UNIVERSITY OF ZIMMBABWE

FACULTY OF ENGINEERING

DEPARTMENT OF CIVIL ENGINEERING

An assessment of surface water availability in the Pungwe sub catchment and development of an appropriate water allocation framework

By

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A thesis submitted in partial fulfilment for the requirements of Masters degree in Water Resources Engineering and Management of the University of Zimbabwe

Supervisors

Mr A Mhizha

Mr E Madamombe

DECLARATION

I, Matimba Nyararai, declare that this research report is my own work. It is being submitted for the degree of Master of Science in Water Resources Engineering and Management of the University of Zimbabwe. It has not been submitted before for any examination for any degree in any other University.

Date ______________________________________

Signature ______________________________________

The findings, interpretations and conclusions expressed in this study neither reflect the views of the University of Zimbabwe, Department of Civil Engineering nor those of the individual members of the MSc Examination committee, nor their respective employees.

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ABBREVIATIONS

ARAs	Regional Water Administrations
CC	Catchment Councils
CRW	Crop Water Requirements
DNA	National Directorate of Water
DSS	Decision Support Systems
IWRM	Integrated Water Resource Management
JWC	Joint Water Commission
MAR	Mean Annual Flow
MASL	Metres Above Sea Level
RSOP	River System Outline Plans
SCCs	Sub Catchment Councils
SCE-UA	Shuffled Complex Evolution
SD	Standard Deviation
SI	Seasonal Index
WAFLEX	Water Allocation Flow Model in Excel
WEAP	Water Evaluation and Planning Model
WRSM	Water Resources Simulation Model
WRYM	Water Resources Yield Model
ZINWA	Zimbabwe National Water Authority

DEDICATION

This work is dedicated to my wife and children

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ABSTRACT

Pungwe River is a transboundary river which is shared between Zimbabwe (4.7% of land area) and Mozambique (97.3% of land area). The two governments are preparing a Bilateral Agreement on the management of water in the Pungwe River basin to allow part of the total runoff generated in Zimbabwe to flow to Mozambique. This is in line with the SADC and other International protocols governing the use of international Rivers. Zimbabwe needs to have a water allocation system that is equitable and fair to comply with this agreement. Part of the catchment from Zimbabwe is not gauged further constraining the testing of alternative allocation systems that can be adopted by Zimbabwe. The aim of this research is to assess surface water availability in the tributaries of Pungwe River and Honde River and develop a water allocation framework to guide Pungwe sub-catchment council in water allocation.

The Pitman model was used to generate surface runoff for the Pungwe River and Honde River catchments. The Pitman model was calibrated and validated using observed runoff for three gauging stations (F14, F22 and F23). A WAFLEX model was set up to evaluate different water allocation systems. The models were run to assess the performance of the different water allocation systems in terms of water shortages for different users within the sub catchment and satisfying proposed international flow obligations. Three water allocation practices were investigated namely proportional, proportional combined with priority and market based water allocation system.

The Pitman model was found to be suitable for modelling the Pungwe Sub-catchment area with model results providing a NSE value of 0.7 and R^2 value of 0.8 between observed and modelled stream flows. Results from the WAFLEX model showed that international obligations would be 100% satisfied under all the water allocation practices in Pungwe micro-catchment. However shortages were noted in Honde micro-catchment. Proportional combined with priority water allocation practice improved satisfaction with an average 20% agricultural water uses in Pungwe micro-catchment and 10% in Honde micro-catchment. Proportional combined with priority water allocation practice was considered the best practice to be used by the sub catchment. The data generated from this research has to be incorporated in the allocation of permits in the sub catchment and transboundary management of the Pungwe Basin.

CHAPTER ONE

1.0 Introduction

1.1 Background

Water use by human beings has increased over the last decades due to economic development, population growth and improved standards of living. Biswas (2011) claimed that the world is going to face an unprecedented water crisis, which will make many countries on the transboundary water courses to wage war with each other. Also, when water resources are shared between two countries, it is clear that transboundary conflicts can arise between upstream and downstream countries (Heyns *et al*., 2008; Brozek, 2013). Kreutzwiser *et al.* (2004) suggested that much of the conflicts surrounding water allocation relate to the inability of allocation arrangements to consider changes in economic, social and hydrological conditions and over-allocation of water resources under drought conditions. Tarlock (1990) defined water allocation as the rules and procedures through which access to water is determined. Water allocation systems focus primarily on efficient and equitable allocation of resources among human uses (Folke, 2003; Richter *et al.*, 2003).

A good example of an international conflict over water resources occurred between India and Pakistan. Nakayama (1996) suggested that the conflict between India and Pakistan was as a result of the division of the Indus River basin into India and Pakistan in 1947 in accordance with the independence of these countries from the United Kingdom and the two nations failed to settle the water resources allocation dispute through bilateral talks. However, twelve years of negotiation led to the 1960 Hindus Treaty Agreement, where the two countries agreed that India was free to use the water from the three tributaries that passes through its land while the remaining water was allocated to Pakistan (Wolf, 1998; Speed *et al.*, 2013). In the Middle East, the war between Israel and Arab nations in 1967 was because the Arabs were planning to divert water from the Jordan River (Wolf, 1998). Robertson (2004) argued that the Nile Basin, the world’s longest river with 10 riparian states, is one of the most discussed river basins on water conflicts and cooperation. Swain (2011) suggested that for most of the 20th century, the Nile River has been the source of political tensions and low-intensity conflicts among three of its major riparian countries (Ethiopia, Sudan and Egypt).

In India water conflicts occurred between the Mysore and Mandras states and this was triggered by the expansion of irrigation area on the upper parts of Cauvery River and its impacts to downstream users (Wolf, 1998; Speed *et al.*, 2013). The conflicts were resolved with the 1892 agreement where the two governments agreed to consult each another before building any major irrigation projects. To reduce further conflicts between the two states the 1924 Cauvery was made after the construction of Krishnarajasagara dam where the volume of water to be released downstream was defined and the limits of irrigable area for both upstream and downstream of the dam was set (Speed *et al.*, 2013).

In Tanzania, the conflicts between irrigators and the environmentalists were witnessed. Examples include the conflicts between irrigation and conservation of natural wetlands in Usangu Basin (Kashaigili *et al.*, 2003). Also the drying up of the Great Ruaha River in Tanzania has resulted in not only social conflicts between upstream and downstream users, but also a denial of adequate water to maintain the fragile ecosystem in the Ruaha National Park (Kashaigili *et al.*, 2005). In order to solve the above conflicts there should be clear rules, enforcement and water allocation practices to best allocate limited water in a catchment. Sivakumar (2011) suggested that in order to solve water allocation problems there is need for a clear vision of the future that covers water availability, demand and the development and implementation of water management plans and practices. Mazvimavi *et al.* (2008) argued that participation of water users during water allocation has the potential to minimize conflicts between upstream and downstream water users. Kujinga *et al.* (2014) argued that policies that pursue water equity aim to ensure that all social groups have access to a fair allocation of water to meet their daily needs. Pungwe sub-catchment is not exempted in water allocation problems and conflict like any other catchment in Southern Africa.

1.2 Problem statement

There is inadequacy knowledge of surface water availability in the tributaries of Pungwe and Honde Rivers where much of the abstraction is taking place. Increased water demand in the Pungwe sub catchment has resulted in increased surface water abstractions through direct pumping from the rivers which resulted in water shortages and conflict over water use amongst small scale farmers (Nyikadzino *et al.*, 2014). Given the problems of water scarcity due to climate change and the possible increases in primary, industrial and agricultural demands within upstream Zimbabwe and downstream Mozambique, there is potential for sub-state and interstate conflicts (Tapela, 2002). Nyikadzino *et al.* (2014) claimed that although there is little data available on unregistered use, illegal abstractions are significant in the Pungwe sub catchment.

1.3 Justification for the study

The research seeks to estimate surface water availability in ungauged tributaries of Pungwe and Honde Rivers in the sub catchment. The research is also going to develop an allocation framework based on WAFLEX for the sub-catchment. Surface water availability and the water allocation framework will then guide the sub-catchment in water allocation and issuing of water permits for both the gauged and ungauged catchments. The sub catchment council requires water allocating tools to adequately determine water use and allocation to guide them in issuing of water permits and satisfying international flow obligations to Mozambique as agreed in the Mozambique Zimbabwe Joint water Agreement of 2002.

1.4 Objectives

1.4.1 Main objective

The main objective of this study is to assess surface water availability in the Pungwe sub catchment and to develop an appropriate water allocation framework for improved water resources management.

1.4.2 Specific Objectives

1. To determine the spatial and temporal surface water availability in the Pungwe sub-catchment using appropriate modelling tools.
2. To quantify the current water uses in the Pungwe sub-catchment and establish the water allocation practice in use.
3. To develop a water allocation model based on WAFLEX for the Pungwe sub-catchment
4. To recommend an appropriate water allocation practice for the Pungwe sub-catchment

1.5 Thesis outline

This thesis is arranged as follows: chapter two reviews literature on water allocation practices, water resources assessment models and water allocation models. Chapter three gives the general description of the study area and the location of Pungwe sub catchment in Zimbabwe and Pungwe basin. This includes the climatic conditions, topography and the geology of the study area. Materials and methods used in this research are discussed in chapter four. This includes the methods used to estimate water uses in the sub catchment and estimation of Pitman parameters using physical catchment characteristics. The setting up of the WAFLEX model was done in this chapter. The results of this research are discussed in chapter five. Lastly conclusions and recommendations from this research are given in chapter six.

CHAPTER TWO

2.0 Literature Review

2.1 Introduction

Water resource planning and management was once an exercise primarily based on engineering considerations. According to Mugatsia (2010), it is now part of a complex, multi-disciplinary investigation bringing in individuals and organisations with different interest. Loucks (1995) indicated that successful planning and management of water resources requires effective IWRM models that can clarify the complex issues that can arise. Chibaga (2002) affirms that water resources management cannot be done effectively without the assessments of available water resources through the use of models. Models are of great value in water resource planning and decision making (Hughes, 1997). Water scarcity is increasing on a global scale. It is estimated that about 2 billion people may face water scarcity by 2050 (Parry, 2007). Hence there is need for proper management of water resources. Kujinga *et al.* (2014) suggested that the government or society can achieve water equity through water allocation and distribution policies. Mugatsia (2010) acknowledges that Decision Support System (DSS) tools can be used to clarify decision problems in water resources such as how much water has to be allocated in the catchment. Increase in water scarcity globally has increased the significance of water management plans in resolving international, regional and local conflicts (Speed *et al.*, 2013).

2.2 International and Regional water management

International laws and regional agreements provide guidelines and rules used in the management and utilization of water resources in international river basins (Kliot *et al.*, 2001). International and regional legal documents used in the management of international river basins are the Helsnki Rules of 1996, the UN Convention on the Law of Non Navigational Uses of International Water Courses of 1997, the SADC protocol on Shared Water Course System of 1995, the Revised SADC protocol on Shared Water Course System of 2000 and the SADC National Water Policy (Tumbare, 1999). The Helsnki rules and UN Convention on the Law of Non Navigational Uses of International Water Courses of 1997 are guided by IWRM principles (Kliot *et al.*, 2001). Each country is entitled to equitable share of water generated within its territory. The equitable share of water is determined by the following factors which are population, past water uses, present water utilization, hydrology of each basin state, percentage area of each basin state, economic needs of each state, social needs of each state and availability of other resources (Tumbare, 1999). The Revised SADC protocol on Shared Water Course System of 2000 gives a common regional approach to development, use and management of water resources (Furlong, 2006). All national legal framework and policies should conform to this regional framework. It harmonises and guarantees national efforts in water uses, development and management to this regional framework (Msangi, 2014). Also the SADC National Water Policy of 2006 is the backbone in water use and management in the region (Msangi, 2014).

The Mozambique Zimbabwe Joint Water Commission of 2002 establishes the joint management of water resource in the Pungwe Basin. It made specific references to the Helsnki rules and UN Convention on the Law of Non Navigational Uses of International Water Courses in this agreement. The Joint water Commission consists of members of ARA Centro in Mozambique and ZINWA Save catchment in Zimbabwe (Tapela, 2002). The Joint Water Commission (JWC) coordinate the development, planning and management of Pungwe basin and supervision and monitoring of the Pungwe Agreement. The main functions of the commission is to advise parties on the potential available water, current water utilisation levels, sustainable water utilisation levels, water allocation data, pollution prevention, providing relevant data and information. The national legal frameworks used for management of the transboundary water resources are National water Policy of 1991 and Water Act of 1991 of Mozambique and in Zimbabwe is the National Water Policy of 2013, Water Act of 1998 and Zimbabwe National Water Authority Act of 1998.

The government of Mozambique adopted a new Water policy in 2007 and this policy superseded the 1995 Water Policy which gave more emphasis on infrastructure development which was destroyed during the civil war. The 2007 policy gave emphasis on integrated water resource management. The institutions which manage water resources in Mozambique are the National Water Council, Ministry of Public Works and Housing, National Directorate of Water (DNA) and Regional Administrators (Tapela, 2002). The National Water Council consists of Ministers whose ministries are related to water and this council is chaired by the Minister of Public works and Housing. The Ministry of Public Works and Housing is responsible for policy formulation, management and development of water resources. The overall management of the water sector is done by DNA which includes surface water resources and ground water. Relevant water legislation is implemented by DNA which include those water quality protection and the management of international rivers. The water law of 1991 decentralises water management and established five Regional Water Administration (ARAs). ARA-Centro is responsible for the management of the Pungwe basin which is shared between Mozambique and Zimbabwe (Tapela, 2006). The main functions of ARA-Centro are formulation and implementation of hydrologic plans within its area of jurisdiction, licensing water users and effluent discharges, administration of public water within its area of jurisdiction, planning, designing and construction of hydraulic works, developing hydrological data required for planning purposes and conflict resolution amongst water users (Swatuk and Van der Zaag, 2008).

2.3 Water management in Zimbabwe

The government of Zimbabwe introduced a legal framework for the management of water resources through the introduction of the Water Act (Chapter 20:24) of 1998 and the Zimbabwe National Water Act (Chapter 20: 25) of 1998 (Zimbabwe, 1998a, b). This follows years of stakeholder consultation through the water resources management strategy project that ran from 1995 to 2000 (WRMS, 2000). The strategy was necessitated by the fact that the water sector have been guided by the Water Act of 1976 since independence. The 1976 Water Act had its own challenges which were limited stakeholder participation, little involvement of private sector in the development of water resources, there were no incentives to attract private capital, the government was only the major financial of water resources development. There was no stated government policy on the development of the water sector and to guide participants who may have wanted to participate (WRMS, 2000). This then led to the development of national water policy in 2013. The national water policy of 2013 and national water laws are used in the management of water in the Pungwe Basin. The Zimbabwe policy on water resources management seeks to promote the sustainable, efficient and integrated utilisation of water for the benefit of all the Zimbabwean people. The policy is based on three fundamental provisions which are; the ownership of the nation’s water resource is vested in the State, there should be equitable access to water by all Zimbabweans and there should be establishment of national and grassroots stakeholder institutions to guide the integrated development, management, allocation and conservation of water resources. The national policy recognises that water pricing promotes efficient utilisation and equitable allocation. The policy also talks about the 'user pays principle', for full cost recovery with a tiered system to allow cross subsidisation between the different socio-economic sub-groups. The policy also recognises different levels of hierarchy in order of priority within the following consumer groups:

1. Primary (human, livestock) consumption
2. Water for urban, industrial and mining purposes
3. Environmental requirements
4. Water for agriculture use
5. Reserves for future use

Allocation strategies are to put emphasis on prioritisation of water use, reallocation, fractional/proportional allocation and drought mitigation.

The legal framework in Zimbabwe decentralises water resource management to the local level through the establishment of catchment and sub-catchment councils to improve administration of water resources (Dube and Swatuk, 2002). Zimbabwe is divided into seven hydrological zones based on the country's major river systems (Mazvimavi *et al.*, 2007). Each catchment area is subdivided into sub-catchments whose boundaries are delineated according to sub-hydrological zones (Tapela, 2002). Each catchment area is under the management of a catchment council, and the sub-catchment areas are managed by sub-catchment councils (Kujinga and Manzungu, 2004). In some parts of the country, the sub catchments have been further sub-divided into micro-catchments (Tapela, 2002).

The responsibilities of the Catchment Councils (CC) include collaborating with the Zimbabwe National Water Authority (ZINWA), in preparing and updating River System Outline Plans (RSOP); deciding on and enforcing all water allocations and reallocations; developing and supervising programs for catchment protection; issuing and overseeing permits for water use; establishing and maintaining, with ZINWA, a data base and information system; and overseeing operations and functions of Sub Catchment Councils

(SCCs) (Zimbabwe, 1998a). The responsibilities of SCCs are to monitor the exercise of permits, water flows and use; to assist in pollution control, catchment protection and data gathering; and to collect from permit holders the levies to be used in the performance of the councils functions (Zimbabwe, 1998a).

The catchment councils and sub-catchment councils are involved in the planning, development and use of water resources (Kujinga, 2002). The water resources management strategy of 1998 indicates that all Zimbabweans should have access to water and that stakeholders should be involved in the management of water resources. The RSOP should comply with the global modern water management strategies through the observation of the Dublin principles in the context of Integrated Water Resource Management approach. The river system outline plans should contain uses of water, volumes allocated to different sectors of the economy, priorities in water allocations and utilisations among other issues. In times of shortages the catchment council is mandated to revise and reallocate the permits in a manner that ensure equitable distribution and allocation of the available water resources. The requirement to ensure equitable distribution and allocation of the available water resources creates challenges for both the catchment and sub catchment councils against the backdrop of increasing and competing water demand and limited water resources.

2.4 Challenges for water resource management

Water is an important resource for human survival which has no substitute. It also vary in space and time, it respects no political boundaries and it has multiple uses hence the need for proper management (Wolf, 1998). Population growth can cause most of the water related problems since an increase in population means an increase in water demand in all water demand sectors unless there are efficient water management practices (Besada and Werner, 2015). According to United Nations (2007) the world population is going to increase from 6.7 billion in 2007 to 7.7 billion by 2020 and to 9.2 billion by 2050. In Africa the population will double in the next 30 years reaching 2 billion people. Most of the population increase is in the developing countries which are already facing water and sanitation problems (Sivakumar, 2011). Population growth and expansion have resulted in the increase of water usage in agriculture and the United nations has estimated that water abstractions have tripled over the past fifty years (WWAP, 2009).

Water availability is going to be affected by climate change. Developing countries in semi-arid regions which already have water management problems are going to be severely negatively impacted by climate change (Andersson *et al.*, 2011). A study done by Langsdale *et al.* (2007) in Okanagan basin in the south central British Colombia showed that climate change lead to frequent and severe water shortages due to reduced water availability and increased demand. In the Pungwe basin annual rainfall is going to be reduced by 10% by 2050 in all sub basin, delay of the rain season by one month and a temperature increase of approximately 1.5^{o} (Andersson *et al.*, 2011). Surface runoff and water availability is going to decrease as a result of rainfall reduction and increase in evaporation (Andersson *et al.*, 2011). According to Andersson *et al.* (2007) river flow is particularly reduced during the end of the dry/start of the wet season (50–60% reduction) which could imply severe consequences for agricultural production.

Population growth and climate change have increased demand in already water stressed water resources (Brozek, 2013). The changing environment results in the need for flexible water allocation systems/practices to accommodate uncertainty in water availability, population growth, and urbanization. Water allocation requires that the available water to be allocated be quantified. Examples of water allocation systems/practices that benefited from available water being quantified can be found in the following prominent basins Inkomati (South Africa), Indus (India/Pakistan), Colorado (United States) and Murray Darling (Australia) (Speed *et al.*, 2013). The Colorado River passes through seven states in the United States of America. The sharing of water was based on Colorado River Compact of 1922. The water was shared equally between four states upstream and three states downstream using the available water estimated in 1922. The Colorado River Compact arose to address water supply, flood challenges and to strike a balance between upstream and downstream demands. The success of this agreement was that it provides a clear and transparent water allocation mechanism and the users were aware of the amount of water available (Speed *et al.*, 2013). However, the main challenges of this agreement were that the available water was less compared to that which was estimated in 1922. There was no provision on environmental flows which led to environmental degradation, there was no provision for adjusting allocation in accordance to water available annually since the lower basin were entitled to a fixed volume and does not provide for reviews over time as demand and priorities change (Speed *et* *al.*, 2013). The government of Pakistan came up with the 1991 Water Accord which was used to share water of Indus River between four provinces. The water available was apportioned using population size and area under irrigation (Speed *et al.*, 2013). The Accord include environmental water requirements and adjustment measure to allow seasonal variations. The Inkomati river basin is shared between Mozambique, South Africa and Swaziland and the basin is considered to be over allocated (Wolf *et al.*, 2005). The government of South Africa developed a water allocation framework on the South African potion of the basin to free up water to meet its International obligation, environmental flows and to minimize potential impacts on the existing water users. Models are used by water manager as tools to assess surface water availability and water allocations in catchment. Water managers also use models to make decisions on water management.

2.5 Models as decision support tools

Models are used to represent the natural systems in order to assess development, allocations, decision making and management of water resources (Caminiti, 2000). Water managers use models to understand complex natural systems better and to predict outcomes after setting different management scenarios. A model is a package that facilitates the simulation of a system out of a conceptual framework of the system. Models identify and evaluate alternatives and help to predict and better understanding of trade-offs among goals, objectives and interests. Different models have been developed for water resources assessments and planning and the choice of the model depend on the purpose and data availability (Schulze, 1995). Rainfall runoff models (see subsection 2.5.2) are used in water resource assessment for estimating generated runoff from ungauged catchments. Water Allocation Models are being widely used in order to assess the impacts of future development trends, water management strategies and climate change on the availability of water resources. Further discussion on water allocation models is made in section 2.10.

2.5.1 Climate change modelling and future water resources assessment

The major climate change challenges is its impacts on water resources and its effects on extreme hydrological conditions. Climate change can increase river discharges in wet areas whilst decreasing river discharges in dry areas. Water managers should incorporate climate change in their planning processes however the information should be relevant to their concerns (Andersson *et al.*, 2011). The major challenges faced by water managers in incorporating climate change in their planning is the level of uncertainties in the estimates and the mismatch in both spatial and temporal scales and translation of climate change data into hydrologic impacts (Langsdale *et al.*, 2007). Water managers cannot rely on global climate models which provides information on a large geographic scale with low spatial resolution since they manage small areas which requires high spatial resolution. Effective decision making on climate change impacts can be archived by regionalisation of global climate change models. Regionalisation can be done using statistical downscaling, simplified post processing of global simulation and the use of regional models. The results from climate change model should then be incorporated in hydrologic models to assess the impacts of climate change to water resources and extreme weather events (Andersson *et al.*, 2011). In modelling climate change impacts on water resources firstly emission scenarios should be analysed and assessed with global climate change models then by regional climate change models. Bias correction and downscaling should be done to the sub basin level (Andersson *et al.*, 2011).

2.5.2 Water resources assessment models

Surface water resources assessments are done to generate surface runoff from ungauged parts of the catchment. The generated surface runoff would then be used for water resources planning and management. Models such as HBV model and Pitman model can be used for surface water assessments. HBV model use daily rainfall data and daily stream flow as in inputs. Daily rainfall and runoff records are generally not available in most parts of Southern Africa hence it is no widely used in this part of the continent. Pitman model is widely used in Southern Africa. It uses monthly rainfall and monthly stream flow as in input data to the models.

2.6 Pitman Model

The Pitman model was developed by Pitman (1973) with the purpose of simulating runoff from gauged and ungauged catchments. The model was widely used in Southern African countries than any other hydrological model (Wilk and Hughes, 2002). Most African countries, Zimbabwe included has problems of data scarcity due to financial problems in setting up measuring gauging stations hence the Pitman model is suitable since it requires minimum data such as monthly rainfall, monthly potential evaporation and catchment area (Kapangaziwiri and Hughes, 2008). Firstly, the rainfall received has to first satisfy interception storage before any runoff is generated. The remaining rainfall is absorbed by the catchment surface (Kapangaziwiri, 2008a). This portion contributes to soil moisture storage and the rest is lost as runoff. Surface runoff from the impervious part of the catchment is computed in proportion to the total catchment area (Wilk and Hughes, 2002). A non-linear power function determines the runoff amount that the soil store produces. One portion is considered to come from the upper zone (soil moisture runoff) and the other from the lower zone (baseflow runoff) (Hughes, 2008). Surface runoff occurs when the moisture storage capacity is exceeded. Evapotranspiration from the main moisture store depends on the potential evapotranspiration and the moisture state of the soil store (Hughes, 2013).

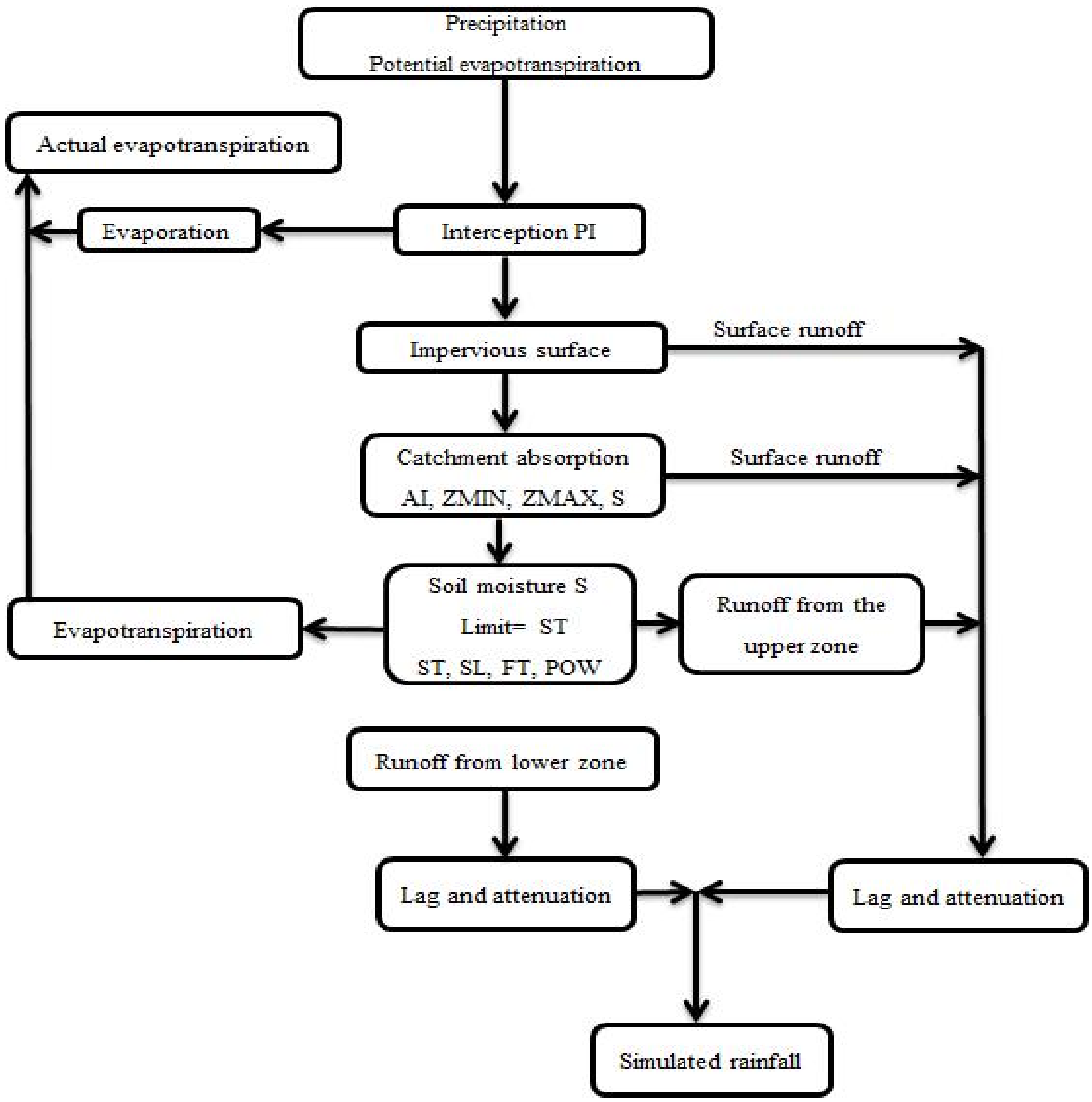

Figure 1 A flow chart of the Pitman model

2.6.1 Calibration of the Pitman Model

Model calibration is the estimation of the model parameters for the purpose of estimating the performance of the model (Ndiritu, 2009a). According to Ndiritu (2009b) the purpose of calibration is to obtain parameters of the catchment which gives the best possible fit between the observed and simulated stream flow. The process also includes parameter sensitivity analysis which shows how the model behaves after changing certain parameter values and the interaction between parameters (Ndiritu, 2009b).

Calibration can be done using the priori and goodness of fit approach. Under the priori approach the model parameters are estimated from catchment characteristics. The goodness of fit approach aims at getting parameters where the observed and simulated values have close correspondence (Ndiritu, 2009a). However model parameters can be estimated using both priori and goodness of fit method where parameters are estimated physically from catchment characteristic and then fine-tuned to get best fit (Ndiritu, 2009b). Mwelwa (2004) suggests that priori quantification of values assumes some knowledge of the relationship between parameter and measurable catchment characteristics.

Pitman (1973) provides some guidelines for initial parameter setting and the model is easy to calibrate. In the calibration performance is usually quantified using three measures which are the mean annual flow (MAR), the standard deviation of the mean annual runoff (SD) and the seasonal distribution of flows quantified by the seasonal index (SI) (Ndiritu, 2009b). In the Pitman model calibration is a multi-objective problem as three performance measures which are the mean annual runoff, the standard deviation and the seasonal index need to be matched between the historic and the simulated flows (Ndiritu, 2009a). The traditional approach to calibration has been the manual calibration of the model against observed data and the use of regionalised parameter sets for use in ungauged basins (Midgley *et al.*, 1994). Table 1 shows the calibration parameters of the Pitman model. Details of their meaning and how they are estimated can be found in Ndiritu (2009a).

Table 1 Calibration parameters of the Pitman Model

Parameter	Units	Description
PI	mm	Interception storage
AI	none	Ratio of impervious area
ZMIN	mm/month	Minimum catchment absorption rate
ZMAX	mm/month	Maximum catchment absorption rate
ST	mm	Maximum moisture storage capacity
SL	mm	Moisture storage capacity below which runoff occurs
FT	mm/month	Runoff from moisture storage at full capacity
GW	mm/month	Maximum groundwater runoff
R	none	Evaporation moisture storage relationship parameter
POW	none	Power of the moisture storage runoff equation
TL	months	Lag of surface and soil moisture runoff
GL	months	Lag for ground water runoff

Automatic calibration is when model parameter values are determined using an automatic technique (Rosenbrock, 1960; James, 1972; Gupta and Sorooshian, 1985; Ndiritu, 2009a) such as shuffled complex evolution (SCE-UA) technique is an effective and efficient automatic calibration technique. The main advantage of automatic calibration is that it is faster and it is less subjective to judgment of the modeler (Duan *et al.*, 1992). According to Ndiritu (2009b) many hydrological modellers in Southern Africa pointed to a perception that automatic calibration is dangerous because the calibrated parameters may not be hydrologically meaningful. Ndiritu (2009a) suggested that in order to use the automatic model calibrator, minimal coding of the catchment simulation model to be calibrated is required to allow the exchange of information between the model and the calibrator.

Manual calibration involves changing one or more parameter values and observe the relationships between observed and simulated values. The main advantage of manual calibration is that it helps the modeller to have a better understanding of catchment characteristics and the interaction with model parameters (Ndiritu, 2009b). The disadvantage of manual calibration is that it is time consuming and confusing if there is high interaction between parameters (Ndiritu, 2009a). Eckhardt and Arnold (2001) claimed that the success of manual calibration depends on experience of the modeller and their knowledge of model components and model parameters.

