systems	Feb 2013	DWA / Luvuvhu GWS
		(ii) Provide inputs in updating the DWA water pricing strategy	April 2013	
		(iii) Engage with irrigators on incentive pricing structure	June 2013	
		(iv) Install accurate flow measurement & implement water billing based on incentive pricing rate	Jan 2014	
		(v) Update the operating rules of Luvuvhu and Lutanyanda weirs to supply irrigators based on incentive pricing rate	Feb 2014	

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

In order for the Luvuvhu GWS to benefit from taking the flow measurements, detailed water balances should be prepared to incorporate actual flow measurements than is currently the case where the GWS has relied on estimates particularly of the water losses. As a first step, water balance assessments should be conducted to include the following:

(i) Luvuvhu weir sub-scheme water balance assessment based on the historic records taken at the diversion point, at the branch canal as well as the canal tail ends.

(ii) Lutanyanda weir sub-scheme water balance assessment by measuring the water measurements at the diversion point, the branch canals to the left and right bank as well as at the canal tail ends.

12.3.4 Target 3: Implementation of WAS programme

The benefits of installing sufficient water measurement cannot be fully realised without the implementation of the WAS programme or a similar such system that can provide detailed analysis of the water balance assessment. The system will need to be linked with the data and records from the flow measurement system. The following actions are required to implement a water accounting system for the Luvuvhu Irrigation Scheme:

(i) Review and evaluate the existing water accounting system being used by the scheme operators and identify where the gaps are;

(ii) Determine how the water release and water use modules should be linked to the flow measurement system;

(iii) Implement the WAS programme or similar system that can provide relevant information on water savings, progress to date and impact on performance indicators.

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

12.3.5 Target 4: Management of aquatic weeds and algae

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

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

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

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

(iv) Invite tenders and implement an aquatic weed and algae removal and control programme for Luvuvhu Irrigation Scheme;

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

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

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

Figure 12.2 below provides a layout plan of where the installation of the telemetry base station, the location of the remote terminal units which will be required to access the flow and level data which can be sent to the base station at the Luvuvhu GWS offices. A number of activities and tasks for implementation of installation of telemetry infrastructure is presented in **Table 12.2** above. As illustrated in the Table, the first priority action plans focuses on designing the telemetry infrastructure and network in the scheme. It is important that the telemetry system first focuses on installing the infrastructure at the two primary canals of Levuvhu and Lutanyanda where the inflow into the scheme takes place, the main branch canals, the balancing dams as well as the canal tail ends.