Manual calibration also works on the basis of the objective of matching the simulated and the observed data. The Pitman model can be calibrated manually. In the calibration of the Pitman model emphasis should be given to these parameters ZMIN, ZAVE, ZMAX, ST, POW, FT, GW and R during manual calibration of the model and other parameters should remain fixed (Ndiritu, 2009b). Pitman model has been calibrated manually mostly as the rainfall-runoff module in Water Resources Simulation Model (WRSM 2000) used in South Africa. Ndiritu (2009a) suggested that in catchments with good vegetation cover, temperate to humid climates and naturally perennial flow systems the parameters ZMIN, ZAVE and ZMAX are frequently not used during the calibration process. ST, POW and FT are normally adjusted to achieve reasonable simulations across a range of different monthly rainfall totals. POW, GW, GL and TL can be adjusted to improve the fit of recession flows during the dry season (Mwelwa, 2004). The evaporation parameter R can also have a significant impact on this aspect of model results. In dry catchments, the calibration process should be concentrated on the ZMIN, ZAVE and ZMAX parameters as compared to POW, FT, GW and R, while ST can be just as important (Ndiritu, 2009b). Since the Pungwe sub-catchment has good vegetation cover and has perennial river flows calibration emphasis should be put on the following parameters POW, FT, GW, R, and ST.

2.6.2 Application of the Pitman Model in Water Resources Assessment

As stated above the Pitman model is incorporated in the Water Resources Simulation Model (WRSM 2000) used in South Africa as the rainfall-runoff module. This model was used to assess surface water availability in the ungauged parts of Zimbabwe (Mazvimavi, 2003). The model was widely used in Southern Africa for water resources assessment.

2.7 Catchment water usage

At catchment water is used for irrigation, livestock watering, urban and rural water supply, mining, hydropower generation and environmental water flows to maintain the ecosystem. These are the main water usage at catchment level. Water use for sustaining ecosystem is gaining popularity as environment has now become a legitimate water user and should be included in the management of water in a river basin.

2.7.1 Water use sectors.

Kutty *et al.* (2012) identified three major water use sectors at river basin scale as municipal, agriculture and industry. Globally, the proportion of water uses by these sectors stand as 70% agriculture, 19% industry and 11% municipal (FAO, 2011). In Europe, 29% goes to agriculture and in Asia, 80% goes to agriculture. In low rainfall areas such as Middle East and North Africa about 80-90% goes to agriculture (Gleick and Ajami, 2014). In Africa, water use by agriculture, industry and municipal is 86%, 10% and 4% whilst in Sub Saharan Africa is 87%, 3% and 10% respectively (FAO, 2011). In Zimbabwe, water use by agriculture, industry and domestic is 79%, 7% and 14% respectively (Gleick and Ajami, 2014). Water demand in the municipal and industry sector is growing faster than the demands in the agricultural sector (Kutty *et al.*, 2012).

2.7.2 Water use estimation

Water use for municipal purposes is estimated using population data and water demands per capita from the World Health Organization (WTO) guidelines. Irrigation water demand is estimated using CROPWAT 8 which takes into consideration the climatic conditions of the area, soil characteristics, types of crops grown and the area under cultivation. Water use in industries is estimated using water audits. In conducting water audits, the amount of water use by a piece of equipment from manuals and operating hours is required to quantify water use.

2.8 Conflicts in water use and allocation

Conflicts between different water uses and users have become common over the years, as demands are placed on limited water resources (Gustard, 2002). A conflict occurred between Senegal and Mauritania when the river receded from its flood plain after the construction of Diama Dam and Manantali Dam (Niasse, 2005). The Senegalese went to prepare their field in the right bank of the river but they were chased by Mauritanian security. The dispute led to the Mauritanian security killing two Senegalese farmers and held thirteen others in custody (Niasse, 2005). A water dispute occurred between Botswana and upstream Namibia in the Okavango River because Botswana claims water for the delta to sustain its eco-tourism whilst Namibia wants piped water to supply its capital with drinking water (Wolf *et al.*, 2005; Kaniaru, 2015).

According to Kashaigili *et al.* (2003), an increase in human population, water scarcity and conflicts over water resources calls for the governments in sub-Saharan Africa to consider a rational and efficient inter-sectoral water allocation. Komakech *et al.* (2012*)* added that the scarcity of water caused by increased demand frequently leads to competition and conflict over water in many river catchments in Sub-Saharan Africa. Many countries in Southern Africa are facing the challenge of effectively managing water resources to meet the requirements of their growing populations (Hirji and Panella, 2003). Bjornlund (2010) postulated that water allocation systems establish availability and priority among a range of water uses such as irrigation, municipal and industrial water supply, hydropower, recreation and environmental requirements.

2.9 Water allocation practices

Approaches on how to share water has become complicated in recent years due to increased demand while in the past it was done considering population growth and even in arbitrary terms (Speed *et al.*, 2013). Speed et *al.* (2013) defined water allocation as the granting of entitlement to abstract and use water and it describes how water is shared between regions, groups and individuals. Water allocation is important when water available fails to meet demand in terms of quality, quantity, reliability and timing of availability. Increase in water scarcity globally, importance of water for economic growth, food production, conflict resolution and conserving health of the ecosystem have increased the significance of water allocation plans and practices (Speed *et al.*, 2013). Water allocation mainly consists of determining water available and how it is shared among water users (Hellegers and Leflaive, 2015). The main water allocation practices available are priority, proportional and market based water allocation practices.

2.9.1 Priority water allocation practice

Water is allocated according to different levels of priority given to the water users. Under this practice the priority of uses need to be identified first and their needs met first before the remaining water is allocated to other uses (Senzanje and van der Zaag, 2004). The water allocation process in a given year should provide that water available should be allocated first to meet high priority demand. As an example during drought years water should meet the basic needs such as drinking water and environmental requirements before allocated to other purposes such as agriculture (Speed *et al.*, 2013). In some cases priorities might be in the form of water reserved for transboundary flows and environmental flows. The water reserved for this might not be a fixed volume but might be given as a proportion of available water (Senzanje and van der Zaag, 2004). Allocation of water using the priority purpose may reserve water for strategic national developmental goals (Hellegers and Leflaive, 2015). The South Africa Water Act of 1998 gave the following water allocation priorities in their order of importance which are basic human needs, ecological needs, international obligations, strategic national government priorities and the remaining water would be allocated among the users in the catchment (Speed *et al.*, 2013).

Another good example of priority water allocation practice is the priority date system which was used in Zimbabwe prior to the 1998 Water Act (Senzanje and van der Zaag, 2004). Under this system the priority was given to those who had applied for the water first. During times of water scarcity the system allowed those who were granted water rights first to take their share first and the right was given in perpetuity. This system had a lot of problems since it discouraged efficient use of water, discriminated against new users, was rigid and defied the principle of equity (Senzanje and van der Zaag, 2004).

2.9.2 Proportional water allocation system

Proportional water allocation practice involves division of available water among users. According to Speed et *al.* (2013) proportional allocation involves considering physical characteristics of a basin such as contribution made to runoff by different states and length of the river lying in the riparian states. Proportional water allocation is when a user has a percentage of the water available and it is dependent on water available (Speed *et al.*, 2013). Under this system water users are given water permits that shows the maximum amount of the water that the user can abstract which is a proportion of total runoff generated in the catchment. The advantages of proportional water allocation system is that it is simple, robust, and predictable, encourages equity and the resources used in operating the system (Senzanje and van der Zaag, 2004). The proportional water allocation system was used in the allocation of water in the Colorado River basin. The contribution to runoff by states and the land area was used in the sharing of the water between the upstream and downstream states (Speed *et al.*, 2013). The upstream states generates much of the runoff whist the downstream states had the largest area contribution in the basin. Proportional allocation system was also used in India between Madhya Pradesh and Gujarat states on the Narmada River (Speed *et al.*, 2013). The proportional water allocation considered the social and economic needs and the proportion of the basin lying in these states and came up with 33% for Gujarat and 67% Madhya Pradesh since 97 % of the basin lies in the Madhya Pradesh territory (Cech, 2010).

2.9.3 Market based water allocation practice.

Market based allocation practice is when the water is allocated through trade and auctions (Speed *et al.*, 2013; Zhao *et al.*, 2013). It is generally applied when there is water scarcity. Market based water allocation system improves water use efficiency and allocation of water between sectors, increases water availability, water is secured for high use values, provide incentives for efficient use of water (Louw and van Schalkwyk, 2000). The disadvantage of the market based water allocation system is that its transaction conveyance infrastructure cost may exceed the social benefits (Zhao *et al.*, 2013).

2.10 Modelling Water Allocation Practices

According to McCartney and Girma (2012), cooperation between the riparian states would be enhanced by the development of shared knowledge bases and appropriate analytical tools to support decision-making processes. This calls for planning and management of water resources at catchment level with appropriate approaches and tools to balance demands of different users. The assessment of different water allocation practices using models helps understanding of the implications of the water allocation practices on policy objectives such as minimising shortages.

2.10.1 Water Evaluation and Planning (WEAP) Model

The Water Evaluation and Planning Model (WEAP) was developed by the Stockholm Environment Institute. The model has been used worldwide for scenario analysis in water resources management. The model employs a priority-based optimisation linear programming algorithm to allocate water (Arranz and McCartney, 2007; McCartney and Girma, 2012). The functions of the model include the simulation of natural hydrological processes to enable assessment of the availability of water within a catchment and simulation of anthropogenic activities superimposed on the natural system to influence water resources and their allocation to enable evaluation of the impact of human water use (Yates *et al.*, 2008). WEAP is an exemplary application linking supply and demand site requirements. Scenario analysis, changes in supply and demand structures can be simulated in order to discover potential shortages and the effects of different management strategies (Yates *et al.*, 2005). Raskin *et al.* (1992) studied on the Aral sea basin water resources management and concluded that the Aral Sea, a huge saline lake located in the arid south-central region of the former U.S.S.R., is vanishing because the inflows from its two feed rivers, the Amudar'ya and Syrdar'ya, have diminished. The loss of river flow is the result of massive increases in river withdrawals in the basins. Zakari *et al.* (2011) also used the model to investigate scenarios of future water resource development in the Niger River Basin in Niger Republic. In recent years WEAP model was used for water resources planning and management. Ospina-Noreña *et al*. (2011) used WEAP model for simulating water resources of the Sinú- Caribe river basin in Colombia to create several baseline and adaptation strategy scenarios for water supply, use and demand, and to make projections for the future including the potential impacts of climate change. The results show that the supply requirement would increase and thus unmet demand would increase more quickly under climate change conditions.

Varela-Ortega *et al.* (2011) studied the upper Guadiana basin in Spain's inland region of Castilla La Mancha, the research focused on the analysis of water and agricultural policies aimed at conserving groundwater resources and maintaining rural livelihoods in a basin in Spain's central arid region using WEAP model. Varela-Ortega *et al.* (2011) showed that the region's current quota-based water policies may contribute to reduce water consumption in the farms but will not be able to recover the aquifer and will inflict income losses to the rural communities. Höllermann *et al*. (2010) modelled the water balance of the Ouémé–Bonou catchment with WEAP and showed that the pressure on Benin's water resources will increase, leading to greater competition for surface water. The WEAP results offered a solid basis to assist planners in developing recommendations for future water resource management by revealing hot spots for action (Höllermann *et al.*, 2010).

Harma *et al*. (2011) used WEAP model to consider future scenarios for water supply and demand in both unregulated and reservoir supported streams that supply the district of Peachl and in British Columbia's Okanagan basin. Results demonstrated that anticipated future climate conditions will critically reduce stream flow relative to projected uses (societal demand and ecological flow requirements) (Harma *et al*., 2011). The storage systems currently in place were found to be unable to meet municipal and in stream flow needs during "normal" precipitation years by the 2050s. Yilmaz and Harmancioglu, (2010) used WEAP model as a simulation and evaluation tool to assess the performance of possible management alternatives in Gediz River basin. The results of the study indicated that the Gediz River basin is quite sensitive to drought conditions, and the agricultural sector is significantly affected by irrigation deficits (Yilmaz and Harmancioglu, 2010). Al-Omari *et al*. (2009) proposed a Water Management Support System using WEAP model in Amman Zarqa Basin in Jordan. In their study the water resources and demands of Amman Zarqa Basin in Jordan were modeled as a network of supply and demand nodes connected by links (Al-Omari *et al*., 2009). The results showed that domestic and industrial demands can be satisfied by proper management of the available resources (Al-Omari *et al*., 2009).

2.10.2 Water Resources Yield Model (WRYM)

This model was developed in South Africa. The model was applied in joint water resource studies with the aim of coming up with water sharing agreements (Juízo and Lidén, 2010). The SADC region prefers WRYM model as a tool for system analysis for international basins (Carmo Vaz and van der Zaag, 2003). The model has been used in the Inkomati and Umbembezi river basin for system analysis. According to Juízo and Lidén (2010) the model relies on a solver that optimizes the water allocation in a river system based on a set of penalties for storage, channels and demands at various nodes and links. The model uses a penalty structure to make decision to store water or allocate water in a system. Links used to supply water to reservoirs are assigned penalties. The WRYM networks are analysed and solved using the selected penalties structures. According to Juízo and Lidén (2010) network solver will minimize the penalties for each time step by choosing the best allocation of water to the different users. The route with minimum penalties is the most attractive used to transfer water to different demand zones from the storage zones.

2.10.3 Water Allocation Flow Model in Excel (WAFLEX) Model

Water Allocation Flow Model in Excel (WAFLEX) is a model that makes use of the spreadsheets. According to Juízo and Lidén (2010) it is a simple model that uses spreadsheets to simulate complex systems and is easy to build as everything is done in EXCEL spreadsheets. It is a spreadsheet simulation model governed by the equation of continuity and the fact that water flows from upstream to downstream. WAFLEX calculates the water demands, supply, and therefore the water shortages as a result of the present management of the system based on a schematisation of the river catchment.

WAFLEX was used in several countries in the SADC region. Mhizha (2000) applied WAFLEX model for reservoir operation in Manyame catchment. Symphorian *et al.* (2003) used the model in the Save catchment to simulate releases from the Osborne dam in order to determine environmental water requirements and concluded that the model can be used to generate environmental releases for Odzi River and it was recommended that the model can be adopted as an aid to environmental flow allocation by the Save Catchment. Khosa (2007) applied the WAFLEX model in the Thuli catchment of Zimbabwe to evaluate the effects of upstream water demand scenarios on downstream users in order to improve on the management of the water resources. The study concluded that at current development levels the water resources in the basin were not enough to meet demands as evidenced by shortages for downstream projects. It was recommended that proposed developments need to be in line with water demand management measures.

CHAPTER THREE

3.0 Study area

3.1 Introduction

The objective of this section is to show the location of the study area in Zimbabwe and in the Pungwe basin. A brief description of the area's climate and hydrology is presented.

3.2 Study Area

Pungwe Basin is shared between Mozambique and Zimbabwe. The Zimbabwean part of the Pungwe Basin is administratively known as the Pungwe sub catchment. The location of Pungwe sub catchment in Zimbabwe and in the Pungwe basin is shown in Figure 2. The sub catchment is located approximately between the latitudes 18° 10'S and 18° 50'S and Longitude 32°37'E and 33° 5 E. Pungwe Basin drains a total catchment area of 31,151 km^2 of which 1,461 km^2 (4.7%) is in Zimbabwe while 29,690 km^2 (95.3%) is in Mozambique. Although Pungwe sub-catchment covers some 5% of the Pungwe basin, it is estimated to produce 28% of the natural runoff (Tapela, 2002). Pungwe sub-catchment contributes a significant proportion of the river's total annual discharge, due to the relatively high precipitation received throughout the year in this upland portion of the Pungwe basin (Tapela, 2006). The sub catchment comprises of three major rivers which are Pungwe River, Honde River Nyamukwarara River that drain into Mozambique from the Eastern Highlands of Zimbabwe. It has only one large dam on the Nyawamba River, a tributary of the main Pungwe River, with the capacity of 17 million m^3, and a small 40,000 m^3 impoundment on the Nyamatsupa River again on the main Pungwe River. The Nyawamba Dam is owned and operated by the Eastern Highlands Tea Estate. Major water supply scheme located on the Pungwe River is the Pungwe Mutare Water Supply Project. Other water supply schemes comprise of small piped water supply systems on tributaries of the Pungwe River and several small irrigation schemes.

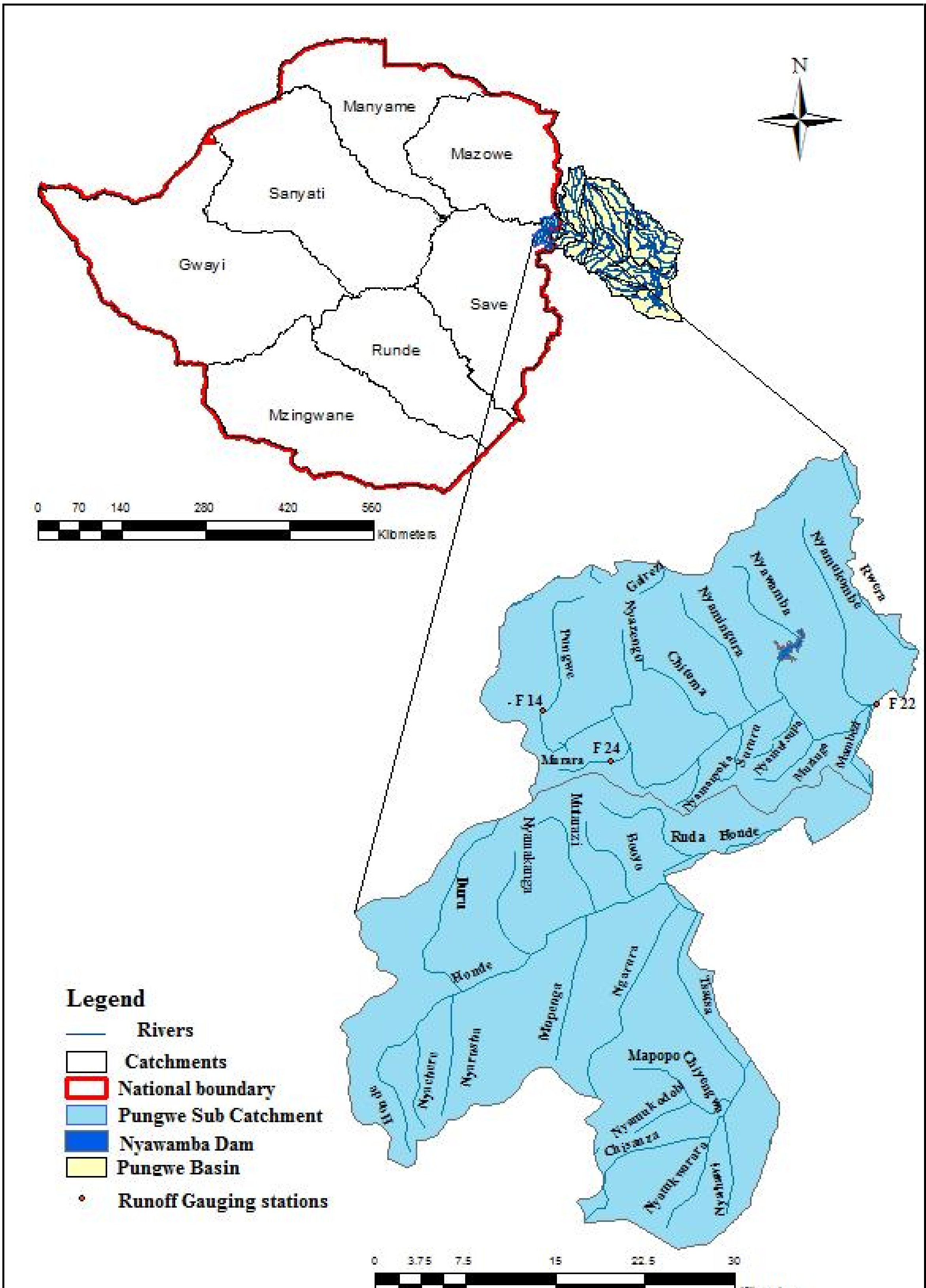

Figure 2 Location of Pungwe Sub catchment

3.3 Climate

Pungwe sub catchment lies in agro ecological region 1 of Zimbabwe which receives above 1500 mm of rainfall per year although the low altitude areas receive less rainfall. The rainfall season of the sub catchment stretches from October to April. The period from May to September is typically dry with very little or no rainfalls being received. The monthly distribution of rainfall between Luleche station and Agritex Hauna Growth Point station are shown in Figure 3. Luleche station received its highest rainfall of about 513 mm during the month of March whist for AGRITEX Hauna station the highest rainfall of 323mm was received during the month of February. Figure 3 shows that Luleche station received rainfall throughout the year whilst the AGRITEX Hauna station had some dry months. There is great variation of rainfall in the Sub catchment with some areas receiving above 2000 mm per year whilst others just received about 1000mm per year. The northern parts of the catchment receive highest rainfall as compared to the southern parts of the catchment. Luleche station receives high annual rainfall totals above 2000mm whilst AGRITEX Hauna Growth Point station receives about 1000mm on average. Rainfall distribution also varies from Eastern parts of the catchment to the Western parts of the catchment. The average annual evaporation in the catchment is about 1700mm per year.

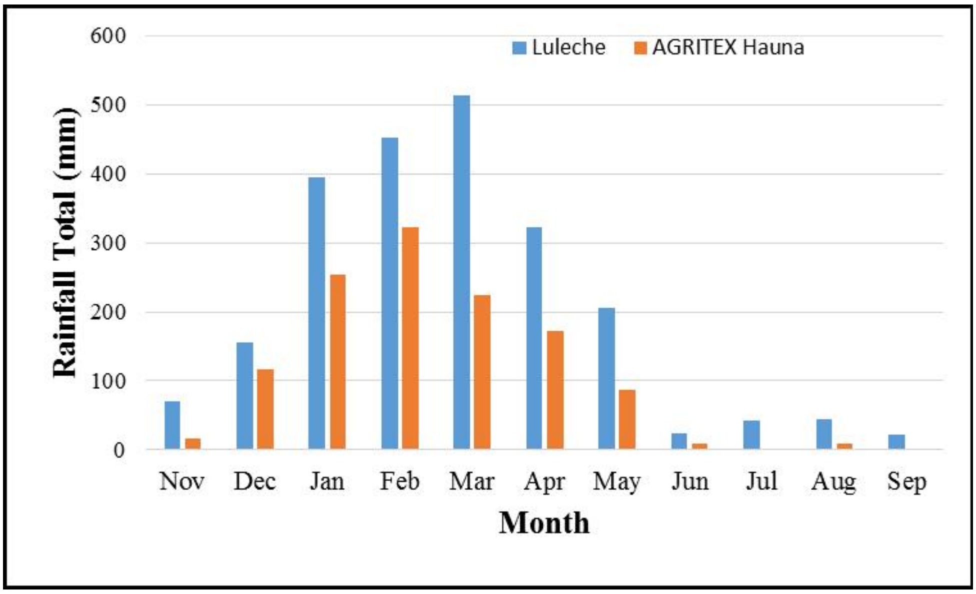

Figure 3 Average monthly rainfall distribution

3.4 Topography and slopes

The Pungwe sub catchment is a highly mountainous catchment. The altitude ranges from 2500 m to 600 m. The altitude at Pungwe Falls is 1500 Metres Above Sea Level (MASL) and the high peak areas such as Mount Inyanga is up to 2500m. The Pungwe River originates 3 kilometres north-west of Mount Inyanga at an altitude of 2120 m. The river flows in an easterly direction and crosses the Mozambique border at an altitude of 600 m above sea level The Honde River originates at an altitude of 1 440 metres above sea level at Watsomba village in the Tsonzo Purchase Land. The Nyamkwarara River rises at an altitude of 1740 metres above sea level in the Stapleford Forest north of Mutare. The river flows through low lying areas at about 1000m to 300m. Figure 4 shows the altitude ranges for Pungwe sub-catchment.

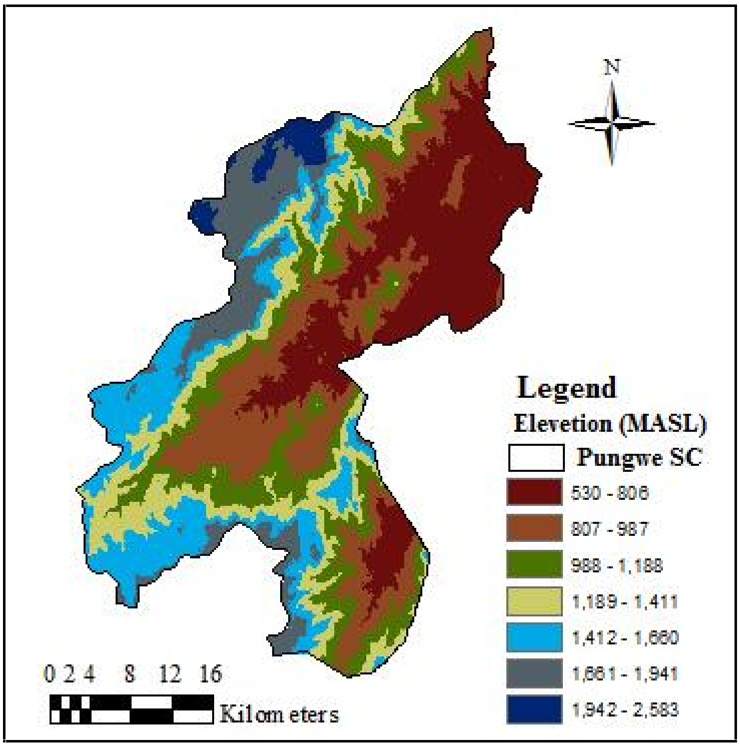

Figure 4 Elevation levels for Pungwe sub catchment

Pungwe sub-catchment is a very mountainous area with slopes ranging from 0% to 72% as shown in Figure 5. The slopes are very important physical characteristics of catchment as they affect the drainage, drainage density of the sub catchment and concentration time of surface runoff. The slope percentages were also used in the estimation of the Pitman parameters.

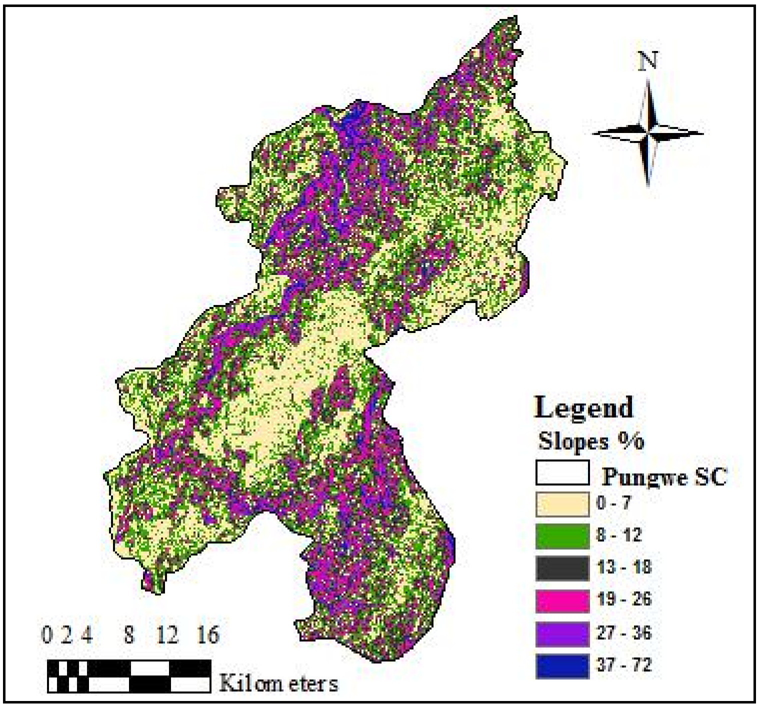

Figure 5 Percentage slopes for Pungwe sub catchment

3.5 Geology and Hydrogeology

The catchment consists of the following geological formations which are gneiss, granite, dolerite and serperntine (SWECO, 2004). The catchment is underlain by non-porous and impermeable basement rocks ground water is governed by fracture zone and weathered zones. The granites and gneisses have low ground water potential. Borehole yields for granite formations varies from 0.1-2l/s whilst for gneiss the yield is less than 1 l/s. The depth to ground water level ranges from 10 to 20m for granites formation (SWECO, 2004). The depth to ground water level for gneiss lies between 15 to 30m. The dolerite formations are generally resistant weathering and they have high borehole yields varying from 1-3l/s. Depth to ground water levels generally ranges from 10 to 30m. The geology and hydrogeological formations of the catchment are shown in Figure 6.

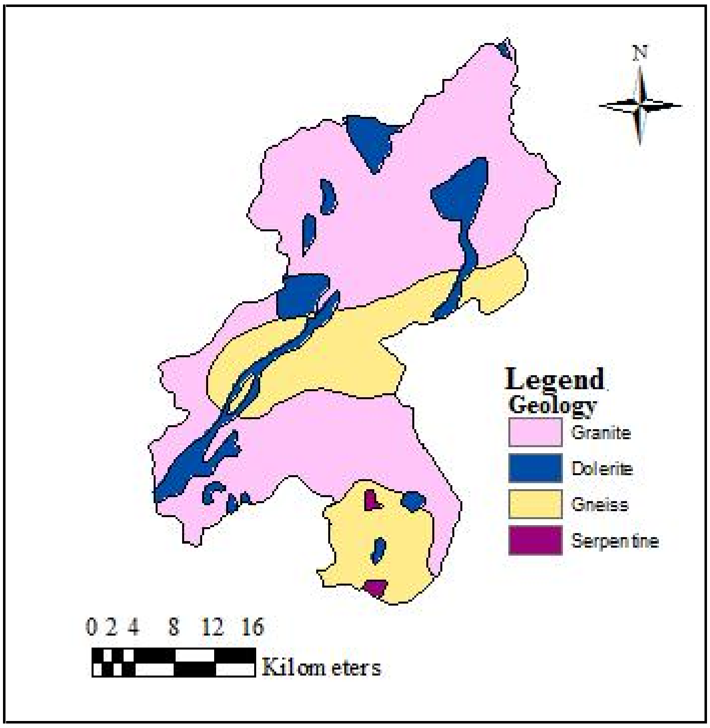

Figure 6 Geology of the Pungwe sub catchment

3.6 Soils

The major soil types in the sub-catchment are lithic leptosols, stagnic phaeozems, fellic soils, haplic arisols, haplic lixisols and chomi-feralic cambisols. The spatial distribution in the sub-catchment is as shown in Figure 7. Determination of soil types in the sub-catchment was very important as one of the physical catchment characteristic which was used in the estimation of Pitman model parameters.

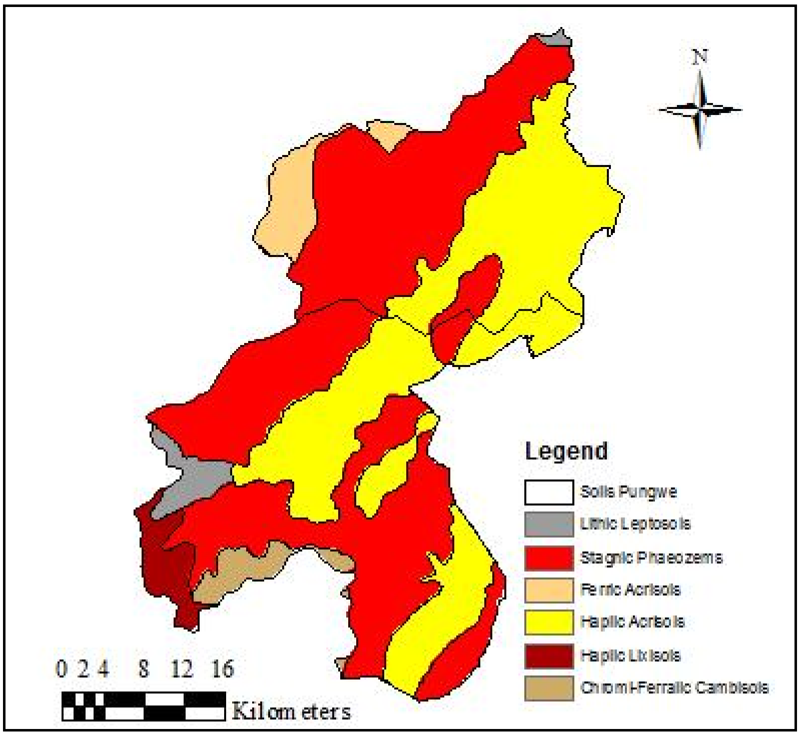

Figure 7 Soil types in the Pungwe sub catchment

CHAPTER FOUR

4.0 Materials and Methods

4.1 Introduction

This chapter outlines the procedures that were used in data collection and analysis. Data for this research was obtained from various institutions which are Meteorological Services Department, Department of Irrigation, Department of Agricultural Extension Services (AGRITEX) and Zimbabwe National Water Authority (ZINWA). The data that was obtained include rainfall, runoff, water permits and evaporation data. Also desktop study was done on the study area to determine the physical characteristics of the catchment. Some demand sites were visited to determine the amount of water being abstracted.

4.2 Data collected and data quality control

Historical data for rainfall and runoff need to be corrected before it is used to estimate water resources. Records normally have errors which can affect estimated values such as mean annual runoff. The rainfall, runoff and evaporation data were physically checked for missing values and outliers. The outliers were replaced with computed from correlation with the nearest station as appropriate for the whole period for each station.

4.2.1 Rainfall data

The rainfall data were collected from Nyanga Research station, Agritex Hauna station and Luleche station. Nyanga Research station was generally of better quality as compared to Hauna station and Luleche station. Generally the data for these stations was of good quality with few gaps. The data gaps on Agritex Hauna station were filled using correlation with Nyanga Research station.

4.2.2 Runoff data

The runoff data from gauging stations F14, F22 and F23 were collected. F14 station is located in the Nyanga national park just downstream of Mutare intake. The data was generally of good quality and reliable. However there were extremely peak flows. The data collected from F14 was from 1960 to 2009 and for F22 was from 1997 to 2012. Runoff gauging station F22 (Katiyo) is just upstream of Zimbabwe Mozambique border. The data was generally of good quality with few gaps. The data for F23 collected was from 2014 to 2016. The data was of good quality with no gaps. F23 gauging station is located on the Honde River.

4.2.3 Water permits data

The water permits data was collected from ZINWA offices and Pungwe Sub Catchment. Of great importance to this data was the grid reference which shows the exact physical location from which the water is being abstracted. The grid references were very important in locating the tributaries from which the water was abstracted.

4.3 Spatial and temporal surface water availability in the catchment

The Pitman model was set up to estimate surface runoff generated in the Pungwe micro catchment (FP) and Honde micro catchment (FH). The model requires catchment area, rainfall and evaporation data as input variables. The catchment areas for the tributaries of Pungwe River and Honde River were calculated from 1 in 50 000 topographic map. The runoff data obtained from the Zimbabwe National Water Authority for gauging station F14, was used for the calibration and validation of the Pitman Model. The rainfall and evaporation data obtained from the Meteorological Services Department of Zimbabwe and Hauna AGRITEX office was used as input data for the model. The rainfall data from 1960 to 2014 was used.

The simulated runoff was calibrated using observed runoff from gauging station F14. The model was calibrated using data from 1970 to 1985 and validated using a different set of data from 1986 to 2009. After the calibration and validation the model was applied to obtain extended time series runoff of 54 years length from October 1960 to September 2014.

Table 2 Calibration parameters of the Pitman Model

Parameter	Parameter value	Units	Description
PI	Estimated	mm	Interception storage
AI	Estimated	none	Ratio of impervious area
ZMIN	Calibrated	mm/month	Minimum catchment absorption rate
ZMAX	Calibrated	mm/month	Maximum catchment absorption rate
ST	Estimated	mm	Maximum moisture storage capacity
SL	0	mm	Moisture storage capacity below which runoff occurs
FT	Estimated	mm/month	Runoff from moisture storage at full capacity
GW	Calibrated	mm/month	Maximum groundwater runoff
R	0	none	Evaporation moisture storage relationship parameter
POW	Calibrated	none	Power of the moisture storage runoff equation
TL	Calibrated	months	Lag of surface and soil moisture runoff
GL	1.5	months	Lag for ground water runoff

The Pitman model has 12 parameters that were calibrated manually. Some model parameters values were estimated using physical catchment characteristics and other parameter values were obtained by calibration. Meigh and Fry (2004) suggested that in catchments with good vegetation cover, temperate to humid climates and naturally perennial flow systems the calibration emphasis should be placed on parameters POW, FT, GW, R and ST whilst in semi-arid to arid catchments emphasis should be placed on ZMIN, ZAVE and ZMAX. Since the Pungwe sub-catchment has good vegetation cover and has perennial river flows the calibration process was done on the following parameters POW, FT, GW, R, and ST. The researcher estimated the values of the following parameters POW, FT, GW, R, and ST using physical catchment characteristics whilst the values of other parameters was obtained from the calibration process by fine tuning them to match simulated values with observations. Table 2 shows the Pitman parameters values which were estimated from catchment characteristics, calibration and set as default values. Figure 8 and Figure 9 shows the schematic setup of the Pitman model for the Pungwe micro catchment and Honde micro catchment respectively. The method used to estimate the Pitman parameters is described in section 4.4.1.1 to 4.4.1.7.

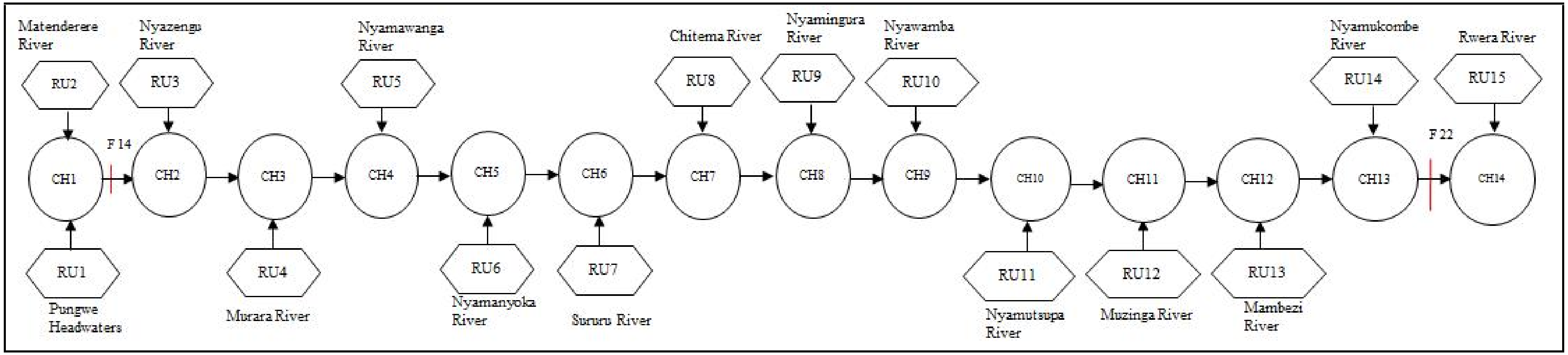

Figure 8 Pungwe Micro catchment Pitman Model schematic set up

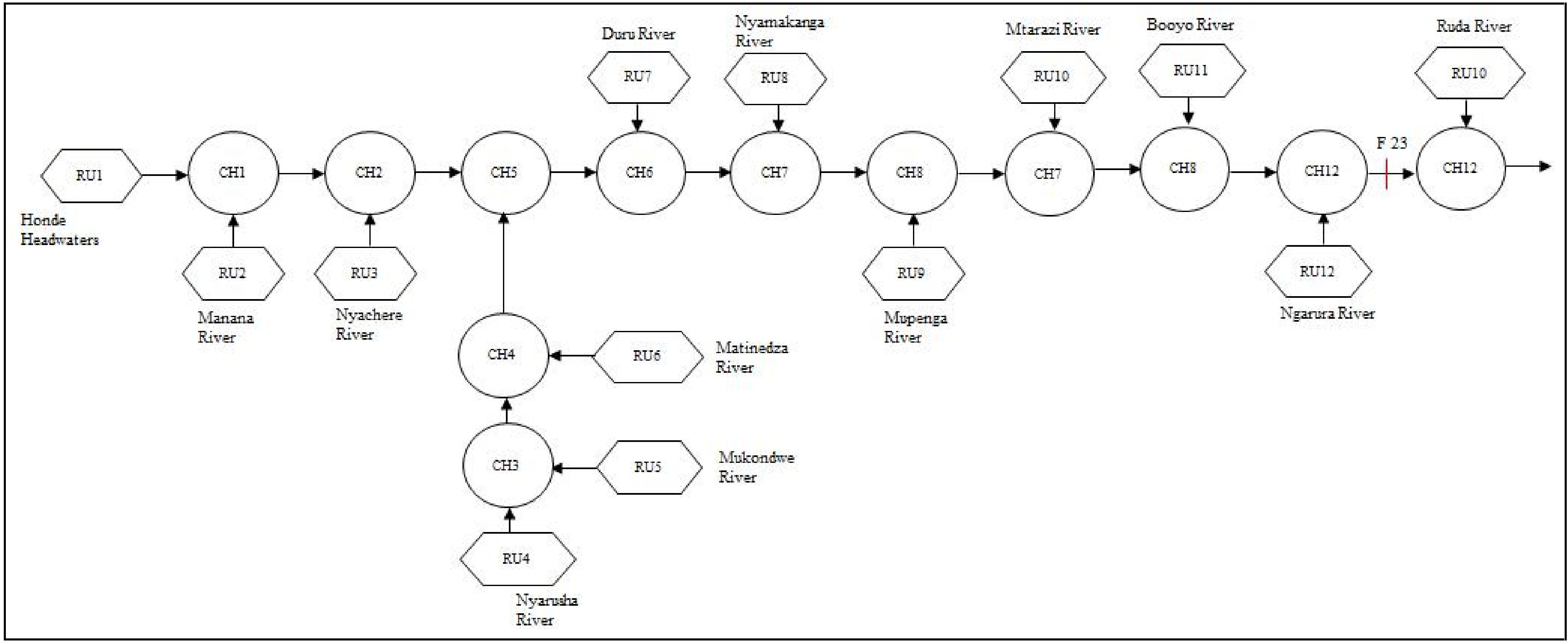

Figure 9 Honde Micro Catchment Pitman Model schematic set up

4.4 Estimation of Pitman Model Parameters

4.4.1 Interception (PI)

Intercepted rainfall can be varied by adjusting the parameter (PI) which is the monthly interception. If rainfall occurs some of it is intercepted by foliage and other objects that stops the rain from reaching the ground. The Equation 3.1 was used to calculate interception as derived by Pitman (1973)

$$I = x(1 - e^{yp}) \quad \dots\dots\dots 3.1$$

$$I = 40 \times (1 - e^{1 \times -0.011})$$

Where

I = Total interception for the month (mm)

P = total precipitation for the month (mm)

y, x = dimensionless constants derived from equation below.

$$x = 13{,}08\pi^{1{,}14} \quad \dots\dots\dots 3.2$$

$$y = 0{,}00009\pi^{0{,}75} - 0{,}011 \quad \dots\dots\dots 3.3$$

4.4.2 Maximum moisture storage capacity (ST)

ST represents the sum of the soil moisture storage (ST_{soil}) and storage in the fracture zone (ST_{unsat}) (Kapangaziwiri, 2008b). ST_{unsat} has the potential to contribute to interflow. ST_{soil} is the soil storage depth at saturation. It is measured in mm. It represents store of infiltrated water before it is lost through evapotranspiration, percolation and runoff. The value of ST_{soil} was estimated using the Equation 3.4.

$$ST_{soil} = POR \times DEP \ (mm) \dots\dots\dots 3.4$$

Where

POR = Porosity (%)

DEP = soil depth (mm)

The soil depth was obtained from the soil maps and from literature. The basin slope ranges from 15%-70% and soil depth ranges from 100-150cm (ISRIC, 2005). The dorminant soil type in the catchment was obtained from 1 in 50 000 soil map for Zimbabwe. The dorminant soil type in the catchment is clay sand soil and the porosity was obtained from Table 3.

Table 3 Showing textural classes and assumed porosity

Source (James, 1972)

Texture class	**Assumed Porosity %**
Sand	42
Loamy sand	40
Sand clay loam	33
Sandy clay	32
clay	39

Storage in the fracture zone (ST_{unsat}) was estimated using equation 3.5. ST_{unsat} has the potential to contribute to interflow. The depth to ground water is 10m (Mazvimavi, 2003).

$$ST_{unsat} = storativity \times DGW\ (mm) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.5$$

Therefore

$$ST = ST_{soil} + ST_{unsat} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.6$$

4.4.3 Runoff from moisture storage at full capacity (FT)

It is the maximum subsurface outflow when the basin's soils are saturated. It occurs through the banks of the active channel. The drainage density ranges from 2,1- 4,0 km/km^2 and depth to the water table is less than 10m (Mazvimavi, 2003). Estimation of FT_{soil} is given by equation 3.7. The hydraulic conductivity values from the literature were used.

Table 4 Hydraulic conductivities from different textural classes

Texture class	(Hughes, 1997)	(Gupta and Sorooshian, 1985)	Estimation from permeability (James, 1972)
sand	4,03	5.04	4.98
Loamy sand	1,22	1,47	1.23
Sand clay loam	0.38	0.10	0,39
Sand clay	0.62	0.03	0,43
clay	0.08	0.01	0.08

$$FT_{soil} \quad = \quad CA \times K \times BS \times 30/100 \quad \text{..}3.7$$

Where

FT_{soil} = maximum subsurface outflow (mm)

K = saturated hydraulic conductivity of the basin soils

BS = mean basin slope

CA = contributing area

where

$$CA \quad = \quad 2 \times DD \times DEP \ /1000 \quad \text{..}3.8$$

Where

DD = Drainage density (km/km^2)

DEP = soil depth (m)

(FT_{unsat}) was determined by equation 3.9

$$FT_{unsat}\ (mm) \quad = \quad 2 \times DD \times T \times VS \times 30/100 \quad \text{..............................}3.9$$

T = Transmissivity (m^{2}d^{-1})

DD = Drainage density

VS = drainage vector slope

The drainage vector slope was assumed to be the same as the basin slope which is 30%

Therefore

$$FT \quad = \quad FT_{soil} + FT_{unsat} \quad \text{..}3.10$$

4.4.4 Power of the moisture storage runoff equation (POW)

POW defines the power (exponent) of the non-linear relationship between the soil moisture content and interflow (Eckhardt and Arnold, 2001). Moisture movement is slower through poorly drained soils and gentle slopes (giving higher values of POW), but quite fast in steeper areas with well-drained soils (lower POW) (Mwelwa, 2004). The basin has steep slopes, well vegetated and deep weathered sand loams (with some clay lenses) (James, 1972).

4.4.5 Minimum and Maximum catchment absorption rate (ZMIN, ZMAX)

Parameters ZMIN, ZAVE and ZMAX are used to quantify the infiltration excess flow process in the model. The parameters depend on the soil surface conditions (determining infiltration rates), the size of the soil moisture store, number and spacing of rain days (which influence the antecedent moisture conditions at the start of a rainstorm event) and typical storm durations (indicative of expected rainfall intensities) (James, 1972; Eckhardt and Arnold, 2001). The values for ZMAX and ZMIN used in this research was obtained through calibration. The values of ZMIN and ZMAX was changed manually until the observed runoff resembles the simulated runoff.

4.4.6 Lag for ground water runoff (GL) and Evaporation moisture storage relationship parameter (R)

For these parameters GL and R default values from the model can be used if there is insufficient data to estimate the parameters. Therefore the default values of 0 for R and 1.25 for GL were used.

4.4.7 Moisture storage capacity below which runoff occurs (SL)

It is the soil moisture storage level below which no runoff from the soil occurs. Generally the value of 0 is used. The researches done by (Rosenbrock, 1960; Mwelwa, 2004) uses the value of zero and they managed to get good results of simulated rainfall. In this research the value of 0 was used.

4.5 Current water uses in the sub-catchment

Water permits issued by the Pungwe sub catchment council were used to estimate water demand for different water sectors. CROPWAT 8.0 model was used to determine irrigation water requirements. CROPWAT is a decision support system developed by the Land and Water Development Division of FAO for planning and management of irrigation (FAO, 1998). It is a tool that is used to carry out standard calculations for reference evapotranspiration, crop water requirements and irrigation requirements. CROPWAT 8.0 model uses the recommended FAO Penman-Monteith method for estimating crop evapotranspiration (FAO, 1998). The meteorological data (such as rainfall, temperature, ET_o, humidity wind speed, sunshine hours and radiation) used in CROPWAT 8.0 model were obtained from Nyanga Research station from the FAO database. These water demands for different water use sectors were later used as input data for the WAFLEX model.

Water use in the Pungwe Sub-catchment is divided into four main categories which are primary water use, Urban Industry Mining (UIM), irrigation and hydropower generation. Under primary water use and UIM there is water used in schools, hospitals, clinics, business centres, Hauna growth point and inter-basin transfers to Mutare city. Water users under irrigation are large scale commercial farmers, small scale communal farmers and government irrigation schemes. In the sub-catchment there are five private hydropower generation companies. The terrain in the sub-catchment allows most of the water users in the different categories to abstract their water through gravity fed pipelines. Most of the government irrigation schemes and small scale communal farmers use High Density Polyethylene pipes (HDPE) to abstract water from rivers by gravity. The pipe sizes used to abstract water for irrigation ranges from 12mm diameter to 250mm diameter pipes depending on the amount of water to be abstracted.

Estimation of the actual water use in the sub-catchment was done through the use of water permit data from the sub-catchment. Water permits issued by the Pungwe sub catchment council were used to identify, quantify and classify water uses in the sub-catchment.

4.5.1 Irrigation water use

Data on crops grown, cropping pattern and area under irrigation was collected from records kept by Department of Irrigation and Agricultural Extension Services of the Ministry of Agriculture, Mechanisation and Irrigation Development stationed at Hauna Growth Point. Radom sampling was done to some irrigation schemes to check the correspondence of the data obtained from the water permits data base and the crop water requirements. Rainfall and evaporation data was obtained from the Department of Meteorological services and

AGRITEX. Crop characteristics data was obtained from FAO irrigation manual**.** The crop water requirements were computed using CROPWAT 8.0 model.

4.5.2 Primary water use and UIM water use

The major water users in this category are Mutare City, Hauna Growth Point, insititutional centres (schools, clinics, hospitals) and rural business centres. Primary water use is the water that basic human consumption and water to sustain the environment and the ecosystems Urban Industry and Mining (UIM) is the water that is used for urban **d**omestic water use, industrial water use and mining water use. For Mutare City and Hauna growth point and institutional centres the abstraction records, water permits and population growth were used to estimate the water use. For water abstracted using gravity fed polyethylene pipe equation 3.11 was used to determine the actual water use.

$$Q = C \times A \times \sqrt{2gh} \quad \text{...} 3.11$$

Q = Discharge (m^3 /s)

C = Discharge coefficient, approximately 0.5

A = Cross-sectional area of pipe (m^2)

g = Gravitational force (9.81 m/s^2)

h = Available head (m)

4.5.3 Hydropower generation

For hydropower generation the actual water use was determined using records of power generated by these stations since the amount of electricity generated depends on flow rate. Under the hydropower generation there is non-withdrawal hence the water is going to be used with downstream users. Also actual water use was determined using equation 3.11.

4.5.4 Downstream water users

The actual water flow measured from gauging station F22 on the Pungwe River and F23 on the Honde River were used to determine whether Zimbabwe is meeting its international obligation of downstream flows to Mozambique. The Zimbabwean government has an international obligation to release 25% of the generated runoff downstream to Mozambique under Mozambique Zimbabwe Joint Water Agreement.

4.6 Water Demand Scenario development

The models were run to assess water shortages under different water demand scenarios as described in Table 5. Water shortages on each scenario were noted. The performance of different water allocation practices (systems) were assessed considering the projected water demand for both Pungwe micro-catchment and Honde micro-catchment. The water demand scenarios are going to be affected by social-economic developments in Zimbabwe. Scenario 1 is based on the assumption that current water demands remain unchanged due to hardship in social economic conditions in the country. Scenario is based on the assumption that there is going to be a steady in the improvement in social and economic conditions in country resulting in medium increase in water demand in the catchment. Scenario 3 is based on the assumptions that there is going the considerable improvement in the social and economic conditions which would trigger high increase in water demands.

Table 5 Development of scenarios for Pungwe sub-catchment

Scenario	Description
1	This was considered as the base scenario. The current water allocation practices was assessed using the current inflows and water demands. This scenario was testing the effects current water allocation practice on water shortages
2	This scenario considers steady improvement in social economic conditions Projected water demand for 2020 and 2030 due to population growth and medium irrigation growth were considered. This was tested using different water allocation practices.
3	The scenario is based on considerable social and economic improvement. Projected water demand for 2020 and 2030 due to population growth and high irrigation growth This scenario was tested using different water allocation practices.

Different water allocation practices were run considering the projected water demand under scenario 2 and 3. Scenarios 2 and 3 considers the population growth for Mutare city and Hauna Growth point. The population growth of 1.3% and 5% for small towns was used to project water demand for Mutare city and Hauna Growth Point respectively (Central

Statistics Office, 2012). For medium irrigation growth an annual growth rate of 5% was used to estimate water demand for irrigation whilst for high growth and annual growth rate of 15% was used to estimate irrigation water demand.

$$P_n = P_o (1 + r)^n \quad \text{...} 3.12$$

P_n = *number of people after n years*

P_o = *initial number of people*

r = *population growth rate* %

n = *number of years*

4.7 WAFLEX Model development

The WAFLEX model was setup for the Pungwe Micro-catchment and the Honde Micro-catchment. The WAFLEX model performs a mass balance of flow sequentially down a river system, making allowance for abstractions and inflows. In this research water used for the same purpose in a tributary was lumped for the easy of presentation of the model. In the Honde Micro-catchment the model was only set for the Honde River and its tributaries. The model did not include Nyamkwarara River and its tributaries since if joins Honde River in Mozambique. The schematic for WAFLEX model for Pungwe Micro-catchment and Honde Micro-catchment are shown in Figure 11 and 13 respectively.

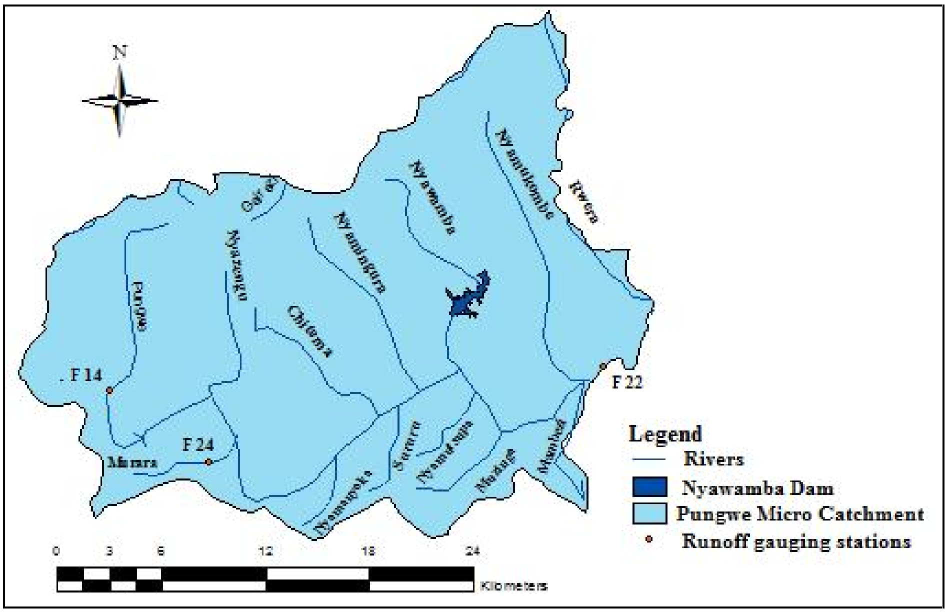

Figure 10 Pungwe Micro Catchment map

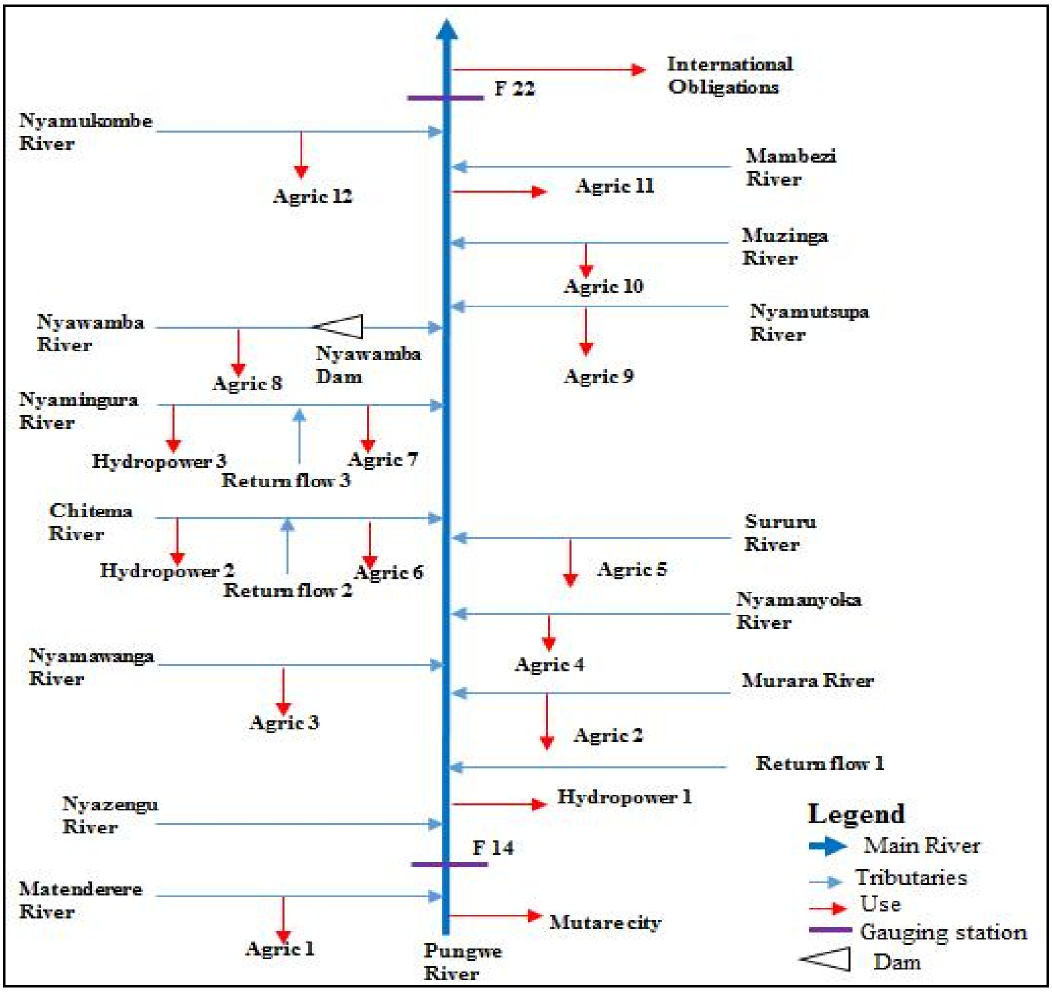

Figure 11 Pungwe Micro Catchment WAFLEX Model schematic set up

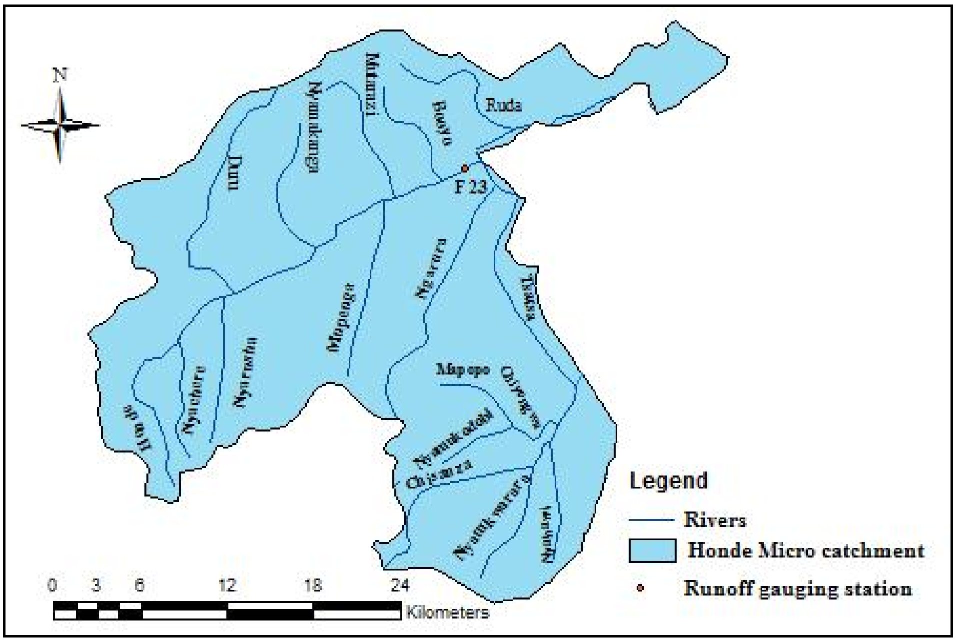

Figure 12 Honde Micro Catchment map

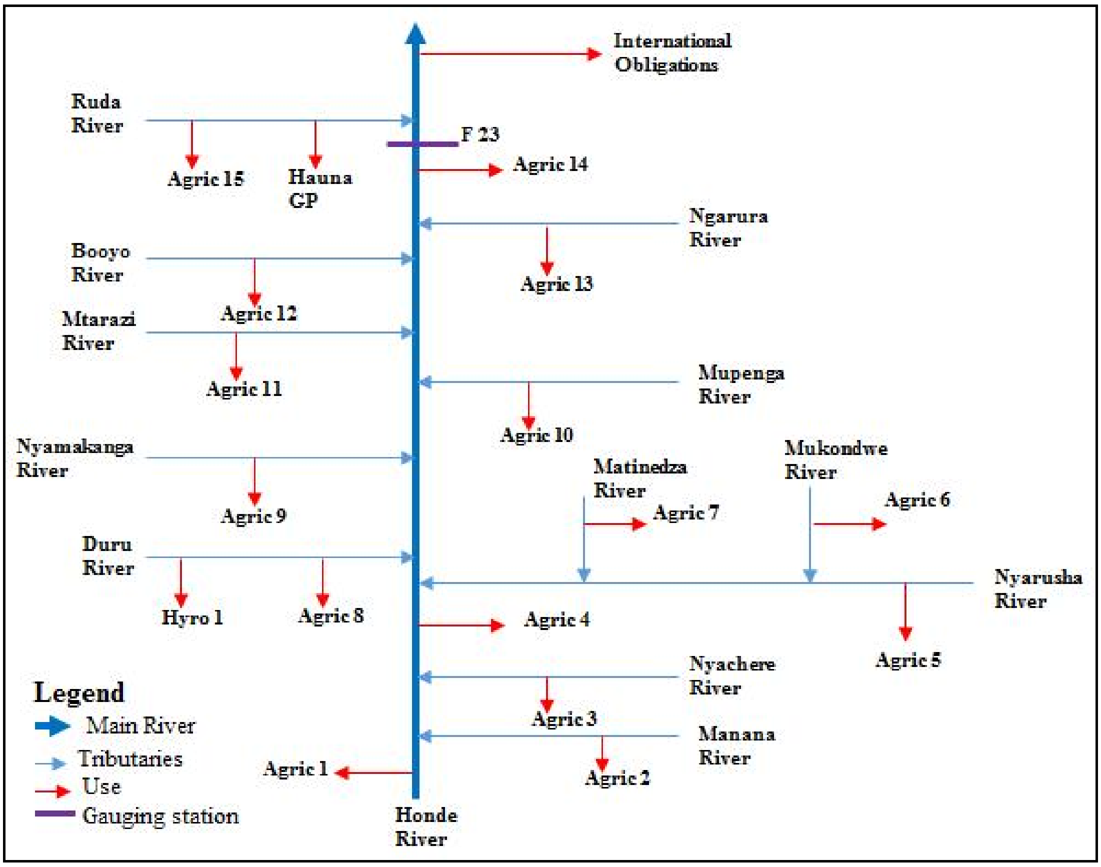

Figure 13 Honde Micro Catchment WAFLEX Model schematic set up

The first step in the development of model was the schematization of the supply and demand sheet of the river system. Inflow points, abstraction points, gauging station and reservoirs were shown in the supply and demand sheet. Water inflows from the supply sheet were summed from upstream to downstream whilst water demands from the demand sheet were summed from downstream to upstream. Water abstracted by hydropower generation was returned to the river downstream its abstraction point since it is a non-withdrawal use. On each cell water balance was calculated and each cell add available water on the upstream cell. Different colours were used to represent inflows and demands. At the confluence of a river and a tributary the cell should sum the flows from the two rivers. If a cell is downstream of an abstraction node the abstracted water should be subtracted from the cell upstream. If the abstracted water is greater than the inflow a zero is put since there are no negative flows. The model was run on monthly time step. Then input series data (inflows, demands and observed flows) were prepared and copied to columns. The VLOOKUP formula was used to look up time step calculations. The = (INDIRECT) function was used to link the supply and demand sheets. Equations were put on each node to allow abstractions. The VISUAL BASIC Program in Microsoft Excel was used to write micros. Figure 14 shows a simple schematic for WAFLEX model in excel spread sheet. Figure 14 is a portion of the upstream of Honde Micro-catchment WAFLEX model (Figure 13) up to agriculture demand 4.