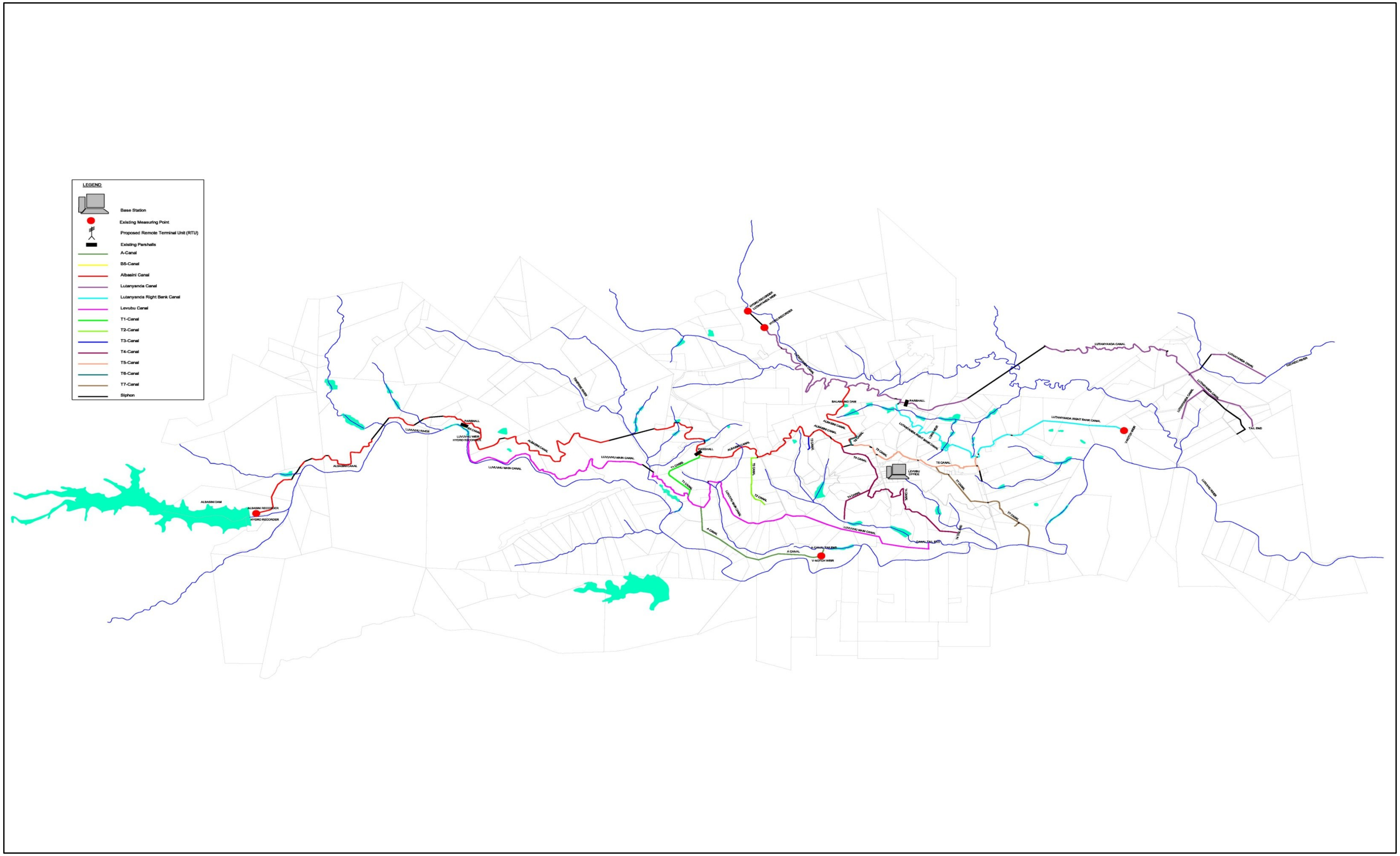

Figure 12.2: Proposed additional flow measurement and refurbishment of the existing telemetry system infrastructure

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

Besides the monitoring of flows, the Luvuvhu WUA will now be 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.

The updating and calibration of the existing Parshall flumes should also be conducted to enable measurements at sluice gates without flow measurements to be done and therefore improve the accuracy of flow measurements in the irrigation scheme.

12.3.7 Target 6: Updating and implementation of the Water Management Plan

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

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

(i) Take flow measurements and conduct a detailed water balance assessment on a monthly basis at scheme and sub-scheme level
(ii) Compile Water Use Efficiency Accounting Reports and submit it on a monthly basis to the DWA Regional Office and SAAWUA
(iii) Do recommendations on observations regarding water conservation issues and report to the Chief Executive: SAAFWUA and DWA on ways to address the identified issues
(iv) Develop activities that build on and complement other WC/WDM initiatives taking place at other water schemes
(v) Present water conservation information and training to irrigators and inform other scheme managers about success stories undertaken by the scheme

(vi) Maintenance and modernisation of the irrigation infrastructure

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

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

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

(x) Annually review and update the WMP with a water conservation program for the scheme with goals, objectives, improved water saving targets, action steps, measures, and timelines taking into consideration the latest measured data and the measures that have already been implemented.