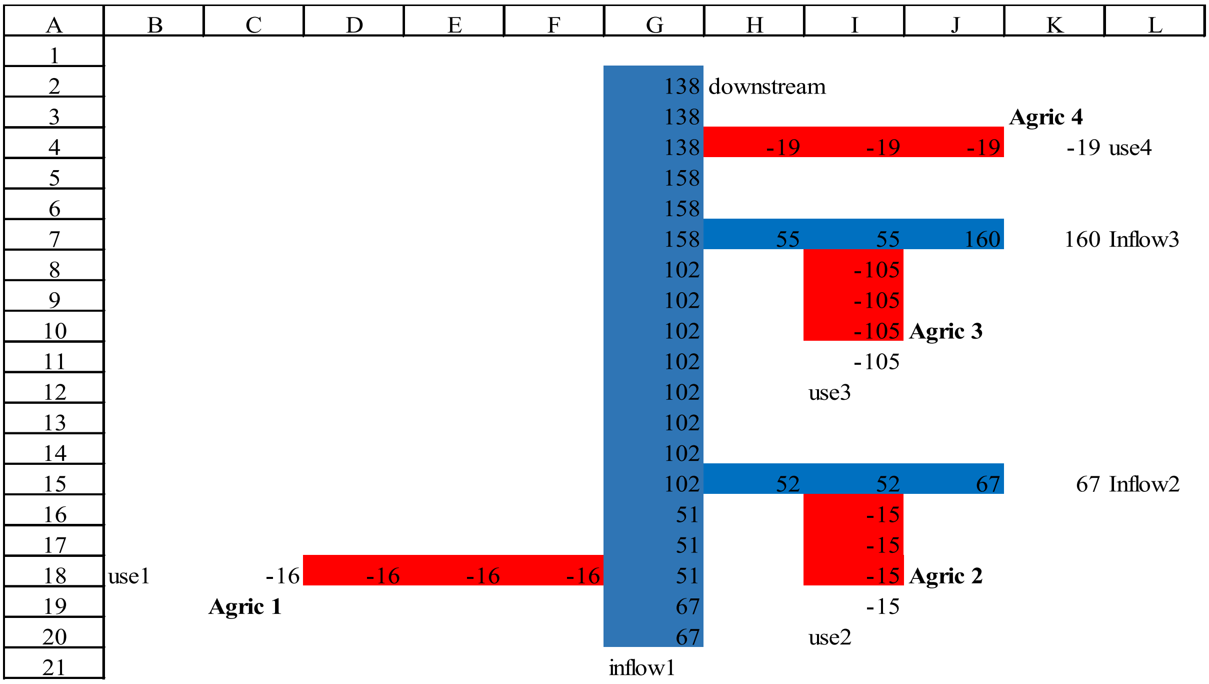

Figure 14 Simple schematic diagram showing the development of WAFLEX model in excel

The following Water balance equations are used in the development of the WAFLEX Model

At every demand Node

$$I - A = O \quad \text{..} 3.13$$

Where

$I = Inflows$

$A = Abtraction\ s$

$O = Outflows$

At a junction between two tributaries

$$I_1 + I_2 = O \quad \text{..} 3.14$$

Where

$I_1 = Inflow\ 1$

$I_2 = Inflow\ 2$

$O = Outflow$

Where the is a reservoir

$$I_r = O_r + A + \Delta S + E_r \quad \text{...} 3.15$$

Where

$I_r = reservoir\ \ Inflow$

$O_r = reservoir\ \ outflow$

$A = Abstractio\,ns$

$E_r = Evaporatio\,n\ \ from\ the\ \ reservoir$

$\Delta S = change\ in\ storage$

The performance of the model for Pungwe Micro-catchment was evaluated using the observed data from gauging stations F14 and F22 on the Pungwe River whilst for Honde Micro-catchment gauging station F23 on the Honde River was used. The data used to check the performance of the model at gauging station F14 was for four years whilst at gauging station F22 was for eight years. River inflows obtained from Pitman model were used as input data for the WAFLEX model. The current water allocation practice was used to test the model performance using the active permits.

Three different water allocation practices were assessed which are the current water allocation practice used by the sub-catchment, proportional combined with priority and market based water allocation practice.

A simple schematic of WAFLEX model with inflows and demands was used to develop different water allocation practices as shown in Figure 15.

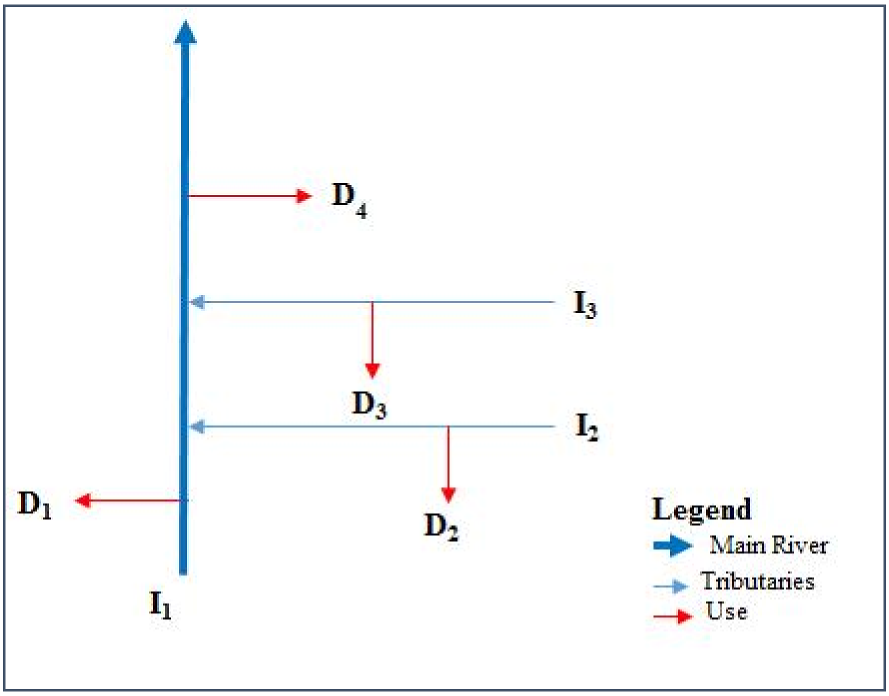

Figure 15 Simple schematic to illustrate development of different water allocation practices

4.7.1 Modelling current water allocation practice

The sub catchment council do an assessment of potential water users before the beginning of the hydrological year. This assessment is done by officers from the sub catchment when doing their water awareness campaigns and collection of water levies. The water permit holder who intend not to use the water in the next hydrological year have to inform the sub catchment council. The permit holders are then allowed to withdraw full amount of the water permitted.

4.7.2 Modelling Proportional water allocation practice

$D_t = D_1 + D_2 + D_3 + D_4$ 3.16

Where

$D_t = total \ \ total$

$D_1 = demand \ 1$

$D_2 = demand \ 2$

$D_3 = demand \ 3$

$D_4 = demand \ 4$

$A_v = I_1 + I_2 + I_3$ 3.17

Where

$A_v = Available \ water$

$I_1 = Inflow \ 1$

$I_2 = Inflow \ 2$

$I_3 = Inflow \ 3$

$if \ \ A_v < D_t$

then

$D_t = rD_1 + rD_2 + rD_3 + rD$ 3.18

where

r is the proportion al reduction factor in water demand

Under this water allocation practice water demands are reduced by the same proportion.

4.7.3 Modelling priority water allocation practice

Water users are given priority. The users with first priorities are satisfied first before the water is allocated to other uses. Under the priority water allocation practice different priority factors are given to different water users according to the priority. The priority factors ranges from 0 to 1. Under this water allocation practice when the runoff is sufficient to meet demands, the permits holder gets full amount of water permitted to them. There is no need to prioritise water allocation since there will be no water shortages when water available fails to meets demands water should be allocated to basic human needs such as drinking and environmental requirements before being allocated to other purposes. The remaining water available is then allocated to agriculture and hydropower generation. Since hydropower generation is non-consumptive use it is given first priority to agriculture. Farmers who are upstream of the hydropower abstraction point are deprived of water whilst the same water from the hydropower generation is returned and can be used by farmers downstream.

$$if \quad A_v < D_t$$
$$then$$
$$D_t = r_1 D_1 + r_2 D_2 + r_3 D_3 + r_4 D_4 \quad \text{.....................................3.19}$$
$$where$$
r_1 *is the priority reduction factor in water demand* 1
r_2 *is the priority reduction factor in water demand* 2
r_3 *is the priority reduction factor in water demand* 3
r_4 *is the priority reduction factor in water demand* 4

4.7.4 Modelling Market based water allocation practice

Under this market based water allocation practice the priority of water use is given to those uses with high market value. Those uses with high market value are given first priority to water use. The water demands are reduced using different factors according to the market value. The factor reduction ranges from 0 to 1. Major crops grown in this sub catchment are tea, coffee and bananas. The economic return of using a cubic meter of water in growing these crops is determined using the market prices of these crops. This was compared with the economic return in using water for hydropower generation and urban water supply. Under this water allocation practice the cost of setting up water supply infrastructure were not considered. The main advantage of this method is that water is used efficiently and that the water is secured for high use values

$$if \quad A_v < D_t$$
$$then$$
$$D_t = p_1 D_1 + p_2 D_2 + p_3 D_3 + p_4 D_4 \quad \text{.....................................3.20}$$
$$where$$
p_1 *is the market reduction factor in water demand* 1
p_2 *is the market reduction factor in water demand* 2
p_3 *is the market reduction factor in water demand* 3
p_4 *is the market reduction factor in water demand* 4

4.7.5 Evaluation of the water allocation practice

The water allocation practices were evaluated using the percentage shortage in amount, the percentage shortage in time and the number of users who are experiencing water shortages. The alternate with the least percentage shortage in amount and time were considered as the best water allocation practice for the sub catchment. The other evaluation criteria used was the percentage shortage in amount and time in satisfying international downstream flow obligations to Mozambique which is 25% of the generated runoff in Zimbabwe. The alternative with least percentage shortage in amount and time was considered as the best water allocation alternative.

CHAPTER FIVE

5.0 Results and Discussion

5.1 Surface water availability

The model was calibrated manually to find a good fit of the observed statistics. This is done by comparing observed and simulated runoff of the model. The performance of the model was checked by comparing the difference in mean annual runoff, standard deviation of annual flows and the coefficient of variability between the observed and simulated runoff. The difference between these should be less than 10% then the results from the model can be safely used for estimating surface runoff. Table 6 shows the relationship between of observed and simulated flows.

Table 6 Percentage difference between observed and simulated runoff

Index	**Units**	**Observed**	**Simulated**
Mean Annual Runoff (MAR)	10^6 m^3	95.98	95.29
Standard deviation of annual flows (S)	10^6 m^3	33.77	31.2
Coefficient of Percentage Variability (S/MAR)	Percentage	35.19	32.74
Autocorrelation coefficient of annual flows	-	0.21	0.23
Mean of logs of annual flows	10^6 m^3	1.95	1.95

The model was calibrated and validated as described in section 4.3. Figure 17 and Figure 18 shows the relationship between the simulated and observed flows using gauging station F14. Figure 17 shows the relationship between the simulated and observed runoff from 1970 to 1986 during the calibration of the model and Figure 18 shows the relationship between simulated and observed runoff during the validation of the model from 1986 to 2010.

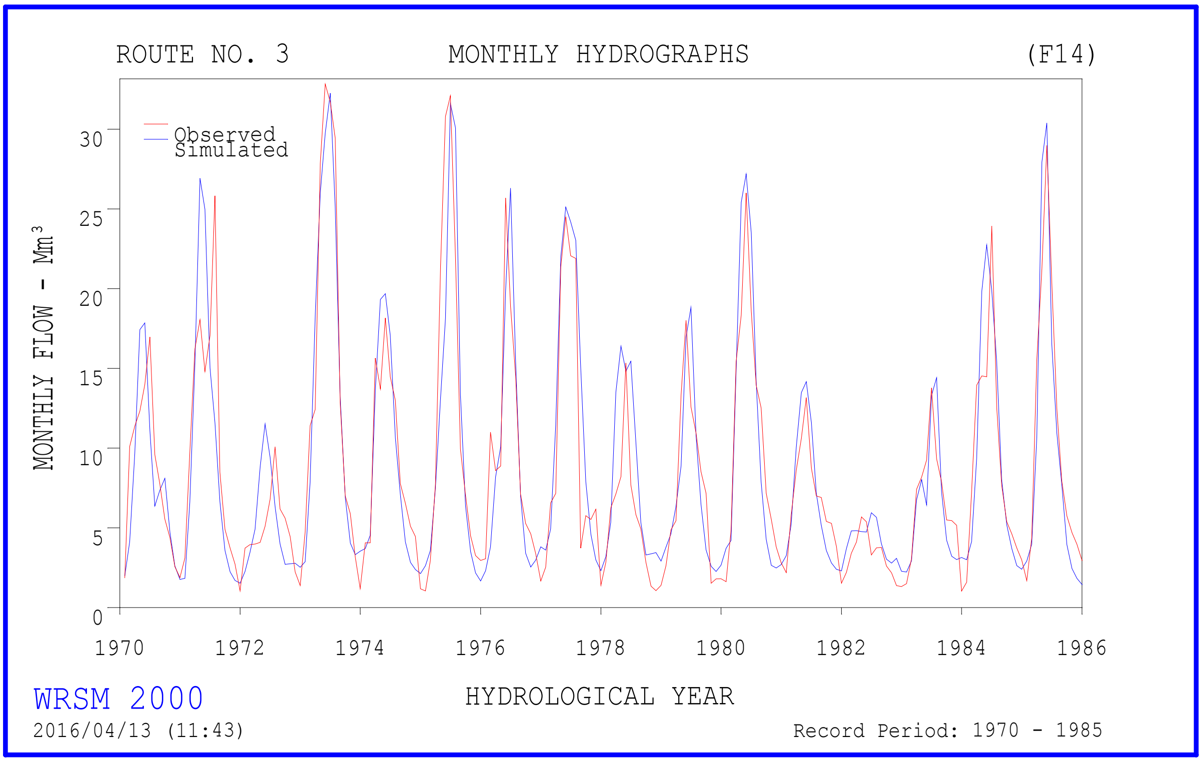

Figure 16 Observed and simulated stream flow from the calibrated Pitman model.

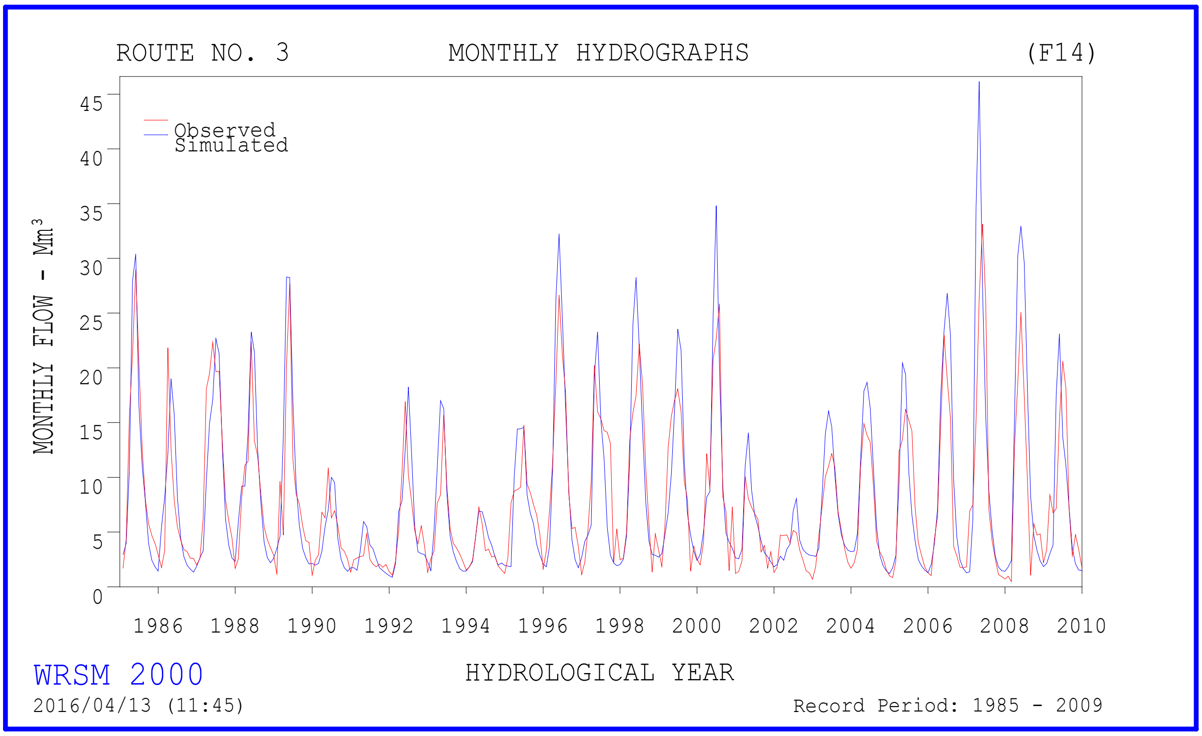

Figure 17 Observed and simulated stream flow for the validated Pitman model

The coefficient of determination of 0.70 shown on Figure 19 shows good results. The coefficient of determination was determined for 30 years from 1970 to 2009. This means that the calibrated Pitman model can be used to generate flows from ungauged parts of the Pungwe Micro-catchment.

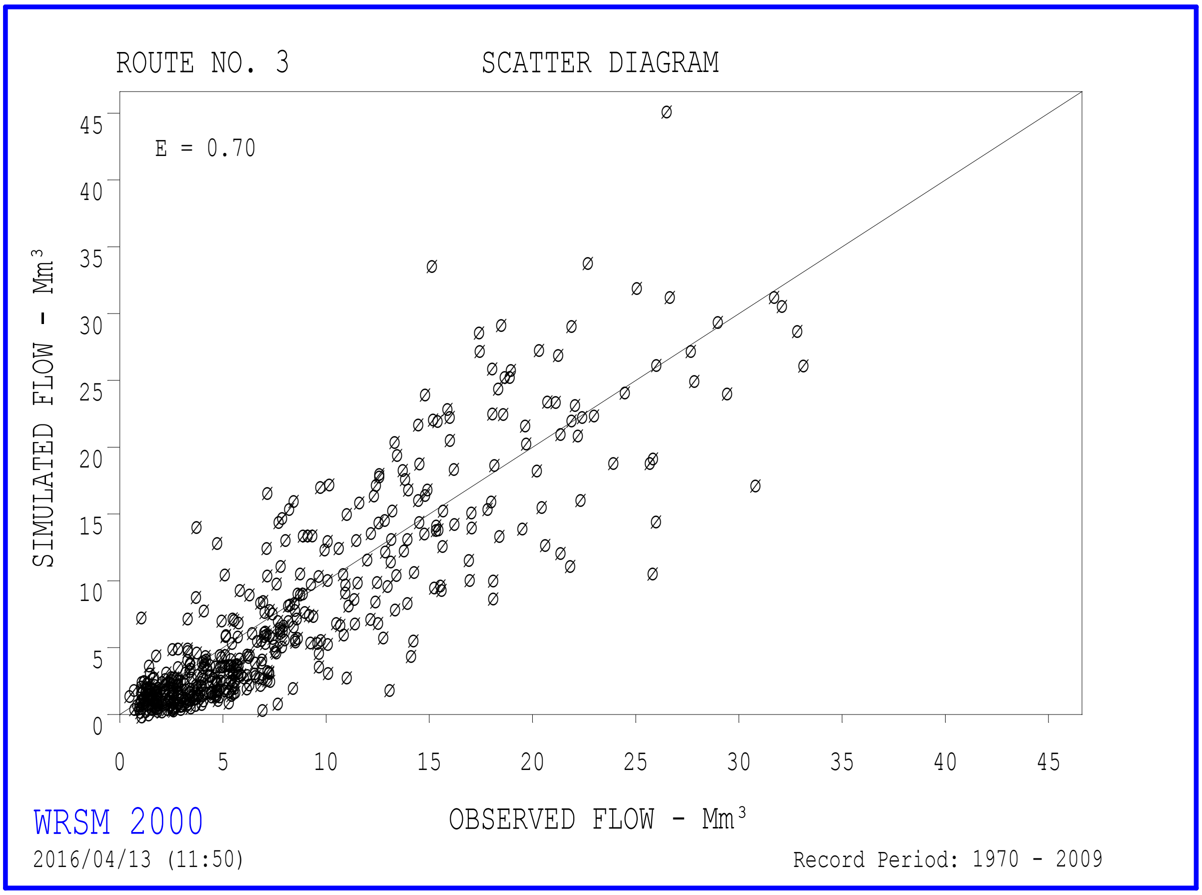

Figure 18 Scatter diagram for the observed and simulated flows from the Pitman model for Pungwe Micro-catchment

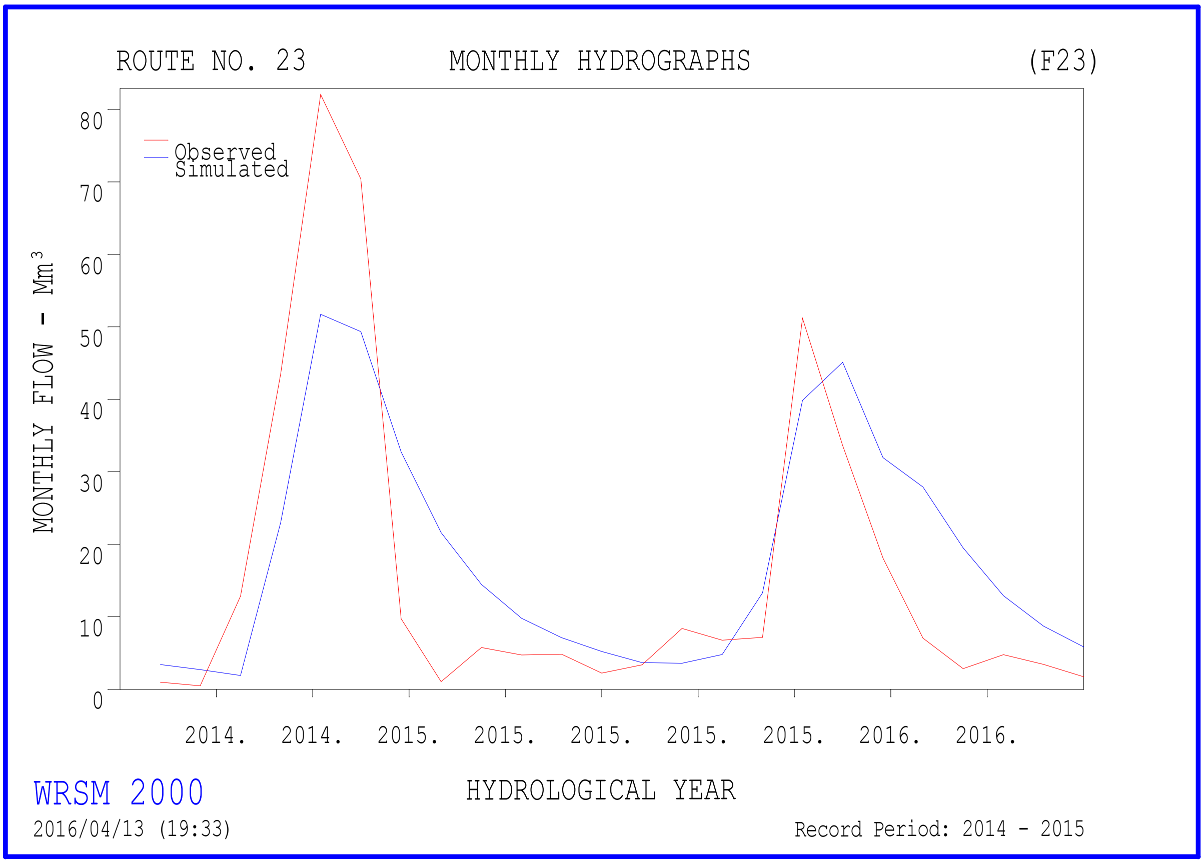

Figure 19 Observed and simulated stream flow from the calibrated Pitman model for Honde Micro-catchment

The model was calibrated using observed data obtained from gauging station F23 from 2014 to 2015. Only data for about one and half years was used in calibration since the gauging station is still new and that was the only available data. The relationship between simulated runoff and observed runoff at gauging station F23 on the Honde River is shown in figure 20. Figure 20 showed that the model simulated well the observed flows.

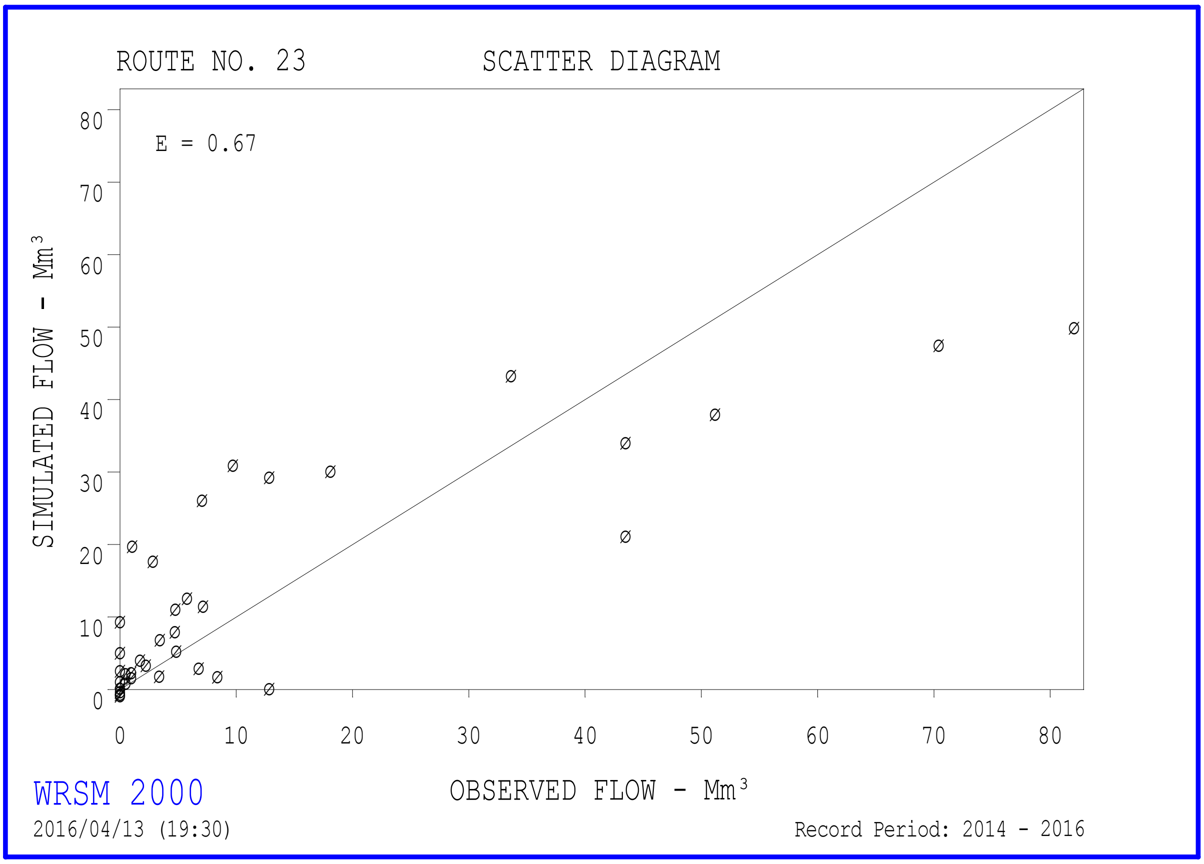

Figure 20 Scatter diagram for the observed and simulated flows from the Pitman model for Honde Micro-catchment

Figure 21 above shows the coefficient of determination of 0.67 after the calibration of the Pitman Model for Honde Micro-catchment. The coefficient of determination of 0.67 showed that the model performance is good hence can be used to simulate runoff the ungauged parts of the Honde Micro-catchment.

The models set generated stream flows for different tributaries of Pungwe River in the Pungwe Micro-catchment and tributaries of Honde River in the Honde Micro-catchment which are ungauged. Table 7 shows mean annual generated runoff for tributaries of Honde River and Pungwe River with their coefficient of variation.

Table 7 Mean annual runoff for different rivers and their coefficient of variation

Micro catchment	**River**	**Mean annual Runoff per annum (Mm^3/annum)**	**coefficient of variation**
Pungwe Micro Catchment	Pungwe headwaters	52.74	0.312
	Matenderere	26.47	0.312
	Nyazengu	76.74	0.315
	Murara	4.92	0.329
	Nyamawanga	12.29	0.312
	Nyamanyoka	7.39	0.312
	Sururu	6.14	0.329
	Chitema	34.41	0.312
	Nyamingura	54.7	0.312
	Nyawamba	57.42	0.312
	Nyamutsupa	13.22	0.298
	Muzinga	12.3	0.312
	Mambezi	5.74	0.312
	Nyamukombe	66.45	0.312
	Rwera	39.38	0.315
Honde Micro Catchment	Manana	4.57	0.420
	Honde headwaters	4.64	0.420
	Nyacheri	11.11	0.423
	Nyarusha	7.41	0.423
	Mukondwe	3.7	0.423
	Matinedza	3.24	0.423
	Duru	39.35	0.423
	Nyamakanga	8.92	0.423
	Mupenga	52.24	0.423
	Mtarazi	26.85	0.423
	Booyo	13.89	0.423
	Ngarura	41.21	0.423
	Ruda	34.72	0.423

The spatial surface water availability in the Pungwe micro-catchment catchment in the tributaries Pungwe H/water, Matenderere, Nyazengu, Murara, Nyamawanga, Nyamanyoka, Sururu, Chitema, Nyamingura, Nyawamba, Nyamutsupa, Muzinga, Mambezi, Nyamukombe, Rwera are 52.74 Mm^3/a, 26.47 Mm^3/a, 76.74 Mm^3/a, 4.92 Mm^3/a, 12.29 Mm^3/a, 7.39 Mm^3/a, 6.14 Mm^3/a, 34.41 Mm^3/a, 54.7 Mm^3/a, 57.42 Mm^3/a, 13.22 Mm^3/a, 12.3 Mm^3/a, 5.74 Mm^3/a, 66.45 Mm^3/a, 39.38 Mm^3/a respectively.

The spatial surface water availability in the Honde micro-catchment in the tributaries Manana, Honde H/W, Nyacheri, Nyarusha, Mukondwe, Matinedza, Duru, Nyamakanga, Mupenga, Mtarazi, Booyo, Ngarura, Ruda are 4.57 Mm^3/a, 4.64 Mm^3/a, 11.11 Mm^3/a, 7.41 Mm^3/a, 3.7 Mm^3/a, 3.24 Mm^3/a, 39.35 Mm^3/a, 8.92 Mm^3/a, 52.24 Mm^3/a, 26.85 Mm^3/a, 13.89 Mm^3/a, 41.21 Mm^3/a, 34.72 Mm^3/a respectively.

Table 8 shows the monthly average generated runoff for Pungwe River. The least amount of generated runoff for the tributaries are obtained during the month of October. The annual totals of the generated runoff were used in choosing the allocation percentage of the face value of water permits and prioritisation of water use sectors in water allocation.

Table 8 Average monthly runoff for Pungwe tributaries in Mm^3

River	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
Upper Pungwe	1.58	2.14	7.13	12.43	12.94	12.01	8.45	4.75	3.57	2.79	2.23	1.77
Nyazengu	1.60	2.17	7.26	12.65	13.18	12.25	8.60	4.80	3.62	2.84	2.27	1.80
Murara	0.11	0.15	0.50	0.87	0.91	0.85	0.59	0.33	0.25	0.20	0.16	0.12
Nyamanyoka	0.14	0.19	0.63	1.09	1.14	1.07	0.76	0.43	0.32	0.25	0.20	0.16
Sururu	1.05	1.42	4.75	8.29	8.64	8.03	5.63	3.15	2.37	1.86	1.49	1.18
Chitema	0.14	0.19	0.63	1.09	1.14	1.06	0.74	0.41	0.31	0.24	0.20	0.16
Nyamingura	1.12	1.53	5.31	9.35	9.94	9.31	6.29	3.27	2.41	1.92	1.56	1.25
Nyamutsupa	0.33	0.46	1.41	2.46	2.64	2.45	1.67	0.92	0.68	0.52	0.41	0.34
Nyawamba	1.29	1.75	5.84	10.18	10.60	9.85	6.92	3.87	2.92	2.28	1.83	1.45
Muzinga	0.28	0.37	1.25	2.18	2.27	2.11	1.48	0.83	0.62	0.49	0.39	0.31
Nyamukombe	1.49	2.02	6.76	11.78	12.27	11.40	8.00	4.48	3.37	2.64	2.12	1.68
Mambezi	1.29	1.75	5.84	10.18	10.60	9.85	6.92	3.87	2.92	2.28	1.83	1.45
Rwera	0.89	1.20	4.00	6.98	7.27	6.76	4.74	2.65	2.00	1.57	1.25	1.00

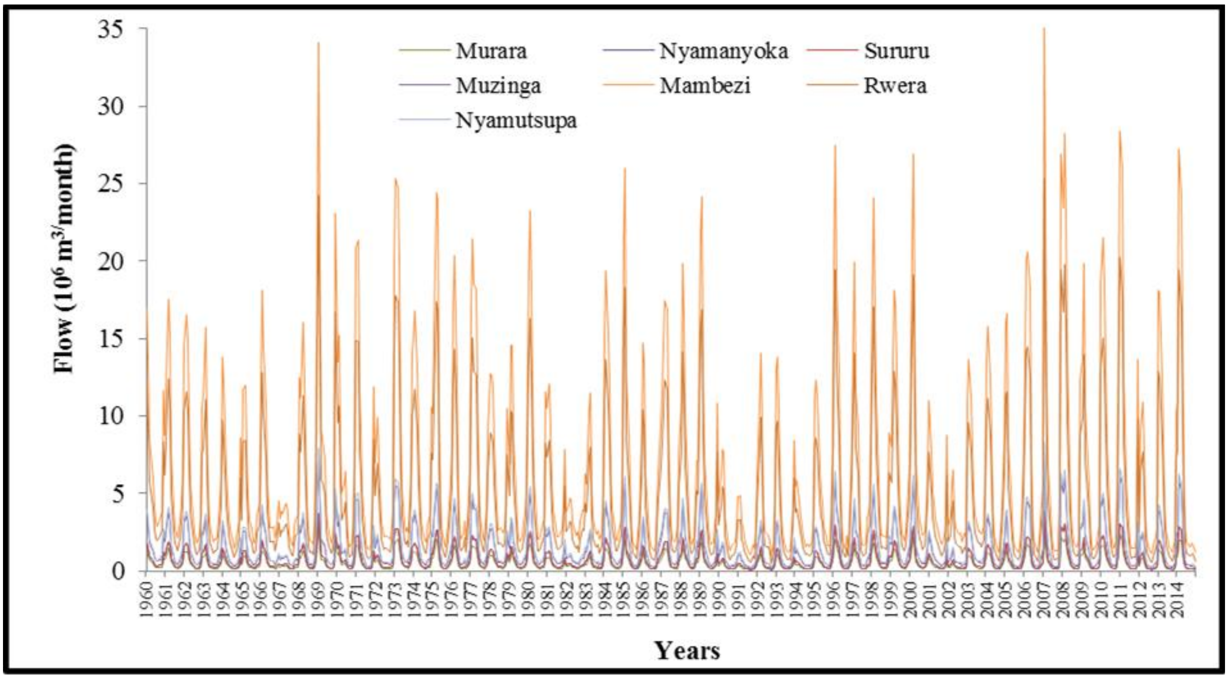

Figure 21 Runoff generated from Pitman model for Pungwe river tributaries

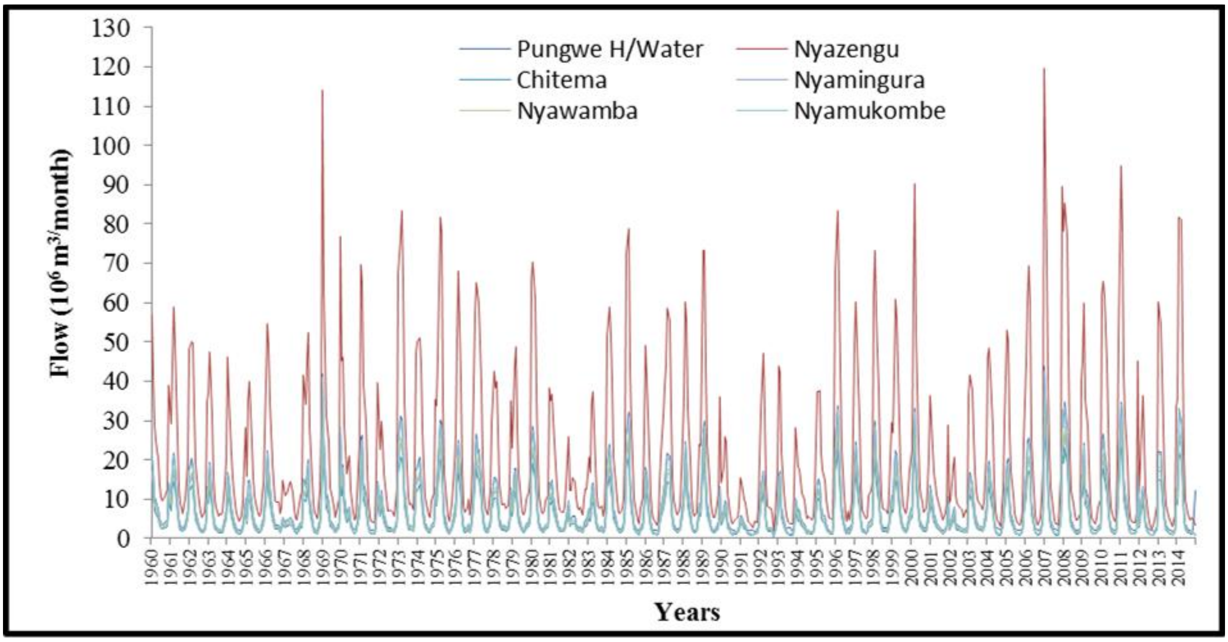

Figure 22 Runoff generated from Pitman model for Pungwe River tributaries

Figure 22 and 23 shows the temporal variation of surface runoff for Pungwe River triburies Nyamingura, Nyawamba, Nyamukombe are the major tributaries of Pungwe River as shown by the amount of generated runoff from Figure 22. Murara, Nyamanyoka,Sururu and Mabezi are smaller tributaries of the Pungwe River as shown by the low generated flows.

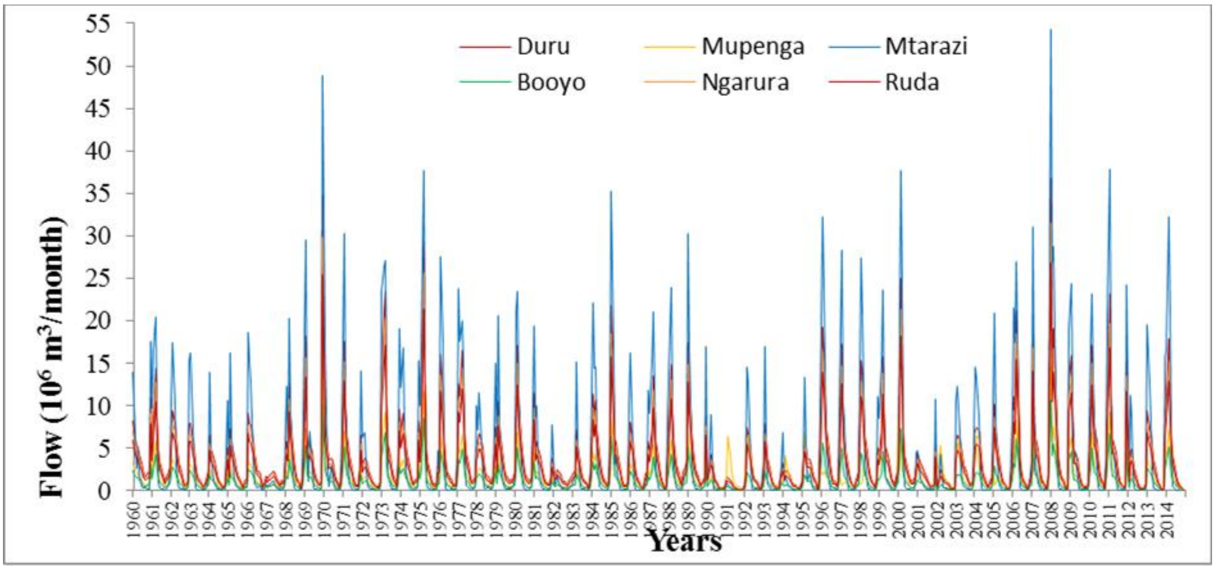

Figure 23 Runoff generated from Pitman model for Honde River major tributaries

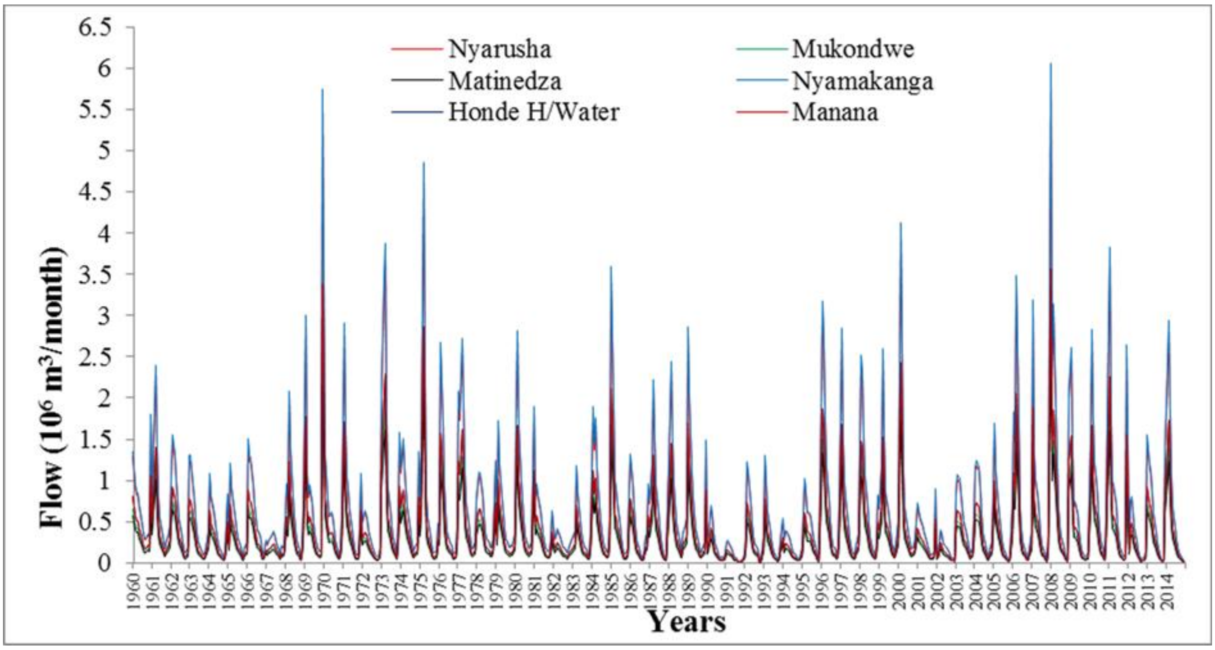

Figure 24 Runoff generated from Pitman model for Honde River minor tributaries

Figure 24 and 25 shows the temporal variation of surface runoff for major and minor Honde River tributaries.

5.2 Water use in Pungwe sub catchment

The sub catchment has a total of 519 registered water users with a total water allocation of 258 M m^3 annually. Also out of 258 M m^3 about 215.7 M m^3 (84%) is allocated in the Pungwe micro catchment and about 42.3 M m^3 (16%) is allocated in the Honde micro catchment. In terms of ground water use in the catchment there are no permits allocated. Water use from groundwater/boreholes whose volume do not exceed 5000 m^3 per annum is not subject to permit. Much of the commercial water use in the catchment is surface runoff and abstraction from water stored in dams.

Table 9 Water permits in the Pungwe Sub catchment

Micro catchment	Active Permits ML	In Active Permits ML	Total ML
Pungwe	191700	24000	**215700**
Honde	25100	17200	**42300**
Total	216800	41200	**258000**

Table 9 shows water allocation in the Pungwe sub catchment. In Honde micro catchment about 59% are active permits and 41% are inactive permits. Pungwe micro-catchment has 89% active permits whilst 11% of the permits are not active.

5.2.1 Water use by sector

The ratio of water allocated to different water users in the catchment using the existing water permit database for the catchment is shown in Table 10. The major water use in the catchment is hydropower generation with about 69.42% of the permitted water in the sub-catchment. About 10.04 % of the water is allocated to urban and rural water supply. The major urban water user is Mutare city. The abstraction of Mutare city is upstream of Pungwe falls. Agricultural sectors use about 20.53% of the permitted water in the Pungwe sub-catchment whilst government use about 0.02%. Government water use these are the permits given to government when constructing roads.

Table 10 Water use by sector in the Pungwe sub catchment

Water use by sector	Percentage of the Total Permitted water
Urban and Rural Water supply	10.04
Agriculture	20.53
Hydropower	69.42
Government	0.02

5.2.2 Actual water use by irrigation

Crop water requirements for irrigation was determined as described in section 4.5.1. Table 11 shows the difference between water permitted by the sub catchment and the crop water requirements determined using CROPWAT 8.0. The Table 11 shows that the difference between the permitted water and crop water requirements for different crops is below 4 %. This showed that the amount of water permitted to these users were not exceeding their water requirements.

Table 11 Comparison between CWR and permitted water

Name of Irrigation scheme	Area km^2	Crop	CWR ML	Water Permitted ML	% Difference
Samanga Dumba	27.5	Banana	295.7	300	1.4
Murara	16.5	Banana	177.4	180	1.4
Chiteme	28	Banana	301.1	312	3.5
Rupinda	24	Banana	258.1	264	2.2
Buwu	16.5	Coffee	177.4	180	1.4
EHPL	240	Tea	1745.2	1771	1.5

5.3 Water allocation

5.3.1 Model Performance

The model performance was tested as described in section 4.7. Figure 26 and Figure 27 shows the relationship between the observed stream flow and the computed steam flow from the WAFLEX model for gauging station F14 and F22 respectively. Model performance was done using active water users. The graphs show that the model can simulate peak stream flows well. Figure 27 and 28 shows that the model is simulating well the observed runoff.

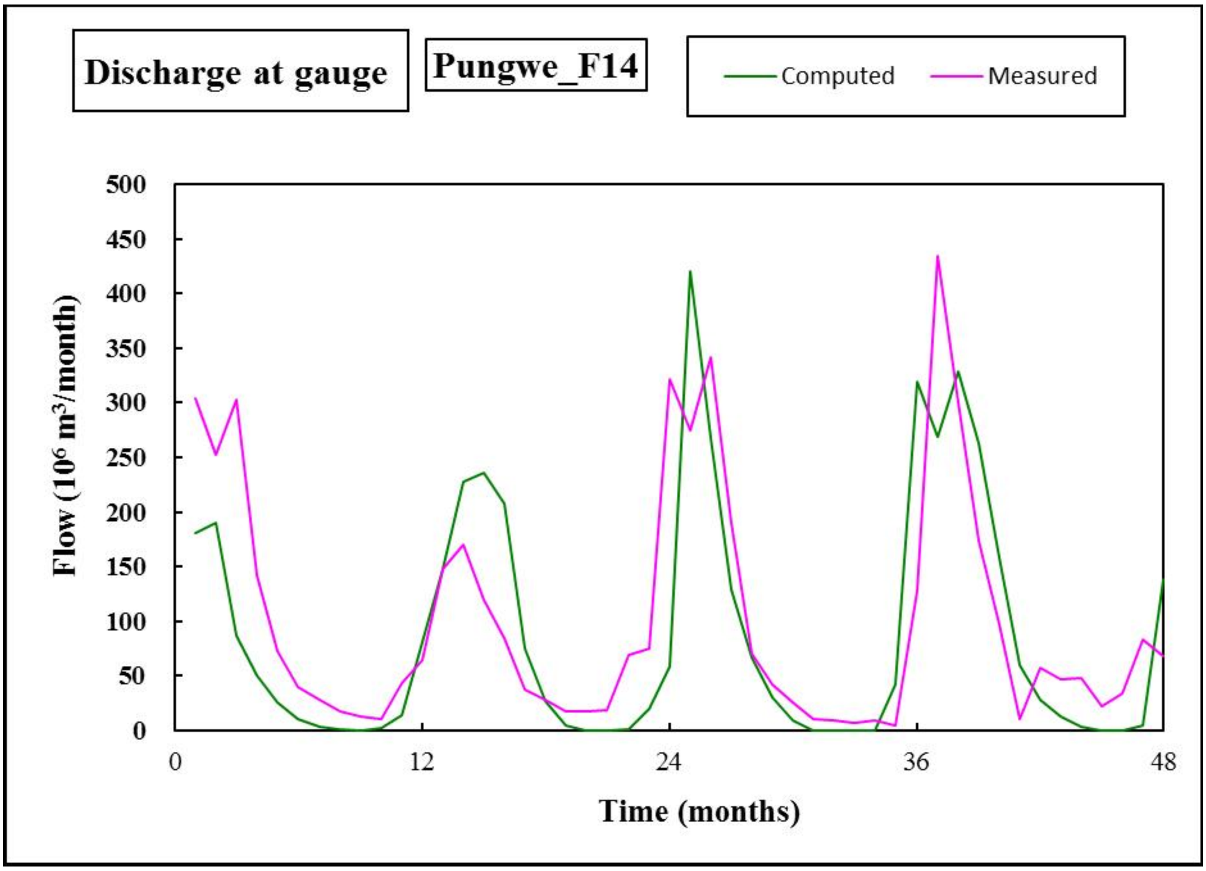

Figure 25 Simulation of observed stream from 2005 to 2008 for F14

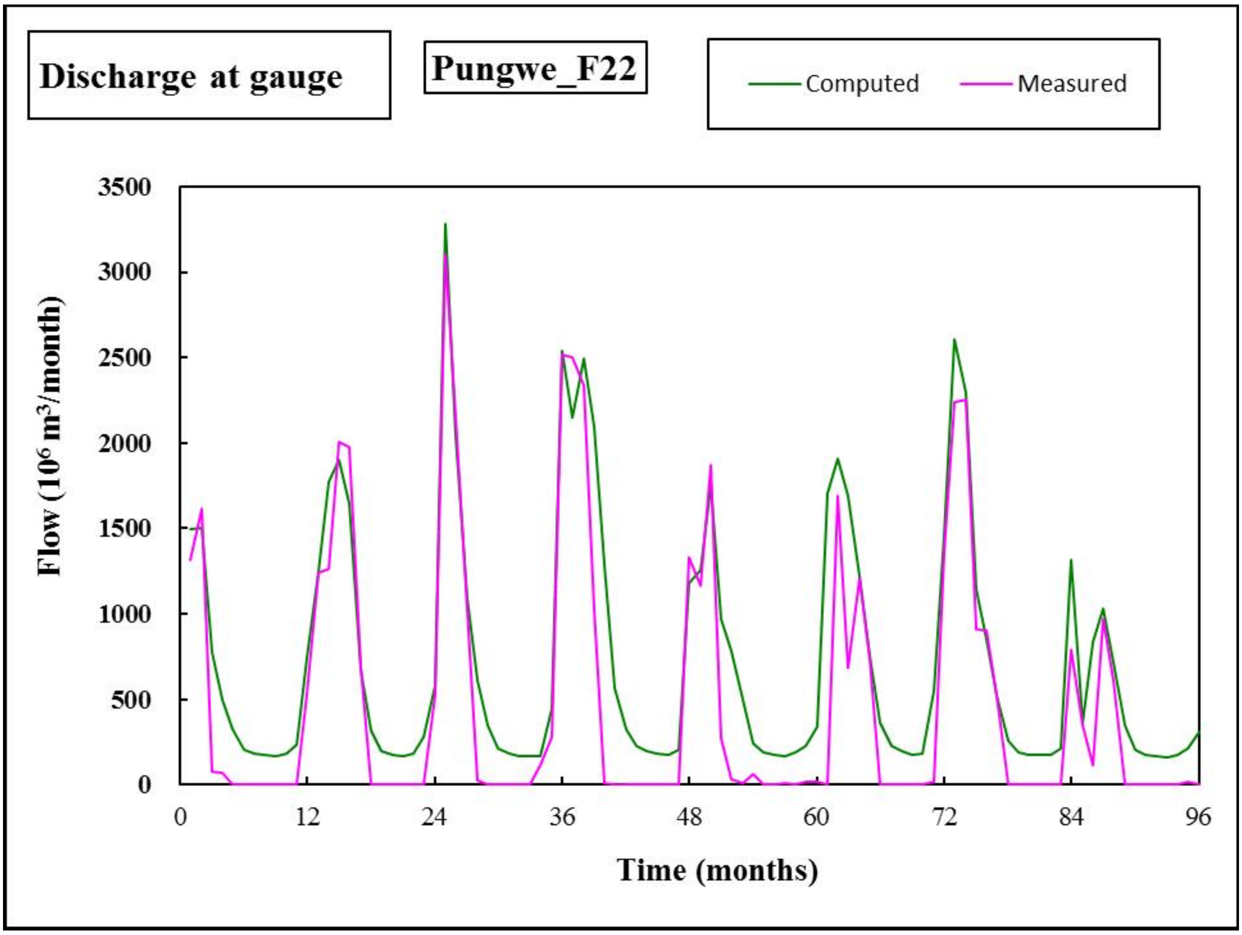

Figure 26 Simulation of observed stream flow from 2005 to 2012 for F22

In Figure 28 the model seemed to be over estimating low flows. This might be caused by errors in taking readings from the gauging stations especially when they are low flow in the river.

The regression coefficient was used to assess the performance of the model. Figure 29 and 30 shows how the model managed to simulate well the observed flows for both F14 and F22. This was supported statically by the regression coefficient R^2 of 0.81 for both F14 and F22. This means that the outputs from the model are reliable and they can be used by the sub-catchment for water resources planning and allocation of water permits.

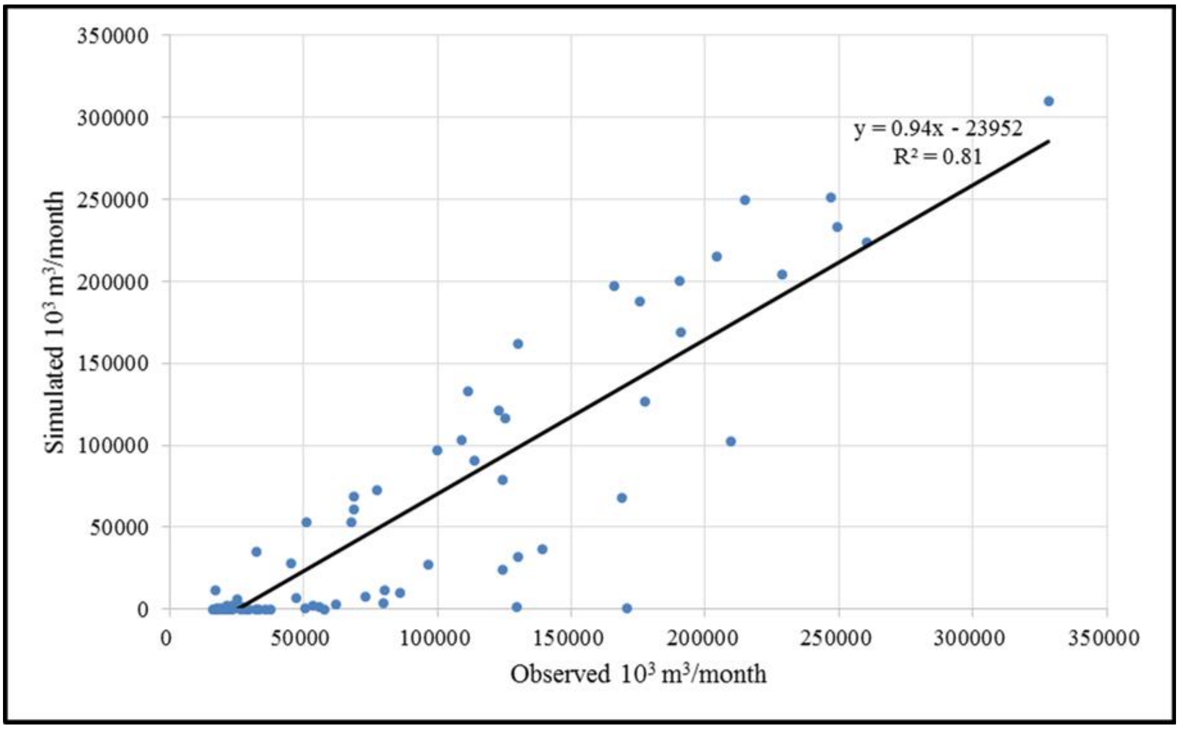

Figure 27 Regression analysis between observed and simulated flow for F22

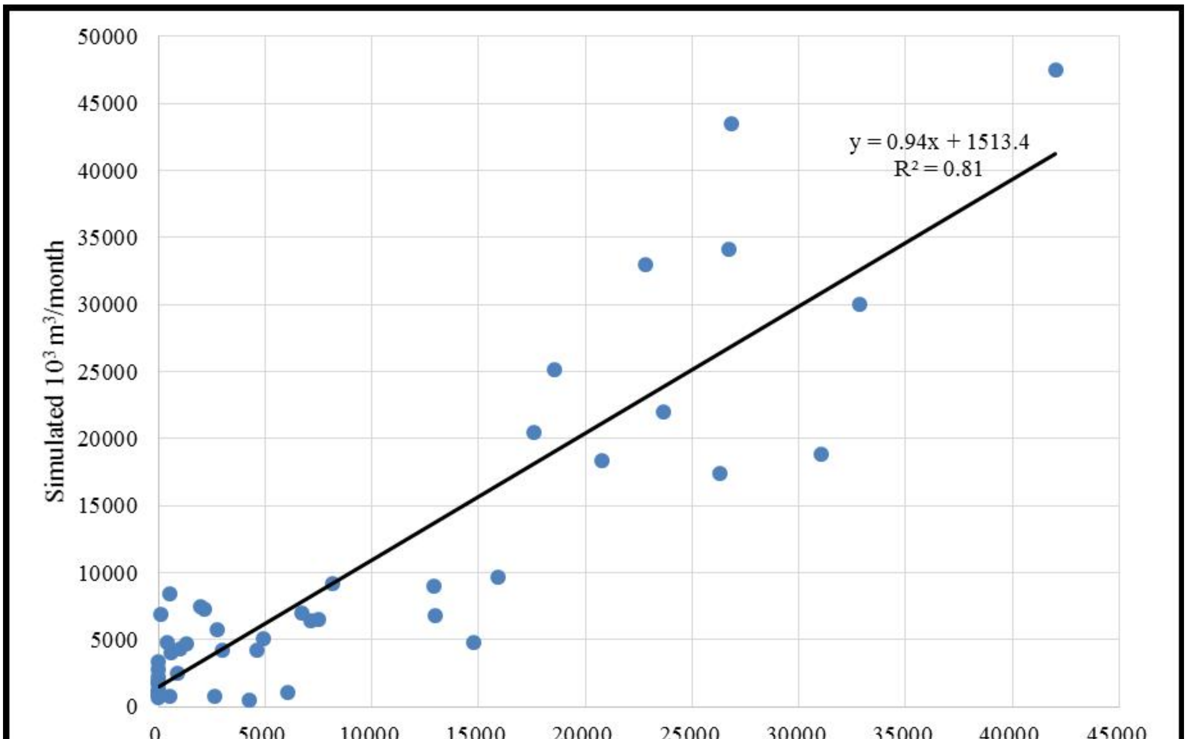

Figure 28 Regression analysis between observed and simulated flow for F14

5.3.2 Scenario 1 Current Water allocation Practice

Different water demand scenarios as described from section 4.7 were evaluated using the WAFLEX model. The current water use in the Pungwe Micro-catchment revealed that there was no significant water shortages in the micro-catchment. Figure 31 shows the satisfaction level in amount of water demanded by different water users. All the agricultural water users were 100% satisfied in the amount demanded. The percentage satisfaction in amount demanded for Mutare city, hydropower 1, hydropower 2 and hydropower 3 were 96%, 80%, 76% and 92% respectively. The shortages in amount and time for water abstracted for hydropower generation shown in Figure 31 illustrated that these companies had installed power generation plants that maximize high flows in the rivers. Figure 31 shows the percentage in time for which the amount of water demanded by different users was satisfied. All the amount demanded by agricultural water uses were satisfied 100% of the time the water was demanded. However the amount of water demanded by Mutare city, hydropower 1, hydropower 2, hydropower 3 were satisfied with 78%, 58%, 51% and 70% respectively of the time the demands were made. All the agricultural water demands were 100% satisfied in amount demanded and the time the amount is demanded.