12.3.8 Target 7: Implement incentive based pricing

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

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

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

(iii) Determine the fixed operation and maintenance costs of the Luvuvhu 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 Luvuvhu Government Water Scheme

Besides the reduction in water use and potential additional revenue that Luvuvhu 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 of the crops
(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 Summary of the implementation plan to achieve proposed water saving targets

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

(i) *Reduce operational losses at canal tail ends* - This measure has highest benefit with estimated water savings of 0.51 million m^3/a. This can be achieve at the least cost as no capital investment requirements is necessary to change the current operating procedures which ensures minimal or nor flows take place at the canal tail ends
(ii) *Improving water measurement system and flow monitoring* - This measure is the main driver for the above intervention. The direct estimated water savings of 0.54 million m^3/a, can be achieved by calibration of the Parshall Flumes and taking flow measurements consistently at the identified critical points. It is also easier to implement and should be considered a priority as all other measures are dependent on availability of sufficient water measurements in the Luvuvhu Irrigation Scheme.
(iii) *Chemical management of aquatic weeds and algae growth in canals* - This measure has the second most benefit with estimated water savings of 0.3 million m^3/a. It should be carried out at the same time as the first intervention measures because of its impact on the hydraulic capacity of the canals.
(iv) *Water Accounting System* - This measure is aligned to the first measure and will provide the system necessary to identify areas where irrigation water management can be improved. The changes in operation of the canals and canal tail ends can result in significant water savings if no water is allowed at the canal tail ends at the end of the scheme.
(v) *Refurbishment of the canals and siphons* - The capital investment requirements for this measure is very high and requires a long lead time to implement. However it has the highest water saving target with approximately 0.86 million m^3/a being able to be achieved over a 10 year period.
(vi) *Incentive based water pricing structure*- This measure has the third most benefit with estimated water savings of 0.22 million m^3/a. However there are legislative and administrative matters that need to be in place to enable incentive based pricing to be

implemented effectively. Therefore a long lead time is required to implement this intervention measure.

The above first three measures indicate that the avoidable beneficial and non-beneficial water losses that will be saved will amount to 1.35 million m^3/a out of a total of 2.24 million m^3/a of the estimated water that can be saved.

12.5 Funding of the Luvuvhu Irrigation Scheme WMP

12.5.1 General

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

It has been proven in the analysis of the identified water use efficiency measures that implementation of these measures provides the most viable option at present to improving irrigation water use efficiency and reduce water losses in the Luvuvhu Irrigation Scheme. However this will come at a cost to the water users. The additional cost for implementing these measures was done using the least cost planning approach where the average incremental costs (AIC) of each intervention measure were determined.

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

12.5.2 Financing by water users of the Luvuvhu GWS

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

It has been proven in the analysis of the identified water use efficiency measures that implementation of these measures provides the most viable option at present to improving irrigation water use efficiency and reduce water losses in the Luvuvhu Irrigation Scheme. However this will come at a cost to the water users. The additional cost for implementing these measures was done using the least cost planning approach where the average incremental costs (AIC) of each intervention measure were determined.

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

12.5.3 Financing by the DWA

The canal infrastructure in the Luvuvhu Irrigation Scheme is owned by the Department of Water Affairs (DWA) as the Luvuvhu is a GWS. The responsibilities of the irrigation scheme include the operation and normal annual maintenance of the infrastructure while the refurbishment of the infrastructure would be carried out by the DWA.

The impact of the aquatic weeds and algae on the condition of some of the infrastructure may have deteriorated to the extent that it requires refurbishment, the cost of which is prohibitive to be carried out by the irrigators through increase in water tariffs. Furthermore this problem is external to the operation of the scheme as the reasons for aquatic weeds may be due to upstream management. This problem is considered a water management area problem and requires the DWA to provide the financing necessary to reduce the water losses due to the aquatic weeds and algae growth in canals resulting in deterioration of the canal system.

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

(i) Implementation of a programme to remove and control the aquatic weeds and algae growth in canal systems.

(ii) Refurbishment of the sections of irrigation canals which are in a bad condition which are identified through a ponding test.

(iii) Implementation of the incentive based pricing by Luvuvhu GWS

13 CONCLUSIONS AND RECOMMENDATIONS

13.1 Conclusions

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

- The Luvuvhu Irrigation Scheme is situated in the Limpopo Water Management Area in the Vhembe District Municipality. The scheme has an enlisted area of 1 854 ha at an allocation of 8 400 ha/a, which excludes any of the river irrigators. The total water allocation from the Luvuvhu River is 15.6 million m^3/a for canal irrigators.
- The main crops that are under irrigation include avocadoes, macadamia, mangoes and as well as annual cash crops such as vegetables and maize.
- The Albasini main canal which was supplied from the Albasini Dam has not been in operation for a long time due to the very low level in the dam. There has been little inflow into the dam due to upstream developments including commercial forestry. Therefore the schedule allocation of 871.4 ha has not been included in the assessment.
- The Luvuvhu Irrigation Scheme has a total length of approximately 98.55 km of irrigation canal including siphons which supplies the irrigators as well as household consumption. There are two main flow measurement structures measuring diversion into the Luvuvhu and Lutanyanda canals. The canals distribute irrigation and domestic water to approximately 66 sluice gates with the flow measured at either the Parshall flumes or V-Notch weirs. However some of the sluice gates were found not to have flow measurement structures.
- Although no detailed condition assessment could be undertaken on the Luvuvhu Irrigation Scheme, a preliminary assessment and discussion with scheme operators indicated that the Luvuvhu canals are in a very poor condition because of age and lack of sufficient maintenance of the canals.
- It was determined that there were significant problems of aquatic weeds and algae growth in the canals that affect the hydraulic performance and condition of the canal system.
- The Luvuvhu GWS is currently operating under water restrictions and therefore the irrigators are supplied with less than their scheduled allocation since 2005. In order to ensure that the irrigators receive a portion of their scheduled quota as and when required, the Luvuvhu GWS operates the irrigation scheme based on “delivery on request” where each water user (irrigator) must submit a written request on a weekly

basis and the water is delivered to some 66 abstraction points along the canal systems. These procedures are not all formerly documented.

- Irrigation water use in Luvuvhu has averaged 2.97 million m^3/a for the available five years of records. The household consumption is very small at 0.22 million m^3/a before the 2005/06 water year.
- The average total water diverted within the Luvuvhu Irrigation Scheme during the same two year period, was 6.7 million m^3/a, for the same period of records available.
- An irrigation water balance assessment conducted for Luvuvhu Irrigation Scheme indicated that the water losses averaged 54% of the total water diverted into the scheme. This amounts to a total gross water losses of 3.6 million m^3/a, for the whole scheme. This was considered to be very high.
- The total water losses were disaggregated to determine the unavoidable and avoidable water losses with a view to establishing the irrigation water delivery BMP for Luvuvhu Irrigation Scheme. The total unavoidable water losses comprising evaporation losses and unavoidable seepage due infrastructure material was determined to be 0.69 million m^3/a, or 10% of the total inflow into the scheme.
- However an assessment of the operational inefficiencies due to over delivery, metering errors, etc. means that approximately 10% of the total releases will unlikely be able to be saved. This translates to 0.67 million m^3/a, which will be uneconomical to save because of the practical inefficiencies inherent in matching supply and demand.
- The water losses that can be saved was determined to be 2.24 million m^3/a out of an average total water loss of 3.60 million m^3/a for the Luvuvhu GWS. This was considered to be operational wastage, leakage and spills which could potentially be saved. However some of the water losses were considered to be beneficial as the water is used by downstream users in the Luvuvhu River catchment.
- Based on the unavoidable water losses, there was significant potential to reduce irrigation water losses and improve irrigation efficiency in the Luvuvhu Irrigation Scheme. The avoidable water losses of 2.24 million m^3/a, was considered to be operational wastage, leakage and spills which could potentially be saved. This also includes the spills at the canal tail ends.
- The irrigation water balance assessment together with discussions with Luvuvhu GWS operators highlighted that there were number of management issues which included the following:
  - (i) Although there are flow measurements, there are a number of measurements which are currently not being read. The most critical points to measure and

monitor flows which are not being done include the canal tail ends as well as measurement of changes in the storage capacity of the balancing dams. Because these critical points are currently not being measured, the integrity and validity of the WUEARs currently being submitted are questionable.