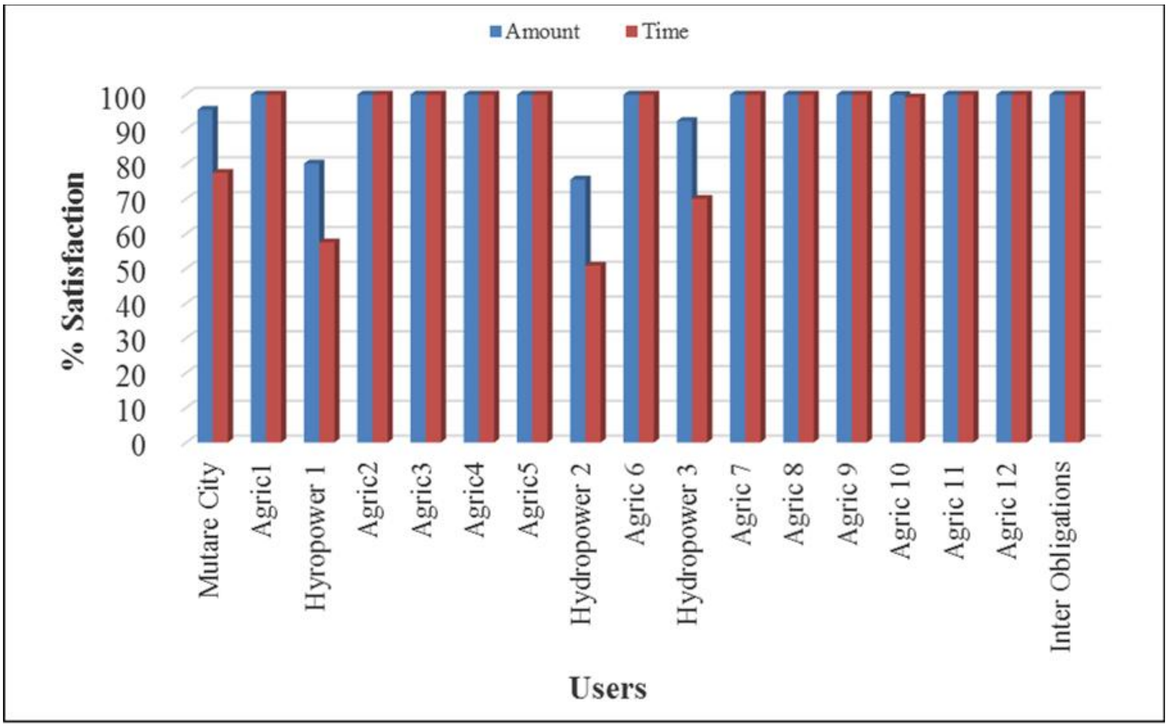

Figure 29 Satisfaction level of current water demands under current water allocation practice for Pungwe Micro catchment

The satisfaction levels for different water users in the Honde micro-catchment is shown in Figure 32 under the current water allocation practice. Agricultural water use 1, 2, 12, 14 and international obligations were satisfied 100% in amount and time. The results revealed that the satisfaction level in amount for agricultural water use 3, 4, 5, 6, 7, 8, 9, 10, 11, 13, 14 and 16 were 98%, 98%, 91%, 57%, 72%, 47%, 53%, 76%, 40%, 73%, 99% and 99% respectively. Also, the satisfaction level in time for agricultural water use 3, 4, 5, 6, 7, 8, 9, 10, 11, 13, 14 and 16 were 97%, 99%, 88%, 67%, 78%, 68%, 63%, 79%, 56%, 78%, 99% and 87% respectively. Under the current water allocation practice, hydropower generation has satisfaction level of 91% in amount and 79% in time whilst Hauna Growth Point had a satisfaction level of 100% in amount and 85% in time. This normally happens between August and November when the flows in the river are low. The researcher also witnessed this when a visit was done to one of the Hauna Growth Point abstraction point which was decommissioned in the month of September due to low river flows. Duru hydropower station normally stops hydropower generation between August and October due to the low flows in the river.

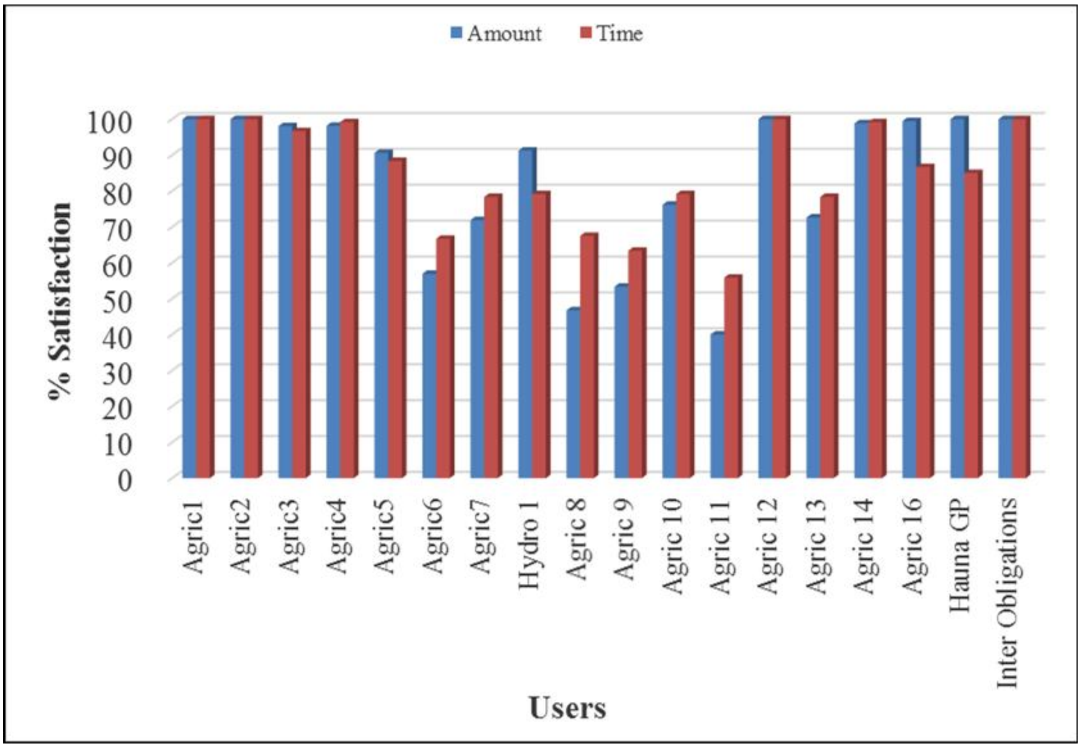

Figure 30 The satisfaction levels for the diferent water users under the current water allocation practice for the Honde Micro-catchment.

5.3.3 Projected water demand in 2020 and 2030 under different growth rates for Pungwe micro catchment

The model was run considering scenario 2. All the demand sites of the model were active. The projected future demand increase in agricultural water use was considered using an average of 5% annual growth rate as low rate and 15% annual growth rate as high growth rate in irrigation. Table 11 shows the percentage in time for which the amount of water demanded by different users was satisfied for Pungwe Micro-catchment. The satisfaction level in amount of water demanded by Mutare city, hydropower 1, 2 and 3 were remained the same since the amount of water at the abstraction points remained low to change the satisfaction levels. Pungwe micro-catchment would experience significant shortages in 2030 under high growth rate scenario. Most of the agricultural water demands were satisfied 100% in amount and time considering low and high growth rates for 2020 and low growth rate for 2030. Pungwe micro-catchment would experience significant shortage in 2030 under high growth rate.

Table 12 Satisfaction level under different projected growth rates for Pungwe Micro catchment

		Satisfaction level in amount (%)				**Satisfaction level in time (%)**			
Growth rate		**Low**	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**
River	Use	**2020**	**2020**	**2030**	**2030**	**2020**	**2020**	**2030**	**2030**
Pungwe H/Water	Mutare City	96	96	96	96	78	78	78	78
Matenderere	Agric1	100	100	100	100	100	100	100	100
Pungwe	Hydropower 1	80	80	80	80	58	58	58	58
Murara	Agric2	88	80	82	37	82	82	77	47
Nyamawanga	Agric3	100	100	100	70	100	100	100	72
Nyamanyoka	Agric4	100	100	100	99	100	100	100	98
Sururu	Agric5	100	100	100	72	100	100	100	72
Chitema	Hydropower 2	76	76	76	76	51	51	51	51
Chitema	Agric 6	100	100	100	100	100	100	100	100
Nyamingura	Hydropower 3	92	92	92	92	70	70	70	70
Nyamingura	Agric 7	100	100	100	79	100	100	100	75
Nyamutsupa	Agric 8	100	100	100	100	100	100	100	100
Nyawamba	Agric 9	100	100	100	56	100	100	99	63
Muzinga	Agric 10	99	97	98	53	98	98	93	63
Nyamukombe	Agric 11	100	100	100	100	100	100	100	98
Pungwe	Agric 12	100	100	100	100	100	100	100	100
Pungwe	International obligations	100	100	100	100	100	100	100	100

5.3.4 Projected water demands for 2020 and 2030 under different growth rates for Honde micro catchment

Table 13 shows the satisfaction level in amount and time for different water users under different water demand projection level for 2020 and 2030. International obligations experienced a shortage of 99% in amount and 78% in time under projected high water demand in 2030. Agricultural water use 12 was 100% satisfied in the amount and time the amount were demanded under projected demands for 2020 and 2030. This is because most of the water abstraction are done in the tributaries of Honde River since most of the water abstractions are done through gravity. However most agricultural water users experienced shortages and further increase in water demands would worsen the shortages in the Honde micro catchment. This showed that Honde micro-catchment is highly committed as compared to Pungwe micro-catchment. Hauna Growth Point is experiencing shortages both in amount and time and further increase in demand would worsen the shortages. The satisfaction levels for Duru hydropower generation remained the same throughout the projection period. The hydropower generation at Duru normally stops between August and October due to low flows in the river depending on the amount of rainfall received in a year. Mtarazi River, Mukondwe River Nyamakanga River, Booyo River, and Msatinedza River are highly committed Rivers as shown by their low satisfaction level in amount and time. Further increase in demands would worsen the water shortages in these tributaries.

Table 13 Satisfaction level under different projected demands for Honde Micro catchment

		Satisfaction level in amount (%)				Satisfaction level in time (%)			
Growth rate		Low	High	Low	High	Low	High	Low	High
River	Use	2020	2020	2030	2030	2020	2020	2030	2030
Honde H/Water	Agric 1	100	99	99	84	99	99	99	86
Manana	Agric 2	100	99	99	86	99	99	99	86
Nyachere	Agric 3	97	92	90	63	95	90	88	68
Honde Main	Agric 4	98	96	95	58	99	97	96	78
Nyarusha	Agric 5	87	79	76	49	86	81	79	59
Mukondwe	Agric 6	53	45	43	18	63	58	53	37
Matinedza	Agric 7	68	60	57	30	74	68	67	43
Duru	Hydro 1	91	91	91	91	79	79	79	79
Duru	Agric 8	36	31	30	12	58	51	49	36
Nyamakanga	Agric 9	49	42	39	15	59	52	51	34
Mupenga	Agric 10	72	65	62	35	78	69	68	48
Mtarazi	Agric 11	37	32	30	17	55	51	50	43
Honde Main	Agric 12	100	100	100	100	100	100	100	100
Booyo	Agric 13	69	61	58	31	76	68	67	43
Ngarura	Agric 14	98	96	94	68	97	93	92	75
Ruda	Agric 15	80	72	70	43	82	78	76	53
Ruda	Haua GP	80	78	74	53	79	77	72	52
Honde	Internatinal Obligations	100	100	100	99	100	100	100	78

5.3.5 Assessment of water shortages using different water allocation practices (systems)

The different water allocation practices which are the current water allocation practice, proportional combined with priority water allocation practice and market based water allocation practice were used to evaluate shortages on different water users. Table 14 shows the level of satisfaction in amount and time by different water users for Pungwe micro-catchment. In all the water allocation practices (systems) international obligations demands were 100% satisfied in both amount and time. Satisfaction levels for Mutare city and all hydropower generation remained the same under all the water allocation practices because water abstractions upstream the abstraction points of these users are insignificant to improve satisfaction level for these users under different water allocation practices. There was an improvement of satisfaction level in amount of about 10% for all agricultural water user under proportional combined with priority water allocation practice as compared to the current water allocation practice. The satisfaction levels in water in time increased with an average of 3% under the market based water allocation practice as compared to the current water allocation practice.

Table 14 Satisfaction level in amount for 2020 projected demand in Pungwe micro catchment

		Satisfaction level in amount (%)					
River	Use	Current		Market based		Proportion with priority	
		Low	High	Low	High	Low	High
Pungwe H/Water	Mutare City	96	96	96	96	96	96
Matenderere	Agric1	100	100	100	100	100	100
Pungwe	Hydropower 1	80	80	80	80	80	80
Murara	Agric2	88	77	91	80	97	86
Nyamawanga	Agric3	100	100	100	100	100	100
Nyamanyoka	Agric4	100	100	100	100	100	100
Sururu	Agric5	100	100	100	100	100	100
Chitema	Hydropower 2	76	76	76	76	76	76
Chitema	Agric 6	100	100	100	100	100	100
Nyamingura	Hydropower 3	92	92	92	92	92	92
Nyamingura	Agric 7	100	100	100	100	100	100
Nyamutsupa	Agric 8	100	100	100	100	100	100
Nyawamba	Agric 9	100	99	100	100	100	100
Muzinga	Agric 10	99	95	100	97	100	99
Nyamukombe	Agric 11	100	100	100	100	100	100
Pungwe	Agric 12	100	100	100	100	100	100
Pungwe	International obligations	100	100	100	100	100	100

The satisfaction level in time for projected 2020 water demands in the Pungwe microcatchment under different water allocation practices is shown in Table 15. Mutare city and hyropower generation used satisfaction levels remained the same under all the water allocation practices. This is because even if the water allocation practice is changed the amount of water flowing through these abstraction points is not high to make improvements on the satisfaction levels of these uses. All the hydropower generation users usually stops hydropower generation between August and November due to low flows in the rivers. All the agricultural water users were 100% satified in time under the different water allocation practices.

Table 15 Satisfaction level in time for 2020 projected demand in Pungwe micro catchment

		Satisfaction level in amount (%)					
River	Use	Current		Market based		Proportion with priority	
		Low	High	Low	High	Low	High
Pungwe H/Water	Mutare City	78	78	78	78	78	78
Matenderere	Agric1	100	100	100	100	100	100
Pungwe	Hydropower 1	58	58	58	58	58	58
Murara	Agric2	82	75	83	77	88	82
Nyamawanga	Agric3	100	100	100	100	100	100
Nyamanyoka	Agric4	100	100	100	100	100	100
Sururu	Agric5	100	100	100	100	100	100
Chitema	Hydropower 2	51	51	51	51	51	51
Chitema	Agric 6	100	100	100	100	100	100
Nyamingura	Hydropower 3	70	70	70	70	70	70
Nyamingura	Agric 7	100	100	100	100	100	100
Nyamutsupa	Agric 8	100	100	100	100	100	100
Nyawamba	Agric 9	100	95	100	98	100	100
Muzinga	Agric 10	98	88	99	93	100	97
Nyamukombe	Agric 11	100	100	100	100	100	100
Pungwe	Agric 12	100	100	100	100	100	100
Pungwe	International obligations	100	100	100	100	100	100

The satisfaction level in amount by different water users are shown in Table 16 for Honde micro-catchment under different water allocation practices (systems). There was an increase of about 2% satisfaction level in amount for agricultural water users under market based water allocation practice as compared to the current water allocation practice. However the satisfaction levels in amount and time for Duru Hydropower power generation remained the same under all the water allocation practices since the abstraction upstream the hydropower generation are insignificant to make any meaningful improvement to satisfaction levels. There was an increase 3% satisfaction in amount for Hauna Growth Point under the market based water allocation practice as compared to the current water allocation practice. Proportional combined with priority water allocation practice increased satisfaction levels in amount and time for Hauna Growth Point with 5% as compared to the current water allocation practice.

International obligations were 99% satisfied in amount under current water allocation practice and market based water allocation practice considering high water demand.

Table 16 Satisfaction level in amount for projected 2020 demands in Honde micro catchment

		Satisfaction level in amount (%)					
River	Use	Current		Market based		Proportion with priority	
		Low	High	Low	High	Low	High
Honde H/Water	Agric 1	100	99	100	99	100	100
Manana	Agric 2	100	99	100	99	100	100
Nyachere	Agric 3	97	92	98	94	99	96
Honde Main	Agric 4	98	96	98	98	98	98
Nyarusha	Agric 5	87	79	89	81	92	85
Mukondwe	Agric 6	53	45	55	47	59	51
Matinedza	Agric 7	68	60	70	62	74	60
Duru	Hydro 1	91	91	91	91	91	91
Duru	Agric 8	36	31	39	36	39	35
Nyamakanga	Agric 9	49	42	51	44	55	47
Mupenga	Agric 10	72	65	74	67	78	71
Mtarazi	Agric 11	37	32	39	33	42	36
Honde Main	Agric 12	100	100	100	100	100	100
Booyo	Agric 13	69	61	71	63	74	67
Ngarura	Agric 14	98	96	99	97	99	98
Ruda	Agric 15	80	72	87	80	86	78
Ruda	Haua GP	80	78	86	80	85	79
Honde	Internatinal Obligations	100	100	100	100	100	100

The satisfaction levels in time for different water demands for Honde micro-catchment under 2020 projected water demands are shown in Table 17. International obligations and agricultural water use 12 were satisfied 100% in time under all the water allocation practices.

However satisfaction level in time for Duru hydropower generation remained the same under the different water allocation practices. The satisfaction levels for agricultural water use increased with an average 2% under the market based water allocation water allocation as compared the current water allocation practice. Proportional combined with priority water allocation improved satisfaction level in time for agricultural water use with about 10% as in comparison with the current water allocation practice.

Table 17 Satisfaction level in time for projected 2020 demands in Honde micro catchment

		Satisfaction level in time (%)					
River	Use	Current		Market based		Proportion with priority	
		Low	High	Low	High	Low	High
Honde H/Water	Agric 1	99	99	99	99	100	99
Manana	Agric 2	99	99	100	99	100	99
Nyachere	Agric 3	95	90	96	92	98	94
Honde Main	Agric 4	99	97	99	98	99	99
Nyarusha	Agric 5	86	81	87	83	91	86
Mukondwe	Agric 6	63	58	64	59	67	59
Matinedza	Agric 7	74	68	76	68	78	68
Duru	Hydro 1	79	79	79	79	79	79
Duru	Agric 8	58	51	59	57	59	54
Nyamakanga	Agric 9	59	52	59	54	64	59
Mupenga	Agric 10	78	69	79	72	79	77
Mtarazi	Agric 11	55	51	55	52	57	55
Honde Main	Agric 12	100	100	100	100	100	100
Booyo	Agric 13	76	68	77	68	79	73
Ngarura	Agric 14	97	93	99	96	99	97
Ruda	Agric 15	82	78	87	82	86	79
Ruda	Haua GP	79	77	84	79	84	79
Honde	Internatinal Obligations	100	100	100	100	100	100

The performance of different water allocation practiced for different projected water demands for 2030 are shown in Table 18. The satisfaction level for Mutare city and for all hydropower generation remained the same. Most of the agricultural water uses were 100% satisfied under the 2030 projected water demands. Highly committed rivers such as Murara River, Sururu River and Nyawamba River improved satisfaction level with an average of 10% under proportional combined with priority water allocation as compared to current water allocation practice. The satisfaction level for agricultural water use improved with an average of 5% under market based water allocation practice as compared as to the current water allocation practice. International obligations was 100% satisfied in amount under all the water allocation practices

Table 18 Satisfaction levels in amount for projected 2030 demands in Pungwe micro catchment

		Satisfaction level in amount (%)					
River	Use	Current		Market based		Proportion with priority	
		Low	High	Low	High	Low	High
Pungwe H/Water	Mutare City	96	96	96	96	96	96
Matenderere	Agric1	100	100	100	100	100	100
Pungwe	Hydropower 1	80	80	80	80	80	80
Murara	Agric2	73	37	76	39	82	44
Nyamawanga	Agric3	100	70	100	74	100	80
Nyamanyoka	Agric4	100	99	100	100	100	100
Sururu	Agric5	100	72	100	75	100	81
Chitema	Hydropower 2	76	76	76	76	76	76
Chitema	Agric 6	100	100	100	100	100	100
Nyamingura	Hydropower 3	92	92	92	92	92	92
Nyamingura	Agric 7	100	79	100	92	100	90
Nyamutsupa	Agric 8	100	100	100	100	100	100
Nyawamba	Agric 9	97	56	98	59	100	64
Muzinga	Agric 10	92	53	94	56	98	61
Nyamukombe	Agric 11	100	100	100	100	100	100
Pungwe	Agric 12	100	100	100	100	100	100
Pungwe	International obligations	100	100	100	100	100	100

Table 19 Satisfaction levels in time for projected 2030 demands in Pungwe micro catchment

		Satisfaction level in amount (%)					
River	Use	Current		Market based		Proportion with priority	
		Low	High	Low	High	Low	High
Pungwe H/Water	Mutare City	78	78	78	78	78	78
Matenderere	Agric1	100	100	100	100	100	100
Pungwe	Hydropower 1	58	58	58	58	58	58
Murara	Agric2	73	47	74	48	77	50
Nyamawanga	Agric3	99	72	100	73	100	76
Nyamanyoka	Agric4	100	98	100	98	100	100
Sururu	Agric5	99	72	100	75	100	77
Chitema	Hydropower 2	51	51	51	51	51	51
Chitema	Agric 6	100	100	100	100	100	100
Nyamingura	Hydropower 3	70	70	70	70	70	70
Nyamingura	Agric 7	100	75	100	83	100	83
Nyamutsupa	Agric 8	100	100	100	100	100	100
Nyawamba	Agric 9	89	63	94	64	99	68
Muzinga	Agric 10	85	63	88	64	93	67
Nyamukombe	Agric 11	100	98	100	98	100	98
Pungwe	Agric 12	100	100	100	100	100	100
Pungwe	International obligations	100	100	100	100	100	100

Table 19 shows the satisfaction level in time for different water users in Pungwe micro-catchment considering projected 2030 water demands. Murara River, Muzinga River and Nyamutsupa Rivers had low levels satisfaction in time. Hydropower generation uses and Mutare City satisfaction levels remained the same under different water allocation practices. International obligations were 100% satisfied in time under all the water allocation practices.

Table 20 Satisfaction levels in amount for Honde micro-catchment in 2030 under different projected water demands

		Satisfaction level in amount (%)					
River	Use	Current		Market based		Proportion with priority	
		Low	High	Low	High	Low	High
River	Use	99	84	99	86	100	90
Honde H/Water	Agric 1	99	86	99	88	100	92
Manana	Agric 2	90	63	92	65	96	69
Nyachere	Agric 3	95	58	96	60	98	65
Honde Main	Agric 4	76	49	79	52	87	55
Nyarusha	Agric 5	43	18	45	19	57	22
Mukondwe	Agric 6	57	30	59	32	53	36
Matinedza	Agric 7	91	91	91	91	91	91
Duru	Hydro 1	30	12	36	16	43	16
Duru	Agric 8	39	15	51	17	54	19
Nyamakanga	Agric 9	62	35	72	37	74	41
Mupenga	Agric 10	30	17	39	17	43	19
Mtarazi	Agric 11	100	100	100	100	100	100
Honde Main	Agric 12	58	31	71	33	71	37
Booyo	Agric 13	94	68	99	70	98	74
Ngarura	Agric 14	70	43	86	50	81	49
Ruda	Agric 15	74	53	85	59	80	59
Ruda	Haua GP	100	99	100	99	100	100
Honde	Internatinal Obligations	99	84	99	86	100	90

Table 20 shows the satisfaction levels in amount for different water allocation practice under the 2030 projected water demands. The satisfaction level for hydropower generation remained at 89% under the different water allocation practices. International obligation was 100% satisfied under the proportional combined with priority allocation practices. The was an improvement in satisfaction levels of about 5% on agricultural water use as compared to current water allocation practice whilst agricultural water use improved with an average of 10% under the priority combined with priority water allocation practice

Table 21 Satisfaction levels in time for Honde micro-catchment in 2030 under different projected water demands

		Satisfaction level in amount (%)					
River	Use	Current		Market based		Proportion with priority	
		Low	High	Low	High	Low	High
Honde H/Water	Agric 1	99	86	99	86	99	88
Manana	Agric 2	99	86	99	87	99	88
Nyachere	Agric 3	88	68	88	71	94	76
Honde Main	Agric 4	96	78	97	80	99	83
Nyarusha	Agric 5	79	59	81	59	86	64
Mukondwe	Agric 6	53	37	57	38	59	39
Matinedza	Agric 7	67	43	68	43	68	48
Duru	Hydro 1	79	79	79	79	79	79
Duru	Agric 8	49	36	58	38	54	38
Nyamakanga	Agric 9	51	34	59	36	59	38
Mupenga	Agric 10	68	48	78	50	77	52
Mtarazi	Agric 11	50	43	55	45	55	45
Honde Main	Agric 12	100	100	100	100	100	100
Booyo	Agric 13	67	43	77	44	73	50
Ngarura	Agric 14	92	75	99	77	97	78
Ruda	Agric 15	76	53	86	59	79	59
Ruda	Haua GP	72	52	83	58	79	58
Honde	International Obligations	100	78	100	80	100	86

Table 21 shows satisfaction level in time for different water allocation practices for Honde microcatchment. There were shortages in Hauna growth point under all the water allocation practices. Agricultural water use 12 was satisfied 100% in time under all the water allocation practices. Duru hydropower generation satisfaction level remained the same under all the water allocation practices

CHAPTER SIX

6.0 Conclusion and recommendations

6.1 Conclusion

The results analysed in Chapter Five draw the following conclusions: The coefficient of determination R^2 is 0.70 for Pungwe Micro-catchment and R^2 is 0.67 for Honde micro-catchment. This shows that the outputs of the models can be confidently used and that the Pitman model can be used to generate surface runoff in Pungwe sub catchment. The methodology used in this research can be used in other ungauged mountainous catchments with similar characteristics as Pungwe sub-catchment where stream flow data is not available.

Water uses in the catchment are irrigation, hydropower, environment, and domestic water supply. A total of 258000ML is permitted water in the Pungwe sub-catchment. Of this permitted water about 86% are active permits whilst 14 % are non-active permits. The major water user is hydropower which is non consumptive use with about 64%.The surface water available can satisfy the current demand since the amount demanded is below the mean annual runoff.

There are no shortages experienced by agricultural water users under the current water allocation practice in the Pungwe micro-catchment. Shortages are experienced with Mutare city, and all the hydropower generation users. Significant water shortage would occur in 2030 after considering high irrigation growth rate of 15% annually to agricultural water users. However, there are no shortages to international obligations even after taking into consideration of high growth rate in irrigation

Honde micro-catchment is experiencing significant water shortages considering the current water demands and surface runoff. This shows that Honde micro-catchment is a highly committed micro-catchment as compared to Pungwe micro-catchment. Projected water demands for 2020 and 2030 would worsen the shortages in some tributaries of Honde River in the Honde micro-catchment. International obligations experienced water shortage in 2030 under the projected high water demand.

There are no improvement in the satisfaction levels for Hauna Growth Point and Hydropower generation even after considering alternative water allocation practices which are market based, water allocation practice and proportional combined with priority water allocation practice. However, proportional combined with priority water allocation practice improved satisfaction with an average of 20% agricultural water uses in Pungwe micro-catchment and 10% in Honde micro-catchment.

6.2 Recommendations

The research recommends that the sub catchment to consider the construction of reservoirs in the sub-catchment to cushion shortages in the near future being caused by increased demands and reduction of runoff due to climate change.

Farmers should adopt sustainable irrigation practices such as drip irrigation which are more efficient and reduce water shortages caused with increased demands and climate change.

Further research should be done to assess the impacts of climate change on surface water availability and its effects on water shortages in the sub-catchment and on meeting international flow obligations

The sub catchment should consider using alternative 1 (proportional combined with priority) water allocation since it increases percentage satisfaction agricultural water users of 20% in the Pungwe sub-catchment and 10% in Honde micro-catchment in areas where there are water shortages.

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Appendix 1 Simulated surface runoff for Pungwe headwaters in Mm^3

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total	Aver
1960	2.15	2.20	12.41	15.41	7.31	6.12	6.37	5.91	4.49	3.70	3.11	2.87	72.05	6.00
1961	2.70	3.46	4.42	6.95	13.17	21.09	15.75	5.55	4.31	3.31	2.66	2.09	85.46	7.12
1962	1.62	2.09	10.32	12.25	12.61	14.45	8.14	5.38	4.23	3.34	2.65	2.00	79.09	6.59
1963	1.55	2.77	3.87	10.17	12.07	6.19	4.35	3.36	2.67	2.14	1.76	1.47	52.37	4.36
1964	1.20	1.59	7.16	11.26	7.43	4.61	4.30	3.62	2.97	2.37	1.84	1.42	49.77	4.15
1965	1.20	1.99	2.51	2.95	9.65	10.21	4.87	4.41	3.58	2.98	2.42	1.87	48.65	4.05
1966	1.47	1.42	2.64	11.66	14.26	11.95	10.03	4.90	4.32	3.56	3.11	2.80	72.13	6.01
1967	2.30	2.04	2.18	2.29	2.57	2.79	3.13	3.40	3.03	2.55	2.02	1.55	29.84	2.49
1968	1.19	2.18	6.39	9.36	7.00	14.46	15.74	6.17	4.47	3.47	2.69	2.06	75.17	6.26
1969	1.77	1.88	31.40	37.45	10.04	5.59	7.05	6.87	4.23	3.33	2.76	2.11	114.47	9.54
1970	1.53	2.06	5.27	11.64	10.96	5.74	4.58	5.16	5.25	3.81	2.94	2.11	61.05	5.09
1971	1.56	4.40	10.39	21.78	18.01	7.88	7.79	5.06	3.89	2.90	2.17	1.61	87.44	7.29
1972	1.27	1.25	1.93	4.44	5.87	4.88	4.09	3.45	2.71	2.19	1.90	1.60	35.58	2.96
1973	1.49	4.86	13.59	19.87	26.11	31.63	19.67	6.55	4.93	3.82	3.04	2.60	138.16	11.51
1974	2.24	2.48	10.60	13.00	13.53	12.61	5.99	5.36	4.04	3.07	2.39	1.84	77.17	6.43
1975	1.63	1.76	4.34	7.55	11.74	32.02	27.48	5.51	4.32	3.31	2.48	1.80	103.93	8.66
1976	1.48	1.60	4.18	5.18	17.13	21.23	8.56	4.53	3.33	2.58	2.27	2.16	74.21	6.18
1977	1.95	2.64	7.06	16.95	19.72	21.14	20.62	10.40	5.07	3.97	3.03	2.25	114.81	9.57
1978	2.00	2.82	10.00	10.85	8.36	10.73	7.55	4.45	3.35	2.82	2.60	2.17	67.68	5.64
1979	2.22	2.33	3.26	4.58	12.89	13.45	5.64	4.87	3.81	2.98	2.47	2.18	60.68	5.06
1980	2.26	2.49	13.41	19.90	21.85	19.72	8.57	5.27	4.09	3.07	2.38	1.97	104.96	8.75
1981	1.78	2.61	5.80	7.56	7.87	7.05	5.08	4.40	3.54	2.79	2.26	1.85	52.60	4.38
1982	2.02	2.41	2.53	2.69	2.82	3.53	3.64	2.86	2.37	2.09	1.97	1.66	30.59	2.55
1983	1.38	1.32	3.51	4.07	3.10	9.42	9.71	3.94	3.16	2.56	2.17	1.88	46.21	3.85
1984	1.61	2.06	5.20	14.95	16.03	14.76	12.51	4.86	3.92	3.18	2.53	1.95	83.56	6.96
1985	1.58	1.91	7.20	24.69	23.65	7.98	6.32	5.75	4.20	3.10	2.33	1.69	90.41	7.53
1986	3.42	4.14	7.86	12.96	9.25	4.93	3.82	2.83	2.12	1.63	1.27	1.04	55.27	4.61
1987	0.96	1.02	5.98	8.46	9.62	18.46	17.72	8.42	4.49	3.45	2.68	2.05	83.30	6.94
1988	3.48	4.79	4.67	9.64	21.10	17.29	6.49	5.57	4.20	3.16	2.43	1.93	84.74	7.06
1989	1.90	2.48	11.33	24.05	22.06	10.75	5.40	4.57	3.58	2.77	2.17	1.69	92.76	7.73
1990	1.29	1.09	1.35	2.47	3.30	5.72	5.95	3.26	2.42	1.85	1.43	1.13	31.26	2.61
1991	0.91	0.74	1.22	2.32	2.50	1.99	1.77	1.53	1.24	1.01	0.83	0.65	16.71	1.39
1992	0.51	0.71	2.93	3.48	9.28	12.08	5.94	3.68	2.77	2.28	2.00	1.66	47.32	3.94
1993	1.22	2.88	5.50	10.88	10.26	4.54	3.59	2.77	2.16	1.69	1.32	1.03	47.83	3.99
1994	0.94	0.98	1.86	2.83	3.10	3.15	2.82	2.47	2.08	1.69	1.41	1.18	24.52	2.04
1995	1.00	0.89	7.73	8.73	7.62	8.57	4.42	4.51	4.41	3.54	2.85	2.19	56.46	4.71
1996	1.60	1.99	6.90	22.45	27.08	17.87	10.86	5.60	4.12	2.98	2.21	1.98	105.63	8.80
1997	2.20	2.55	3.14	18.16	18.80	7.40	7.37	4.09	2.99	2.28	1.81	1.45	72.26	6.02
1998	1.29	2.33	7.32	19.29	23.11	16.37	9.75	5.07	3.88	2.95	2.38	1.93	95.68	7.97
1999	1.60	2.29	3.33	5.78	10.37	21.10	18.19	6.05	4.95	4.37	3.55	2.66	84.24	7.02
2000	2.23	2.82	4.51	4.76	24.12	32.04	12.61	4.82	3.70	3.01	2.58	2.05	99.27	8.27
2001	1.56	1.68	7.62	8.64	4.00	3.89	3.76	3.41	2.79	2.30	1.90	1.48	43.02	3.58
2002	1.14	1.02	0.94	1.36	1.62	3.71	4.16	2.14	1.97	1.83	1.65	1.46	23.00	1.92
2003	1.36	1.80	4.98	8.08	9.18	8.98	6.81	5.16	4.32	3.57	2.96	2.43	59.63	4.97
2004	1.99	2.65	7.60	11.62	12.62	12.11	7.83	4.45	3.23	2.35	1.75	1.27	69.48	5.79
2005	0.96	1.11	6.19	15.05	12.13	4.89	4.23	3.48	2.68	2.05	1.60	1.20	55.56	4.63
2006	1.06	1.74	3.46	13.54	16.94	23.44	20.50	4.72	3.47	2.55	1.89	1.37	94.69	7.89
2007	0.98	3.61	34.45	38.64	13.44	8.90	5.31	4.38	3.29	2.40	1.80	1.36	118.57	9.88
2008	1.06	0.92	13.94	24.05	23.57	22.71	12.35	4.68	3.59	2.85	2.25	1.68	113.66	9.47
2009	1.28	1.26	1.42	16.42	17.68	4.90	5.66	4.80	3.55	2.62	1.97	1.47	63.01	5.25
2010	1.16	5.08	15.11	16.10	19.80	20.69	12.11	8.23	4.41	3.29	2.51	1.84	110.32	9.19
2011	1.29	1.23	16.47	32.50	19.57	6.43	6.83	5.69	4.17	3.05	2.27	1.69	101.18	8.43
2012	1.26	1.24	1.48	2.21	6.42	8.06	5.16	3.63	2.69	1.99	1.49	1.09	36.70	3.06
2013	0.79	0.90	10.60	16.97	11.10	8.95	7.30	4.47	3.42	2.61	2.00	1.50	70.60	5.88
2014	1.17	0.95	0.72	12.72	26.17	19.58	8.41	4.56	3.43	2.57	2.02	1.59	83.89	6.99

Appendix 2 Simulated surface runoff for Nyazengu River in Mm^3

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total	Aver
1960	2.18	2.24	12.63	15.68	7.44	6.23	6.48	6.01	4.57	3.77	3.16	2.92	73.31	6.11
1961	2.74	3.53	4.50	7.07	13.44	21.57	16.04	5.56	4.34	3.35	2.70	2.13	86.96	7.25
1962	1.64	2.13	10.50	12.46	12.86	14.75	8.27	5.44	4.29	3.40	2.69	2.03	80.47	6.71
1963	1.57	2.82	3.94	10.35	12.29	6.30	4.43	3.42	2.72	2.18	1.79	1.49	53.29	4.44
1964	1.22	1.62	7.29	11.46	7.56	4.69	4.37	3.69	3.02	2.41	1.87	1.45	50.64	4.22
1965	1.22	2.03	2.55	3.00	9.82	10.39	4.95	4.49	3.65	3.03	2.47	1.90	49.50	4.13
1966	1.50	1.45	2.69	11.86	14.51	12.21	10.23	4.95	4.38	3.61	3.16	2.85	73.39	6.12
1967	2.34	2.08	2.21	2.33	2.61	2.83	3.19	3.46	3.08	2.60	2.05	1.58	30.36	2.53
1968	1.22	2.22	6.50	9.53	7.12	14.72	16.03	6.28	4.54	3.53	2.73	2.10	76.49	6.37
1969	1.80	1.91	31.95	38.12	10.22	5.67	7.17	6.99	4.31	3.39	2.80	2.14	116.48	9.71
1970	1.56	2.10	5.37	11.85	11.15	5.84	4.66	5.25	5.34	3.88	2.99	2.14	62.12	5.18
1971	1.59	4.48	10.57	22.16	18.33	8.04	7.93	5.13	3.95	2.94	2.21	1.63	88.97	7.41
1972	1.29	1.27	1.97	4.51	5.97	4.97	4.16	3.51	2.75	2.23	1.93	1.63	36.20	3.02
1973	1.52	4.95	13.83	20.23	26.68	32.32	19.97	6.54	4.96	3.86	3.08	2.65	140.59	11.72
1974	2.28	2.52	10.79	13.23	13.82	12.85	6.06	5.44	4.10	3.12	2.43	1.87	78.52	6.54
1975	1.66	1.79	4.41	7.68	11.95	32.70	28.01	5.51	4.36	3.35	2.52	1.83	105.76	8.81
1976	1.50	1.63	4.25	5.27	17.43	21.64	8.73	4.58	3.38	2.62	2.30	2.19	75.51	6.29
1977	1.99	2.69	7.19	17.24	20.13	21.63	21.04	10.52	5.06	4.00	3.07	2.28	116.83	9.74
1978	2.03	2.86	10.17	11.04	8.50	10.95	7.69	4.51	3.39	2.86	2.64	2.21	68.86	5.74
1979	2.26	2.37	3.32	4.66	13.11	13.69	5.74	4.96	3.88	3.03	2.51	2.22	61.75	5.15
1980	2.30	2.53	13.64	20.24	22.33	20.14	8.66	5.30	4.13	3.11	2.42	2.01	106.81	8.90
1981	1.81	2.66	5.90	7.69	8.01	7.17	5.17	4.48	3.60	2.84	2.30	1.88	53.52	4.46
1982	2.06	2.45	2.57	2.73	2.87	3.59	3.70	2.91	2.41	2.13	2.01	1.69	31.13	2.59
1983	1.40	1.34	3.57	4.14	3.15	9.58	9.88	4.01	3.21	2.61	2.21	1.92	47.02	3.92
1984	1.64	2.10	5.29	15.21	16.33	15.10	12.74	4.88	3.96	3.23	2.56	1.98	85.02	7.09
1985	1.61	1.95	7.33	25.12	24.10	8.13	6.40	5.84	4.27	3.16	2.37	1.72	91.99	7.67
1986	3.48	4.21	8.00	13.19	9.41	5.02	3.89	2.88	2.15	1.66	1.29	1.05	56.24	4.69
1987	0.98	1.04	6.09	8.61	9.78	18.84	18.10	8.53	4.51	3.48	2.72	2.08	84.77	7.06
1988	3.54	4.87	4.75	9.81	21.55	17.63	6.55	5.64	4.26	3.21	2.47	1.96	86.23	7.19
1989	1.94	2.52	11.53	24.48	22.52	10.97	5.43	4.62	3.63	2.81	2.21	1.72	94.38	7.87
1990	1.31	1.11	1.38	2.52	3.36	5.82	6.06	3.32	2.47	1.88	1.45	1.15	31.81	2.65
1991	0.92	0.76	1.24	2.36	2.54	2.02	1.80	1.56	1.26	1.03	0.84	0.65	16.99	1.42
1992	0.47	0.69	3.02	3.57	9.46	12.30	6.05	3.75	2.82	2.32	2.04	1.69	48.17	4.01
1993	1.24	2.93	5.59	11.07	10.44	4.62	3.65	2.82	2.20	1.72	1.34	1.04	48.67	4.06
1994	0.96	1.00	1.90	2.88	3.16	3.21	2.87	2.51	2.12	1.72	1.43	1.20	24.95	2.08
1995	1.02	0.90	7.86	8.88	7.76	8.72	4.50	4.59	4.48	3.60	2.90	2.23	57.46	4.79
1996	1.62	2.03	7.02	22.85	27.63	18.28	11.02	5.62	4.16	3.02	2.24	2.01	107.49	8.96
1997	2.24	2.59	3.20	18.48	19.13	7.53	7.50	4.17	3.04	2.32	1.84	1.48	73.52	6.13
1998	1.31	2.37	7.45	19.63	23.59	16.74	9.89	5.09	3.92	2.99	2.41	1.96	97.36	8.11
1999	1.63	2.33	3.39	5.88	10.56	21.56	18.55	6.09	5.00	4.43	3.60	2.70	85.72	7.14
2000	2.27	2.87	4.58	4.85	24.54	32.70	12.88	4.83	3.74	3.05	2.62	2.08	101.01	8.42
2001	1.59	1.71	7.75	8.79	4.07	3.96	3.82	3.47	2.84	2.34	1.93	1.50	43.77	3.65
2002	1.16	1.03	0.95	1.39	1.65	3.78	4.23	2.18	2.00	1.86	1.68	1.49	23.40	1.95
2003	1.39	1.83	5.07	8.23	9.34	9.15	6.94	5.24	4.39	3.63	3.01	2.47	60.67	5.06
2004	2.03	2.70	7.74	11.82	12.88	12.38	7.95	4.49	3.27	2.39	1.77	1.29	70.70	5.89
2005	0.98	1.12	6.30	15.31	12.34	4.97	4.30	3.54	2.73	2.09	1.63	1.22	56.53	4.71
2006	1.08	1.77	3.52	13.78	17.25	23.96	20.89	4.72	3.49	2.58	1.92	1.39	96.35	8.03
2007	1.00	3.67	35.06	39.35	13.73	9.05	5.35	4.44	3.34	2.44	1.83	1.39	120.65	10.05
2008	1.08	0.94	14.18	24.47	24.01	23.21	12.59	4.69	3.62	2.88	2.28	1.71	115.65	9.64
2009	1.30	1.28	1.44	16.71	17.99	4.99	5.76	4.89	3.61	2.66	2.00	1.49	64.12	5.34
2010	1.18	5.17	15.37	16.38	20.23	21.14	12.31	8.32	4.42	3.32	2.54	1.86	112.26	9.35
2011	1.31	1.25	16.76	33.07	19.91	6.54	6.95	5.79	4.25	3.10	2.31	1.71	102.96	8.58
2012	1.28	1.26	1.50	2.25	6.53	8.20	5.25	3.70	2.73	2.02	1.51	1.11	37.35	3.11
2013	0.80	0.91	10.79	17.26	11.29	9.13	7.44	4.53	3.47	2.65	2.03	1.53	71.84	5.99
2014	1.19	0.97	0.73	12.94	26.63	19.93	8.56	4.64	3.49	2.61	2.06	1.61	85.36	7.11

Appendix 3 Simulated surface runoff for Murara River in Mm^3

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total	Aver
1960	0.15	0.15	0.87	1.08	0.51	0.43	0.45	0.41	0.32	0.26	0.22	0.20	5.06	0.42
1961	0.19	0.24	0.31	0.49	0.93	1.49	1.11	0.38	0.30	0.23	0.19	0.15	6.00	0.50
1962	0.11	0.15	0.72	0.86	0.89	1.02	0.57	0.38	0.30	0.23	0.19	0.14	5.55	0.46
1963	0.11	0.19	0.27	0.71	0.85	0.43	0.31	0.24	0.19	0.15	0.12	0.10	3.68	0.31
1964	0.08	0.11	0.50	0.79	0.52	0.32	0.30	0.25	0.21	0.17	0.13	0.10	3.49	0.29
1965	0.08	0.14	0.18	0.21	0.68	0.72	0.34	0.31	0.25	0.21	0.17	0.13	3.41	0.28
1966	0.10	0.10	0.19	0.82	1.00	0.84	0.71	0.34	0.30	0.25	0.22	0.20	5.06	0.42
1967	0.16	0.14	0.15	0.16	0.18	0.20	0.22	0.24	0.21	0.18	0.14	0.11	2.09	0.17
1968	0.08	0.15	0.45	0.66	0.49	1.01	1.11	0.43	0.31	0.24	0.19	0.14	5.28	0.44
1969	0.12	0.13	2.20	2.63	0.70	0.39	0.49	0.48	0.30	0.23	0.19	0.15	8.03	0.67
1970	0.11	0.14	0.37	0.82	0.77	0.40	0.32	0.36	0.37	0.27	0.21	0.15	4.28	0.36
1971	0.11	0.31	0.73	1.53	1.26	0.55	0.55	0.35	0.27	0.20	0.15	0.11	6.14	0.51
1972	0.09	0.09	0.14	0.31	0.41	0.34	0.29	0.24	0.19	0.15	0.13	0.11	2.50	0.21
1973	0.10	0.34	0.95	1.40	1.84	2.23	1.38	0.45	0.34	0.27	0.21	0.18	9.70	0.81
1974	0.16	0.17	0.74	0.91	0.95	0.89	0.42	0.38	0.28	0.22	0.17	0.13	5.42	0.45
1975	0.11	0.12	0.30	0.53	0.82	2.26	1.93	0.38	0.30	0.23	0.17	0.13	7.29	0.61
1976	0.10	0.11	0.29	0.36	1.20	1.49	0.60	0.32	0.23	0.18	0.16	0.15	5.21	0.43
1977	0.14	0.19	0.50	1.19	1.39	1.49	1.45	0.73	0.35	0.28	0.21	0.16	8.06	0.67
1978	0.14	0.20	0.70	0.76	0.59	0.76	0.53	0.31	0.23	0.20	0.18	0.15	4.75	0.40
1979	0.16	0.16	0.23	0.32	0.90	0.94	0.40	0.34	0.27	0.21	0.17	0.15	4.26	0.35
1980	0.16	0.17	0.94	1.40	1.54	1.39	0.60	0.37	0.29	0.21	0.17	0.14	7.37	0.61
1981	0.12	0.18	0.41	0.53	0.55	0.49	0.36	0.31	0.25	0.20	0.16	0.13	3.69	0.31
1982	0.14	0.17	0.18	0.19	0.20	0.25	0.26	0.20	0.17	0.15	0.14	0.12	2.15	0.18
1983	0.10	0.09	0.25	0.29	0.22	0.66	0.68	0.28	0.22	0.18	0.15	0.13	3.24	0.27
1984	0.11	0.14	0.36	1.05	1.13	1.04	0.88	0.34	0.27	0.22	0.18	0.14	5.86	0.49
1985	0.11	0.13	0.51	1.73	1.66	0.56	0.44	0.40	0.29	0.22	0.16	0.12	6.34	0.53
1986	0.24	0.29	0.55	0.91	0.65	0.35	0.27	0.20	0.15	0.11	0.09	0.07	3.88	0.32
1987	0.07	0.07	0.42	0.59	0.67	1.30	1.25	0.59	0.31	0.24	0.19	0.14	5.85	0.49
1988	0.24	0.34	0.33	0.68	1.49	1.22	0.45	0.39	0.29	0.22	0.17	0.14	5.95	0.50
1989	0.13	0.17	0.80	1.69	1.55	0.76	0.37	0.32	0.25	0.19	0.15	0.12	6.51	0.54
1990	0.09	0.08	0.09	0.17	0.23	0.40	0.42	0.23	0.17	0.13	0.10	0.08	2.19	0.18
1991	0.06	0.05	0.09	0.16	0.18	0.14	0.12	0.11	0.09	0.07	0.06	0.04	1.17	0.10
1992	0.03	0.05	0.21	0.25	0.65	0.85	0.42	0.26	0.19	0.16	0.14	0.12	3.32	0.28
1993	0.09	0.20	0.39	0.76	0.72	0.32	0.25	0.19	0.15	0.12	0.09	0.07	3.36	0.28
1994	0.07	0.07	0.13	0.20	0.22	0.22	0.20	0.17	0.15	0.12	0.10	0.08	1.72	0.14
1995	0.07	0.06	0.54	0.61	0.53	0.60	0.31	0.32	0.31	0.25	0.20	0.15	3.96	0.33
1996	0.11	0.14	0.48	1.58	1.91	1.26	0.76	0.39	0.29	0.21	0.15	0.14	7.41	0.62
1997	0.15	0.18	0.22	1.27	1.32	0.52	0.52	0.29	0.21	0.16	0.13	0.10	5.07	0.42
1998	0.09	0.16	0.51	1.35	1.63	1.15	0.68	0.35	0.27	0.21	0.17	0.14	6.71	0.56
1999	0.11	0.16	0.23	0.41	0.73	1.49	1.28	0.42	0.35	0.31	0.25	0.19	5.91	0.49
2000	0.16	0.20	0.32	0.33	1.69	2.26	0.89	0.33	0.26	0.21	0.18	0.14	6.97	0.58
2001	0.11	0.12	0.53	0.61	0.28	0.27	0.26	0.24	0.20	0.16	0.13	0.10	3.02	0.25
2002	0.08	0.07	0.07	0.10	0.11	0.26	0.29	0.15	0.14	0.13	0.12	0.10	1.61	0.13
2003	0.10	0.13	0.35	0.57	0.64	0.63	0.48	0.36	0.30	0.25	0.21	0.17	4.18	0.35
2004	0.14	0.19	0.53	0.82	0.89	0.85	0.55	0.31	0.23	0.16	0.12	0.09	4.88	0.41
2005	0.07	0.08	0.43	1.06	0.85	0.34	0.30	0.24	0.19	0.14	0.11	0.08	3.90	0.32
2006	0.07	0.12	0.24	0.95	1.19	1.65	1.44	0.33	0.24	0.18	0.13	0.10	6.64	0.55
2007	0.07	0.25	2.42	2.71	0.95	0.62	0.37	0.31	0.23	0.17	0.13	0.10	8.32	0.69
2008	0.07	0.06	0.98	1.69	1.66	1.60	0.87	0.32	0.25	0.20	0.16	0.12	7.98	0.66
2009	0.09	0.09	0.10	1.15	1.24	0.34	0.40	0.34	0.25	0.18	0.14	0.10	4.42	0.37
2010	0.08	0.36	1.06	1.13	1.40	1.46	0.85	0.57	0.31	0.23	0.18	0.13	7.74	0.65
2011	0.09	0.09	1.16	2.28	1.37	0.45	0.48	0.40	0.29	0.21	0.16	0.12	7.10	0.59
2012	0.09	0.09	0.10	0.16	0.45	0.57	0.36	0.25	0.19	0.14	0.10	0.08	2.58	0.21
2013	0.06	0.06	0.74	1.19	0.78	0.63	0.51	0.31	0.24	0.18	0.14	0.11	4.95	0.41
2014	0.08	0.07	0.05	0.89	1.84	1.37	0.59	0.32	0.24	0.18	0.14	0.11	5.89	0.49

Appendix 4 Simulated surface runoff for Nyamanyoka River in Mm^3

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total	Aver
1960	0.19	0.19	1.09	1.35	0.64	0.54	0.58	0.54	0.40	0.33	0.27	0.25	6.37	0.53
1961	0.24	0.30	0.39	0.61	1.16	1.88	1.41	0.49	0.39	0.30	0.24	0.19	7.59	0.63
1962	0.14	0.18	0.91	1.08	1.11	1.30	0.74	0.48	0.38	0.30	0.24	0.18	7.03	0.59
1963	0.14	0.24	0.34	0.89	1.06	0.55	0.39	0.30	0.24	0.19	0.16	0.13	4.64	0.39
1964	0.11	0.14	0.63	0.99	0.65	0.41	0.38	0.33	0.27	0.21	0.16	0.13	4.42	0.37
1965	0.11	0.18	0.22	0.26	0.85	0.90	0.43	0.40	0.33	0.27	0.22	0.17	4.32	0.36
1966	0.13	0.13	0.23	1.02	1.25	1.08	0.91	0.44	0.39	0.32	0.28	0.25	6.42	0.53
1967	0.20	0.18	0.19	0.20	0.23	0.25	0.28	0.31	0.27	0.23	0.18	0.14	2.65	0.22
1968	0.11	0.19	0.56	0.82	0.61	1.29	1.43	0.57	0.40	0.31	0.24	0.18	6.72	0.56
1969	0.16	0.16	2.75	3.29	0.88	0.49	0.63	0.62	0.38	0.30	0.24	0.19	10.09	0.84
1970	0.14	0.18	0.46	1.02	0.96	0.51	0.41	0.46	0.47	0.34	0.26	0.19	5.40	0.45
1971	0.14	0.39	0.91	1.91	1.58	0.70	0.70	0.45	0.35	0.26	0.19	0.14	7.72	0.64
1972	0.11	0.11	0.17	0.39	0.52	0.43	0.37	0.31	0.25	0.20	0.17	0.14	3.17	0.26
1973	0.13	0.43	1.19	1.75	2.30	2.81	1.78	0.60	0.43	0.34	0.27	0.23	12.25	1.02
1974	0.20	0.22	0.93	1.14	1.19	1.11	0.53	0.48	0.37	0.28	0.21	0.16	6.82	0.57
1975	0.15	0.16	0.38	0.66	1.03	2.87	2.47	0.48	0.39	0.29	0.22	0.16	9.26	0.77
1976	0.13	0.14	0.37	0.45	1.50	1.89	0.78	0.40	0.30	0.23	0.20	0.19	6.60	0.55
1977	0.17	0.23	0.62	1.49	1.74	1.89	1.87	0.94	0.44	0.35	0.26	0.20	10.20	0.85
1978	0.17	0.25	0.88	0.95	0.73	0.97	0.69	0.40	0.30	0.25	0.23	0.19	6.02	0.50
1979	0.20	0.21	0.29	0.40	1.13	1.18	0.50	0.44	0.35	0.27	0.22	0.19	5.38	0.45
1980	0.20	0.22	1.18	1.75	1.93	1.76	0.77	0.47	0.37	0.27	0.21	0.18	9.31	0.78
1981	0.16	0.23	0.51	0.66	0.69	0.62	0.45	0.40	0.32	0.25	0.20	0.17	4.67	0.39
1982	0.18	0.21	0.22	0.24	0.25	0.31	0.32	0.26	0.22	0.19	0.18	0.15	2.73	0.23
1983	0.12	0.12	0.31	0.36	0.27	0.83	0.86	0.36	0.29	0.23	0.19	0.17	4.10	0.34
1984	0.14	0.18	0.46	1.31	1.41	1.33	1.13	0.43	0.35	0.28	0.22	0.17	7.42	0.62
1985	0.14	0.17	0.63	2.17	2.08	0.71	0.56	0.52	0.38	0.28	0.21	0.15	7.98	0.67
1986	0.30	0.36	0.69	1.14	0.81	0.43	0.34	0.26	0.19	0.15	0.11	0.09	4.89	0.41
1987	0.09	0.09	0.53	0.74	0.84	1.65	1.61	0.77	0.40	0.30	0.23	0.18	7.43	0.62
1988	0.31	0.42	0.41	0.85	1.86	1.54	0.59	0.50	0.38	0.28	0.22	0.17	7.52	0.63
1989	0.17	0.22	1.00	2.11	1.94	0.95	0.48	0.41	0.33	0.25	0.19	0.15	8.20	0.68
1990	0.12	0.10	0.12	0.22	0.29	0.50	0.53	0.30	0.22	0.17	0.13	0.10	2.79	0.23
1991	0.08	0.07	0.11	0.20	0.22	0.18	0.16	0.14	0.11	0.09	0.07	0.06	1.49	0.12
1992	0.04	0.06	0.26	0.31	0.82	1.06	0.53	0.33	0.25	0.21	0.18	0.15	4.20	0.35
1993	0.11	0.25	0.48	0.96	0.90	0.40	0.32	0.25	0.20	0.15	0.12	0.09	4.24	0.35
1994	0.08	0.09	0.16	0.25	0.27	0.28	0.25	0.22	0.19	0.15	0.13	0.11	2.19	0.18
1995	0.09	0.08	0.68	0.77	0.67	0.75	0.39	0.41	0.40	0.32	0.25	0.19	5.00	0.42
1996	0.14	0.18	0.61	1.97	2.38	1.60	0.98	0.49	0.37	0.27	0.20	0.18	9.36	0.78
1997	0.19	0.22	0.28	1.59	1.65	0.65	0.65	0.37	0.27	0.21	0.16	0.13	6.39	0.53
1998	0.12	0.21	0.64	1.69	2.04	1.47	0.88	0.45	0.35	0.26	0.21	0.17	8.49	0.71
1999	0.14	0.20	0.29	0.51	0.91	1.88	1.65	0.56	0.44	0.38	0.31	0.23	7.52	0.63
2000	0.20	0.25	0.40	0.42	2.12	2.84	1.14	0.43	0.33	0.27	0.23	0.18	8.79	0.73
2001	0.14	0.15	0.67	0.76	0.35	0.34	0.34	0.31	0.26	0.21	0.17	0.13	3.82	0.32
2002	0.10	0.09	0.08	0.12	0.14	0.33	0.37	0.19	0.18	0.16	0.15	0.13	2.05	0.17
2003	0.12	0.16	0.44	0.71	0.81	0.81	0.63	0.46	0.39	0.32	0.26	0.22	5.32	0.44
2004	0.18	0.23	0.67	1.02	1.11	1.09	0.71	0.40	0.29	0.21	0.16	0.11	6.18	0.52
2005	0.09	0.10	0.54	1.32	1.06	0.43	0.38	0.32	0.25	0.19	0.14	0.11	4.92	0.41
2006	0.10	0.15	0.30	1.19	1.49	2.09	1.83	0.42	0.31	0.23	0.17	0.12	8.40	0.70
2007	0.09	0.32	3.02	3.40	1.19	0.78	0.47	0.39	0.30	0.22	0.16	0.12	10.46	0.87
2008	0.10	0.08	1.22	2.11	2.07	2.03	1.11	0.41	0.32	0.25	0.20	0.15	10.07	0.84
2009	0.11	0.11	0.12	1.44	1.55	0.43	0.50	0.43	0.32	0.24	0.18	0.13	5.58	0.46
2010	0.10	0.45	1.33	1.41	1.75	1.85	1.11	0.75	0.39	0.29	0.22	0.16	9.81	0.82
2011	0.11	0.11	1.44	2.85	1.72	0.57	0.64	0.54	0.37	0.27	0.20	0.15	8.96	0.75
2012	0.11	0.11	0.13	0.19	0.56	0.71	0.46	0.33	0.25	0.18	0.13	0.10	3.26	0.27
2013	0.07	0.08	0.93	1.49	0.97	0.81	0.67	0.40	0.31	0.23	0.18	0.13	6.28	0.52
2014	0.10	0.08	0.06	1.12	2.30	1.72	0.75	0.41	0.31	0.23	0.18	0.14	7.41	0.62

Appendix 5 Simulated surface runoff for Chitema River in Mm^3

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total	Aver
1960	1.43	1.46	8.27	10.27	4.87	4.08	4.25	3.94	3.00	2.47	2.07	1.91	48.03	4.00
1961	1.80	2.31	2.95	4.63	8.80	14.13	10.51	3.64	2.85	2.19	1.77	1.39	56.98	4.75
1962	1.08	1.40	6.88	8.16	8.43	9.66	5.42	3.57	2.81	2.22	1.76	1.33	52.72	4.39
1963	1.03	1.85	2.58	6.78	8.05	4.13	2.90	2.24	1.78	1.43	1.18	0.98	34.91	2.91
1964	0.80	1.06	4.78	7.51	4.95	3.07	2.87	2.42	1.98	1.58	1.22	0.95	33.18	2.76
1965	0.80	1.33	1.67	1.97	6.43	6.80	3.25	2.94	2.39	1.99	1.62	1.25	32.43	2.70
1966	0.98	0.95	1.76	7.77	9.51	8.00	6.70	3.24	2.87	2.37	2.07	1.87	48.09	4.01
1967	1.53	1.36	1.45	1.52	1.71	1.86	2.09	2.27	2.02	1.70	1.35	1.03	19.89	1.66
1968	0.80	1.45	4.26	6.24	4.66	9.64	10.50	4.11	2.97	2.31	1.79	1.37	50.12	4.18
1969	1.18	1.25	20.93	24.97	6.70	3.72	4.70	4.58	2.82	2.22	1.84	1.41	76.31	6.36
1970	1.02	1.37	3.52	7.76	7.31	3.83	3.05	3.44	3.50	2.54	1.96	1.40	40.70	3.39
1971	1.04	2.94	6.93	14.52	12.01	5.27	5.20	3.36	2.59	1.93	1.45	1.07	58.29	4.86
1972	0.85	0.83	1.29	2.96	3.91	3.25	2.73	2.30	1.80	1.46	1.27	1.07	23.72	1.98
1973	1.00	3.24	9.06	13.25	17.48	21.17	13.09	4.29	3.25	2.53	2.02	1.73	92.11	7.68
1974	1.49	1.65	7.07	8.67	9.05	8.42	3.97	3.56	2.69	2.05	1.59	1.23	51.44	4.29
1975	1.09	1.17	2.89	5.03	7.83	21.43	18.35	3.61	2.85	2.20	1.65	1.20	69.29	5.77
1976	0.98	1.07	2.79	3.45	11.42	14.18	5.72	3.00	2.21	1.71	1.51	1.44	49.47	4.12
1977	1.30	1.76	4.71	11.30	13.19	14.17	13.78	6.89	3.32	2.62	2.01	1.49	76.54	6.38
1978	1.33	1.88	6.66	7.24	5.57	7.17	5.04	2.95	2.22	1.87	1.73	1.45	45.12	3.76
1979	1.48	1.55	2.17	3.06	8.59	8.97	3.76	3.25	2.54	1.99	1.65	1.45	40.46	3.37
1980	1.51	1.66	8.94	13.26	14.63	13.20	5.67	3.47	2.71	2.04	1.58	1.31	69.98	5.83
1981	1.19	1.74	3.86	5.04	5.25	4.70	3.39	2.93	2.36	1.86	1.51	1.23	35.07	2.92
1982	1.35	1.60	1.69	1.79	1.88	2.35	2.43	1.91	1.58	1.39	1.32	1.11	20.39	1.70
1983	0.92	0.88	2.34	2.71	2.06	6.28	6.47	2.63	2.10	1.71	1.45	1.26	30.80	2.57
1984	1.07	1.38	3.47	9.96	10.70	9.89	8.35	3.20	2.59	2.11	1.68	1.30	55.71	4.64
1985	1.05	1.28	4.80	16.46	15.79	5.33	4.20	3.83	2.80	2.07	1.55	1.13	60.27	5.02
1986	2.28	2.76	5.24	8.64	6.17	3.29	2.55	1.89	1.41	1.09	0.84	0.69	36.85	3.07
1987	0.64	0.68	3.99	5.64	6.41	12.35	11.86	5.59	2.95	2.28	1.78	1.36	55.54	4.63
1988	2.32	3.19	3.11	6.43	14.12	11.55	4.29	3.69	2.79	2.10	1.62	1.29	56.49	4.71
1989	1.27	1.65	7.56	16.04	14.76	7.19	3.55	3.03	2.38	1.84	1.45	1.13	61.84	5.15
1990	0.86	0.72	0.90	1.65	2.20	3.81	3.97	2.17	1.62	1.23	0.95	0.75	20.84	1.74
1991	0.60	0.50	0.81	1.54	1.67	1.33	1.18	1.02	0.83	0.67	0.55	0.43	11.13	0.93
1992	0.31	0.45	1.98	2.34	6.20	8.06	3.96	2.46	1.85	1.52	1.33	1.11	31.56	2.63
1993	0.81	1.92	3.66	7.25	6.84	3.02	2.39	1.85	1.44	1.13	0.88	0.68	31.89	2.66
1994	0.63	0.65	1.24	1.89	2.07	2.10	1.88	1.64	1.39	1.13	0.94	0.79	16.35	1.36
1995	0.67	0.59	5.15	5.82	5.08	5.72	2.95	3.01	2.94	2.36	1.90	1.46	37.64	3.14
1996	1.06	1.33	4.60	14.97	18.10	11.98	7.22	3.68	2.73	1.98	1.47	1.32	70.42	5.87
1997	1.47	1.70	2.10	12.11	12.54	4.93	4.92	2.73	1.99	1.52	1.21	0.97	48.17	4.01
1998	0.86	1.55	4.88	12.86	15.46	10.97	6.48	3.33	2.57	1.96	1.58	1.29	63.79	5.32
1999	1.07	1.53	2.22	3.85	6.92	14.12	12.15	3.99	3.28	2.90	2.36	1.77	56.16	4.68
2000	1.49	1.88	3.00	3.18	16.08	21.43	8.44	3.17	2.45	2.00	1.72	1.36	66.18	5.51
2001	1.04	1.12	5.08	5.76	2.67	2.59	2.51	2.27	1.86	1.53	1.27	0.98	28.68	2.39
2002	0.76	0.68	0.62	0.91	1.08	2.47	2.77	1.43	1.31	1.22	1.10	0.97	15.33	1.28
2003	0.91	1.20	3.32	5.39	6.12	5.99	4.54	3.43	2.88	2.38	1.97	1.62	39.75	3.31
2004	1.33	1.77	5.07	7.75	8.44	8.11	5.21	2.94	2.14	1.56	1.16	0.84	46.32	3.86
2005	0.64	0.74	4.13	10.03	8.08	3.26	2.82	2.32	1.79	1.37	1.07	0.80	37.04	3.09
2006	0.71	1.16	2.30	9.03	11.30	15.70	13.69	3.09	2.29	1.69	1.26	0.91	63.13	5.26
2007	0.65	2.41	22.97	25.78	9.00	5.93	3.51	2.91	2.19	1.60	1.20	0.91	79.04	6.59
2008	0.71	0.61	9.29	16.03	15.73	15.20	8.25	3.07	2.37	1.89	1.49	1.12	75.77	6.31
2009	0.85	0.84	0.94	10.95	11.79	3.27	3.77	3.20	2.37	1.74	1.31	0.98	42.01	3.50
2010	0.77	3.39	10.07	10.73	13.25	13.85	8.07	5.45	2.90	2.18	1.67	1.22	73.55	6.13
2011	0.86	0.82	10.98	21.67	13.04	4.28	4.56	3.79	2.78	2.03	1.52	1.12	67.45	5.62
2012	0.84	0.83	0.98	1.48	4.28	5.37	3.44	2.42	1.79	1.33	0.99	0.72	24.47	2.04
2013	0.53	0.60	7.07	11.31	7.40	5.98	4.88	2.97	2.27	1.74	1.33	1.00	47.07	3.92
2014	0.78	0.64	0.48	8.48	17.45	13.06	5.61	3.04	2.29	1.71	1.35	1.06	55.92	4.66