(ii) Because of lack of sufficient flow measurements, the Luvuvhu GWS is not conducting detailed water balance assessments. The current water balance assessments include estimation of flows at some of the points where measurements exist. These include the canal tail ends. There is a need to address this in order to clearly determine where and how much water can be considered as water losses.

(iii) There are problems with the accuracy of some of the measurements at the sluice gates because there are no flow measurements or the condition of the measurement structure is very poor. Therefore the actual volume of water delivered to some of the irrigators may be overstated.

(iv) There is no flow monitoring system in place besides the manual monitoring taking place. This is because the flow recorders which were used to monitor the flows and levels at different critical points such as canal tail ends are not operational.

(v) Not all the modules of the WAS programme which was installed are being utilised. The main ones which are the water release and measured data are currently not being used. Together with the compatibility issues of the telemetry system only the administration modules is being utilised.

(vi) The condition of the canal infrastructure was in a very poor state resulting in significant water leakages.

- 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 Luvuvhu irrigation scheme. 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 Luvuvhu Water Management Plan

A water management plan for the Luvuvhu 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 54% to 20% of the total inflow into the irrigation scheme include the following:

(i) *Reduce operational losses at canal tail ends* - This measure has highest benefit with estimated water savings of 0.51 million m^3/a. This can be achieve at the least cost as no capital investment requirements is necessary to change the current operating procedures which ensures minimal or nor flows take place at the canal tail ends

(ii) *Improving water measurement system and flow monitoring* - This measure is the main driver for the above intervention. The direct estimated water savings of 0.54 million m^3/a, can be achieved by calibration of the Parshall Flumes and taking flow measurements consistently at the identified critical points. It is also easier to implement and should be considered a priority as all other measures are dependent on availability of sufficient water measurements in the Luvuvhu Irrigation Scheme.

(iii) *Chemical management of aquatic weeds and algae growth in canals* - This measure has the second most benefit with estimated water savings of 0.3 million m^3/a. It should be carried out at the same time as the first intervention measures because of its impact on the hydraulic capacity of the canals.

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

(v) *Refurbishment of the canals and siphons* - The capital investment requirements for this measure is very high and requires a long lead time to implement. However it has the highest water saving target with approximately 0.86 million m^3/a being able to be achieved over a 10 year period.

(vi) *Incentive based water pricing structure*- This measure has the third most benefit with estimated water savings of 0.22 million m^3/a. However there are legislative and administrative matters that need to be in place to enable incentive based pricing to be implemented effectively. Therefore a long lead time is required to implement this intervention measure.

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 are recommended based on the beneficiaries of the intervention measures. The recommendation is that

(i) Luvuvhu GWS 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 Luvuvhu to fulfil its legal requirements in terms of the National Water Act on reporting and efficient management of irrigation water. These include updating the flow measurements, refurbishing the telemetry system and to fully implement the WAS programme.

(ii) The DWA owns the infrastructure in Luvuvhu Irrigation Scheme. The refurbishment of the canal infrastructure including management of the aquatic weeds and algae requires significant funding which cannot be met for the maintenance budget of Luvuvhu. As the water savings from the refurbishment of canals will benefit downstream consumers, the financing of the refurbishment of the infrastructure should be undertaken by the DWA. This also includes the implementation of incentive based pricing which will improve the on-farm irrigation efficiency while the savings will benefit downstream users unless Luvuvhu can use the water to expand.

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