Appendix 6 Simulated surface runoff for Sururu River in Mm^3

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total	Aver
1960	0.19	0.19	1.09	1.35	0.64	0.54	0.56	0.52	0.39	0.32	0.27	0.25	6.32	0.53
1961	0.24	0.30	0.39	0.61	1.16	1.86	1.38	0.48	0.37	0.29	0.23	0.18	7.50	0.62
1962	0.14	0.18	0.91	1.07	1.11	1.27	0.71	0.47	0.37	0.29	0.23	0.18	6.94	0.58
1963	0.14	0.24	0.34	0.89	1.06	0.54	0.38	0.29	0.23	0.19	0.15	0.13	4.59	0.38
1964	0.11	0.14	0.63	0.99	0.65	0.40	0.38	0.32	0.26	0.21	0.16	0.12	4.37	0.36
1965	0.11	0.17	0.22	0.26	0.85	0.90	0.43	0.39	0.31	0.26	0.21	0.16	4.27	0.36
1966	0.13	0.12	0.23	1.02	1.25	1.05	0.88	0.43	0.38	0.31	0.27	0.25	6.33	0.53
1967	0.20	0.18	0.19	0.20	0.23	0.24	0.27	0.30	0.27	0.22	0.18	0.14	2.62	0.22
1968	0.10	0.19	0.56	0.82	0.61	1.27	1.38	0.54	0.39	0.30	0.24	0.18	6.59	0.55
1969	0.16	0.16	2.75	3.29	0.88	0.49	0.62	0.60	0.37	0.29	0.24	0.18	10.04	0.84
1970	0.13	0.18	0.46	1.02	0.96	0.50	0.40	0.45	0.46	0.33	0.26	0.18	5.36	0.45
1971	0.14	0.39	0.91	1.91	1.58	0.69	0.68	0.44	0.34	0.25	0.19	0.14	7.67	0.64
1972	0.11	0.11	0.17	0.39	0.51	0.43	0.36	0.30	0.24	0.19	0.17	0.14	3.12	0.26
1973	0.13	0.43	1.19	1.74	2.30	2.79	1.72	0.56	0.43	0.33	0.27	0.23	12.12	1.01
1974	0.20	0.22	0.93	1.14	1.19	1.11	0.52	0.47	0.35	0.27	0.21	0.16	6.77	0.56
1975	0.14	0.15	0.38	0.66	1.03	2.82	2.41	0.47	0.38	0.29	0.22	0.16	9.12	0.76
1976	0.13	0.14	0.37	0.45	1.50	1.87	0.75	0.39	0.29	0.23	0.20	0.19	6.51	0.54
1977	0.17	0.23	0.62	1.49	1.74	1.86	1.81	0.91	0.44	0.34	0.26	0.20	10.07	0.84
1978	0.17	0.25	0.88	0.95	0.73	0.94	0.66	0.39	0.29	0.25	0.23	0.19	5.94	0.49
1979	0.19	0.20	0.29	0.40	1.13	1.18	0.49	0.43	0.33	0.26	0.22	0.19	5.32	0.44
1980	0.20	0.22	1.18	1.75	1.93	1.74	0.75	0.46	0.36	0.27	0.21	0.17	9.21	0.77
1981	0.16	0.23	0.51	0.66	0.69	0.62	0.45	0.39	0.31	0.24	0.20	0.16	4.61	0.38
1982	0.18	0.21	0.22	0.24	0.25	0.31	0.32	0.25	0.21	0.18	0.17	0.15	2.68	0.22
1983	0.12	0.12	0.31	0.36	0.27	0.83	0.85	0.35	0.28	0.22	0.19	0.17	4.05	0.34
1984	0.14	0.18	0.46	1.31	1.41	1.30	1.10	0.42	0.34	0.28	0.22	0.17	7.33	0.61
1985	0.14	0.17	0.63	2.17	2.08	0.70	0.55	0.50	0.37	0.27	0.20	0.15	7.93	0.66
1986	0.30	0.36	0.69	1.14	0.81	0.43	0.34	0.25	0.19	0.14	0.11	0.09	4.85	0.40
1987	0.08	0.09	0.52	0.74	0.84	1.62	1.56	0.74	0.39	0.30	0.23	0.18	7.31	0.61
1988	0.31	0.42	0.41	0.85	1.86	1.52	0.56	0.49	0.37	0.28	0.21	0.17	7.43	0.62
1989	0.17	0.22	0.99	2.11	1.94	0.95	0.47	0.40	0.31	0.24	0.19	0.15	8.14	0.68
1990	0.11	0.10	0.12	0.22	0.29	0.50	0.52	0.29	0.21	0.16	0.13	0.10	2.74	0.23
1991	0.08	0.07	0.11	0.20	0.22	0.17	0.16	0.13	0.11	0.09	0.07	0.06	1.46	0.12
1992	0.04	0.06	0.26	0.31	0.82	1.06	0.52	0.32	0.24	0.20	0.18	0.15	4.15	0.35
1993	0.11	0.25	0.48	0.95	0.90	0.40	0.32	0.24	0.19	0.15	0.12	0.09	4.20	0.35
1994	0.08	0.09	0.16	0.25	0.27	0.28	0.25	0.22	0.18	0.15	0.12	0.10	2.15	0.18
1995	0.09	0.08	0.68	0.77	0.67	0.75	0.39	0.40	0.39	0.31	0.25	0.19	4.95	0.41
1996	0.14	0.17	0.60	1.97	2.38	1.58	0.95	0.48	0.36	0.26	0.19	0.17	9.27	0.77
1997	0.19	0.22	0.28	1.59	1.65	0.65	0.65	0.36	0.26	0.20	0.16	0.13	6.34	0.53
1998	0.11	0.20	0.64	1.69	2.03	1.44	0.85	0.44	0.34	0.26	0.21	0.17	8.39	0.70
1999	0.14	0.20	0.29	0.51	0.91	1.86	1.60	0.53	0.43	0.38	0.31	0.23	7.39	0.62
2000	0.20	0.25	0.40	0.42	2.12	2.82	1.11	0.42	0.32	0.26	0.23	0.18	8.71	0.73
2001	0.14	0.15	0.67	0.76	0.35	0.34	0.33	0.30	0.25	0.20	0.17	0.13	3.77	0.31
2002	0.10	0.09	0.08	0.12	0.14	0.33	0.36	0.19	0.17	0.16	0.14	0.13	2.02	0.17
2003	0.12	0.16	0.44	0.71	0.80	0.79	0.60	0.45	0.38	0.31	0.26	0.21	5.23	0.44
2004	0.17	0.23	0.67	1.02	1.11	1.07	0.68	0.39	0.28	0.21	0.15	0.11	6.09	0.51
2005	0.08	0.10	0.54	1.32	1.06	0.43	0.37	0.30	0.24	0.18	0.14	0.11	4.87	0.41
2006	0.09	0.15	0.30	1.19	1.49	2.07	1.80	0.41	0.30	0.22	0.17	0.12	8.31	0.69
2007	0.09	0.32	3.02	3.39	1.18	0.78	0.46	0.38	0.29	0.21	0.16	0.12	10.40	0.87
2008	0.09	0.08	1.22	2.11	2.07	2.00	1.09	0.40	0.31	0.25	0.20	0.15	9.97	0.83
2009	0.11	0.11	0.12	1.44	1.55	0.43	0.50	0.42	0.31	0.23	0.17	0.13	5.53	0.46
2010	0.10	0.45	1.33	1.41	1.74	1.82	1.06	0.72	0.38	0.29	0.22	0.16	9.68	0.81
2011	0.11	0.11	1.44	2.85	1.72	0.56	0.60	0.50	0.37	0.27	0.20	0.15	8.88	0.74
2012	0.11	0.11	0.13	0.19	0.56	0.71	0.45	0.32	0.24	0.17	0.13	0.10	3.22	0.27
2013	0.07	0.08	0.93	1.49	0.97	0.79	0.64	0.39	0.30	0.23	0.18	0.13	6.19	0.52
2014	0.10	0.08	0.06	1.12	2.30	1.72	0.74	0.40	0.30	0.23	0.18	0.14	7.36	0.61

Appendix 7 Simulated surface runoff for Nyamingura River in Mm^3

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total	Aver
1960	1.38	1.43	9.26	11.44	5.10	4.18	5.11	4.73	2.97	2.49	2.12	1.98	52.20	4.35
1961	1.86	2.45	3.13	5.00	10.63	16.99	11.82	3.64	2.87	2.25	1.84	1.47	63.96	5.33
1962	1.14	1.50	7.75	9.08	10.11	11.75	5.93	3.55	2.83	2.28	1.83	1.40	59.15	4.93
1963	1.10	2.01	2.77	7.52	9.04	4.44	2.93	2.30	1.86	1.50	1.25	1.05	37.76	3.15
1964	0.86	1.14	5.34	8.35	5.30	3.14	2.96	2.51	2.08	1.68	1.32	1.03	35.70	2.97
1965	0.87	1.45	1.78	2.06	7.13	7.46	3.33	3.04	2.49	2.10	1.72	1.34	34.77	2.90
1966	1.06	1.02	1.91	8.74	10.58	9.63	8.09	3.23	2.89	2.41	2.14	1.95	53.65	4.47
1967	1.60	1.43	1.52	1.58	1.78	1.93	2.17	2.36	2.08	1.78	1.42	1.11	20.75	1.73
1968	0.86	1.59	4.73	6.87	4.96	11.57	12.79	4.46	2.93	2.32	1.83	1.42	56.35	4.70
1969	1.23	1.31	23.98	29.19	7.86	3.69	5.33	5.19	2.80	2.24	1.88	1.46	86.16	7.18
1970	1.08	1.48	3.86	8.63	7.98	3.94	3.14	3.65	3.72	2.67	2.09	1.52	43.76	3.65
1971	1.14	3.29	7.78	17.16	14.05	5.90	5.86	3.33	2.60	1.98	1.51	1.13	65.72	5.48
1972	0.90	0.88	1.36	3.20	4.19	3.37	2.79	2.37	1.89	1.55	1.35	1.15	24.99	2.08
1973	1.07	3.60	10.19	15.66	20.71	24.47	15.15	4.68	3.23	2.55	2.07	1.79	105.18	8.76
1974	1.55	1.74	7.93	9.64	10.84	10.01	3.98	3.61	2.74	2.13	1.68	1.31	57.17	4.76
1975	1.17	1.24	3.16	5.51	9.41	25.55	21.11	3.59	2.88	2.25	1.72	1.27	78.84	6.57
1976	1.05	1.12	3.05	3.72	12.83	16.76	6.89	2.98	2.23	1.76	1.56	1.49	55.43	4.62
1977	1.35	1.88	5.21	12.67	15.63	16.99	15.94	7.68	3.31	2.65	2.07	1.55	86.94	7.24
1978	1.40	1.99	7.43	7.97	6.85	8.91	5.52	2.92	2.24	1.92	1.79	1.50	50.45	4.20
1979	1.56	1.63	2.31	3.25	9.54	9.88	3.87	3.36	2.66	2.12	1.77	1.57	43.53	3.63
1980	1.62	1.76	10.10	15.36	17.26	15.42	6.23	3.46	2.73	2.09	1.65	1.38	79.05	6.59
1981	1.25	1.86	4.22	5.45	6.32	5.57	3.34	2.94	2.40	1.92	1.58	1.30	38.15	3.18
1982	1.44	1.69	1.75	1.85	1.93	2.45	2.53	1.97	1.65	1.47	1.39	1.18	21.30	1.77
1983	0.98	0.93	2.57	2.93	2.15	6.94	7.09	2.69	2.18	1.80	1.54	1.34	33.14	2.76
1984	1.14	1.48	3.81	11.18	12.75	12.01	9.34	3.18	2.61	2.16	1.74	1.37	62.79	5.23
1985	1.11	1.36	5.35	18.67	18.59	6.40	4.47	4.10	2.78	2.10	1.60	1.18	67.71	5.64
1986	2.52	3.00	5.78	9.58	6.63	3.37	2.65	1.99	1.51	1.18	0.93	0.76	39.90	3.33
1987	0.70	0.73	4.49	6.26	7.00	14.58	14.23	6.16	2.94	2.30	1.82	1.41	62.63	5.22
1988	2.53	3.45	3.27	7.02	16.76	14.03	4.64	3.68	2.81	2.15	1.68	1.35	63.38	5.28
1989	1.34	1.74	8.48	18.81	17.36	7.87	3.54	3.05	2.43	1.91	1.52	1.20	69.25	5.77
1990	0.92	0.78	0.95	1.75	2.31	4.08	4.23	2.23	1.69	1.31	1.02	0.81	22.08	1.84
1991	0.66	0.54	0.88	1.64	1.73	1.35	1.21	1.05	0.86	0.71	0.59	0.46	11.66	0.97
1992	0.33	0.49	2.18	2.51	6.91	8.94	4.14	2.50	1.92	1.59	1.41	1.18	34.10	2.84
1993	0.87	2.14	4.05	8.04	7.47	3.09	2.47	1.93	1.53	1.21	0.96	0.75	34.52	2.88
1994	0.68	0.70	1.34	2.01	2.14	2.15	1.92	1.69	1.44	1.18	1.00	0.84	17.09	1.42
1995	0.71	0.63	5.86	6.53	5.56	6.21	3.00	3.11	3.06	2.46	2.01	1.56	40.70	3.39
1996	1.15	1.45	5.14	16.97	21.34	14.47	8.03	3.69	2.75	2.04	1.53	1.40	79.96	6.66
1997	1.55	1.77	2.19	13.68	14.08	5.26	5.24	2.80	2.09	1.61	1.30	1.05	52.61	4.38
1998	0.93	1.69	5.42	14.50	18.25	13.29	7.19	3.32	2.59	2.01	1.64	1.35	72.18	6.02
1999	1.13	1.64	2.36	4.15	7.83	16.60	14.32	4.33	3.25	2.92	2.41	1.84	62.76	5.23
2000	1.56	1.99	3.21	3.35	18.95	25.30	9.45	3.16	2.47	2.05	1.77	1.42	74.69	6.22
2001	1.10	1.19	5.69	6.36	2.73	2.66	2.58	2.36	1.95	1.62	1.35	1.06	30.64	2.55
2002	0.83	0.73	0.67	0.98	1.14	2.71	3.00	1.45	1.35	1.26	1.14	1.02	16.27	1.36
2003	0.95	1.26	3.63	5.89	7.15	7.21	4.93	3.39	2.88	2.43	2.04	1.69	43.45	3.62
2004	1.40	1.90	5.62	8.57	10.14	9.99	5.73	2.92	2.16	1.61	1.21	0.89	52.14	4.35
2005	0.68	0.78	4.62	11.29	8.90	3.31	2.89	2.40	1.88	1.46	1.15	0.88	40.26	3.35
2006	0.77	1.25	2.48	10.13	13.38	18.64	15.52	3.09	2.32	1.74	1.31	0.96	71.60	5.97
2007	0.70	2.70	26.34	30.04	10.76	6.51	3.48	2.92	2.24	1.66	1.27	0.97	89.60	7.47
2008	0.76	0.66	10.64	18.27	18.43	18.00	9.23	3.06	2.40	1.93	1.55	1.18	86.12	7.18
2009	0.90	0.89	0.98	12.48	13.33	3.38	3.93	3.31	2.46	1.84	1.41	1.07	45.98	3.83
2010	0.84	3.82	11.41	12.00	15.71	16.66	9.34	6.02	2.89	2.20	1.71	1.27	83.88	6.99
2011	0.91	0.87	12.54	24.71	14.58	5.09	5.65	4.06	2.73	2.03	1.54	1.16	75.88	6.32
2012	0.88	0.87	1.02	1.54	4.68	5.82	3.55	2.48	1.87	1.41	1.07	0.79	25.98	2.17
2013	0.58	0.65	8.05	12.79	8.14	7.09	5.74	2.93	2.29	1.78	1.38	1.05	52.48	4.37
2014	0.82	0.67	0.51	9.73	19.94	14.86	6.13	3.03	2.32	1.77	1.41	1.12	62.33	5.19

Appendix 8 Simulated surface runoff for Nyamutsupa River in Mm^3

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total	Aver
1960	0.43	0.45	2.39	2.97	1.50	1.26	1.35	1.24	0.84	0.67	0.56	0.54	14.21	1.18
1961	0.55	0.74	0.94	1.43	2.91	4.42	3.03	1.04	0.80	0.60	0.48	0.40	17.34	1.44
1962	0.33	0.45	2.01	2.39	2.73	3.10	1.60	1.01	0.79	0.61	0.48	0.38	15.88	1.32
1963	0.32	0.58	0.81	2.00	2.47	1.34	0.86	0.66	0.52	0.40	0.33	0.29	10.55	0.88
1964	0.25	0.35	1.41	2.19	1.48	0.94	0.87	0.73	0.59	0.46	0.35	0.28	9.90	0.82
1965	0.26	0.43	0.54	0.63	1.88	1.98	0.98	0.88	0.70	0.57	0.46	0.37	9.68	0.81
1966	0.31	0.32	0.57	2.27	2.81	2.54	2.09	0.92	0.80	0.65	0.57	0.53	14.38	1.20
1967	0.48	0.46	0.50	0.52	0.56	0.59	0.65	0.69	0.60	0.49	0.38	0.31	6.23	0.52
1968	0.26	0.46	1.27	1.84	1.40	3.04	3.28	1.20	0.83	0.63	0.48	0.39	15.07	1.26
1969	0.36	0.41	5.96	7.46	2.29	1.06	1.36	1.31	0.79	0.61	0.50	0.40	22.50	1.88
1970	0.32	0.44	1.06	2.27	2.19	1.19	0.91	1.01	1.01	0.72	0.55	0.41	12.06	1.01
1971	0.33	0.89	2.03	4.53	3.78	1.54	1.52	0.95	0.73	0.53	0.39	0.30	17.52	1.46
1972	0.26	0.28	0.42	0.90	1.17	0.98	0.83	0.69	0.54	0.42	0.36	0.32	7.16	0.60
1973	0.32	0.98	2.64	4.21	5.37	6.04	3.79	1.25	0.90	0.69	0.55	0.49	27.21	2.27
1974	0.46	0.54	2.08	2.55	2.95	2.72	1.14	1.02	0.76	0.57	0.44	0.35	15.58	1.30
1975	0.34	0.39	0.89	1.50	2.55	6.45	5.28	1.02	0.80	0.60	0.45	0.34	20.61	1.72
1976	0.30	0.35	0.85	1.05	3.29	4.30	1.89	0.86	0.62	0.47	0.41	0.41	14.80	1.23
1977	0.40	0.56	1.41	3.40	4.07	4.24	3.98	1.98	0.93	0.71	0.54	0.42	22.65	1.89
1978	0.41	0.59	1.97	2.14	1.96	2.43	1.49	0.84	0.62	0.51	0.47	0.41	13.86	1.15
1979	0.45	0.51	0.70	0.96	2.51	2.60	1.13	0.97	0.75	0.57	0.47	0.43	12.03	1.00
1980	0.47	0.55	2.62	4.14	4.54	3.85	1.67	0.99	0.76	0.56	0.43	0.37	20.95	1.75
1981	0.37	0.55	1.18	1.52	1.83	1.63	0.97	0.84	0.67	0.51	0.41	0.35	10.83	0.90
1982	0.41	0.52	0.56	0.59	0.61	0.73	0.75	0.59	0.48	0.41	0.38	0.33	6.36	0.53
1983	0.30	0.30	0.73	0.84	0.65	1.83	1.88	0.79	0.62	0.49	0.41	0.37	9.22	0.77
1984	0.34	0.45	1.06	2.90	3.38	3.17	2.42	0.91	0.73	0.58	0.46	0.37	16.78	1.40
1985	0.33	0.41	1.43	4.82	4.80	1.72	1.20	1.09	0.78	0.57	0.42	0.32	17.87	1.49
1986	0.67	0.84	1.57	2.68	1.96	0.97	0.76	0.56	0.42	0.31	0.24	0.20	11.18	0.93
1987	0.21	0.23	1.17	1.65	1.87	3.76	3.62	1.61	0.82	0.62	0.48	0.38	16.43	1.37
1988	0.69	0.97	0.98	2.03	4.36	3.55	1.28	1.05	0.78	0.57	0.44	0.36	17.07	1.42
1989	0.39	0.53	2.22	4.95	4.54	2.03	1.02	0.87	0.67	0.51	0.40	0.32	18.45	1.54
1990	0.27	0.25	0.31	0.52	0.68	1.13	1.17	0.66	0.48	0.36	0.27	0.22	6.31	0.53
1991	0.20	0.18	0.27	0.48	0.52	0.42	0.37	0.32	0.25	0.20	0.16	0.13	3.49	0.29
1992	0.10	0.15	0.59	0.70	1.79	2.31	1.16	0.73	0.54	0.43	0.38	0.32	9.21	0.77
1993	0.26	0.59	1.10	2.12	2.01	0.93	0.74	0.57	0.44	0.33	0.25	0.21	9.54	0.79
1994	0.20	0.23	0.40	0.59	0.64	0.65	0.58	0.50	0.41	0.33	0.27	0.23	5.03	0.42
1995	0.21	0.21	1.50	1.69	1.49	1.67	0.89	0.89	0.85	0.67	0.53	0.43	11.03	0.92
1996	0.34	0.43	1.37	4.31	5.47	3.75	2.11	1.05	0.77	0.54	0.40	0.37	20.91	1.74
1997	0.45	0.55	0.69	3.50	3.62	1.53	1.50	0.81	0.58	0.43	0.34	0.28	14.30	1.19
1998	0.27	0.49	1.45	3.77	4.67	3.37	1.90	0.95	0.72	0.54	0.43	0.37	18.93	1.58
1999	0.33	0.49	0.70	1.17	2.17	4.28	3.59	1.16	0.91	0.79	0.64	0.50	16.74	1.40
2000	0.46	0.60	0.95	1.00	4.87	6.41	2.48	0.90	0.69	0.55	0.47	0.39	19.76	1.65
2001	0.32	0.37	1.50	1.70	0.83	0.80	0.77	0.69	0.55	0.44	0.36	0.29	8.64	0.72
2002	0.25	0.24	0.23	0.31	0.35	0.74	0.82	0.44	0.39	0.35	0.31	0.29	4.71	0.39
2003	0.29	0.40	1.01	1.61	2.03	2.02	1.35	0.97	0.80	0.65	0.54	0.46	12.13	1.01
2004	0.41	0.57	1.52	2.34	2.73	2.60	1.54	0.84	0.60	0.43	0.32	0.24	14.12	1.18
2005	0.20	0.24	1.21	2.88	2.34	0.98	0.85	0.70	0.53	0.39	0.30	0.24	10.87	0.91
2006	0.23	0.37	0.72	2.62	3.51	4.77	3.92	0.88	0.64	0.46	0.34	0.26	18.71	1.56
2007	0.20	0.71	6.51	7.61	2.89	1.70	1.01	0.84	0.62	0.44	0.33	0.26	23.13	1.93
2008	0.22	0.21	2.66	4.56	4.70	4.59	2.39	0.88	0.67	0.52	0.41	0.32	22.12	1.84
2009	0.26	0.28	0.32	3.14	3.37	0.98	1.12	0.95	0.69	0.50	0.37	0.29	12.28	1.02
2010	0.25	1.00	2.91	3.24	4.06	4.12	2.38	1.57	0.81	0.59	0.45	0.34	21.72	1.81
2011	0.26	0.27	3.14	6.16	3.75	1.45	1.52	1.10	0.77	0.55	0.41	0.31	19.69	1.64
2012	0.26	0.27	0.33	0.47	1.26	1.57	1.02	0.73	0.53	0.38	0.28	0.21	7.32	0.61
2013	0.17	0.20	2.03	3.24	2.20	1.93	1.54	0.84	0.64	0.48	0.36	0.28	13.92	1.16
2014	0.24	0.22	0.17	2.42	4.95	3.81	1.70	0.87	0.65	0.47	0.37	0.30	16.18	1.35

Appendix 9 Simulated surface runoff for Nyawamba River in Mm^3

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total	Aver
1960	1.76	1.80	10.16	12.61	5.98	5.01	5.22	4.84	3.68	3.03	2.55	2.35	58.99	4.92
1961	2.21	2.84	3.62	5.69	10.80	17.33	12.91	4.49	3.50	2.70	2.17	1.71	69.97	5.83
1962	1.32	1.71	8.45	10.03	10.34	11.86	6.66	4.39	3.46	2.73	2.17	1.63	64.75	5.40
1963	1.27	2.27	3.17	8.33	9.89	5.07	3.56	2.75	2.19	1.75	1.44	1.20	42.88	3.57
1964	0.98	1.30	5.86	9.22	6.08	3.77	3.52	2.97	2.43	1.94	1.50	1.17	40.75	3.40
1965	0.98	1.63	2.05	2.41	7.90	8.36	3.99	3.61	2.93	2.44	1.99	1.53	39.83	3.32
1966	1.21	1.16	2.16	9.55	11.68	9.81	8.22	3.99	3.52	2.91	2.54	2.29	59.05	4.92
1967	1.88	1.67	1.78	1.87	2.10	2.28	2.56	2.78	2.48	2.09	1.65	1.27	24.43	2.04
1968	0.98	1.78	5.23	7.66	5.73	11.84	12.90	5.05	3.65	2.84	2.20	1.69	61.55	5.13
1969	1.45	1.54	25.70	30.67	8.22	4.57	5.77	5.63	3.47	2.73	2.26	1.73	93.72	7.81
1970	1.26	1.69	4.32	9.53	8.97	4.70	3.75	4.22	4.30	3.12	2.40	1.73	49.98	4.17
1971	1.28	3.61	8.50	17.83	14.75	6.46	6.38	4.13	3.18	2.37	1.78	1.31	71.59	5.97
1972	1.04	1.02	1.58	3.63	4.80	4.00	3.35	2.82	2.22	1.80	1.56	1.31	29.13	2.43
1973	1.22	3.98	11.12	16.27	21.44	25.98	16.08	5.29	4.00	3.11	2.48	2.13	113.11	9.43
1974	1.83	2.03	8.68	10.65	11.11	10.33	4.88	4.38	3.30	2.51	1.96	1.51	63.18	5.26
1975	1.33	1.44	3.55	6.18	9.61	26.29	22.53	4.45	3.51	2.70	2.03	1.47	85.09	7.09
1976	1.21	1.31	3.42	4.24	14.02	17.40	7.02	3.69	2.72	2.11	1.85	1.76	60.76	5.06
1977	1.60	2.16	5.78	13.87	16.19	17.38	16.92	8.47	4.09	3.23	2.47	1.83	94.00	7.83
1978	1.63	2.30	8.18	8.89	6.84	8.80	6.19	3.63	2.73	2.30	2.13	1.78	55.41	4.62
1979	1.82	1.91	2.67	3.75	10.55	11.01	4.62	3.99	3.12	2.44	2.02	1.78	49.68	4.14
1980	1.85	2.04	10.98	16.29	17.95	16.19	6.98	4.28	3.33	2.50	1.95	1.61	85.94	7.16
1981	1.46	2.14	4.75	6.19	6.45	5.77	4.16	3.60	2.90	2.28	1.85	1.51	43.06	3.59
1982	1.66	1.97	2.07	2.20	2.31	2.89	2.98	2.34	1.94	1.71	1.62	1.36	25.04	2.09
1983	1.13	1.08	2.88	3.33	2.54	7.71	7.95	3.23	2.58	2.10	1.78	1.54	37.83	3.15
1984	1.32	1.69	4.26	12.24	13.14	12.13	10.25	3.94	3.19	2.60	2.06	1.60	68.41	5.70
1985	1.29	1.57	5.90	20.21	19.39	6.54	5.16	4.70	3.44	2.54	1.90	1.38	74.02	6.17
1986	2.80	3.39	6.44	10.61	7.57	4.04	3.13	2.32	1.73	1.33	1.04	0.85	45.25	3.77
1987	0.79	0.83	4.90	6.93	7.87	15.15	14.55	6.87	3.64	2.81	2.19	1.67	68.20	5.68
1988	2.85	3.92	3.82	7.89	17.33	14.18	5.28	4.54	3.43	2.58	1.99	1.58	69.38	5.78
1989	1.56	2.03	9.28	19.69	18.11	8.82	4.38	3.72	2.92	2.27	1.78	1.38	75.94	6.33
1990	1.05	0.89	1.11	2.02	2.71	4.68	4.87	2.67	1.99	1.51	1.17	0.92	25.60	2.13
1991	0.74	0.61	1.00	1.90	2.05	1.63	1.45	1.25	1.02	0.83	0.68	0.52	13.67	1.14
1992	0.38	0.55	2.43	2.87	7.61	9.90	4.87	3.01	2.27	1.86	1.64	1.36	38.76	3.23
1993	1.00	2.36	4.50	8.90	8.40	3.71	2.94	2.27	1.77	1.39	1.08	0.84	39.16	3.26
1994	0.77	0.80	1.53	2.32	2.54	2.58	2.31	2.02	1.70	1.38	1.15	0.96	20.08	1.67
1995	0.82	0.73	6.33	7.15	6.24	7.02	3.62	3.69	3.61	2.90	2.34	1.79	46.23	3.85
1996	1.31	1.63	5.65	18.38	22.22	14.69	8.87	4.54	3.35	2.43	1.80	1.62	86.48	7.21
1997	1.80	2.09	2.57	14.87	15.40	6.06	6.04	3.35	2.45	1.86	1.48	1.19	59.16	4.93
1998	1.06	1.91	5.99	15.80	18.97	13.45	7.96	4.11	3.16	2.41	1.94	1.58	78.33	6.53
1999	1.31	1.88	2.72	4.73	8.49	17.33	14.91	4.91	4.03	3.57	2.90	2.18	68.97	5.75
2000	1.83	2.31	3.69	3.90	19.75	26.29	10.35	3.90	3.01	2.46	2.11	1.67	81.27	6.77
2001	1.28	1.37	6.24	7.07	3.28	3.18	3.08	2.79	2.29	1.88	1.55	1.21	35.22	2.93
2002	0.93	0.83	0.77	1.12	1.33	3.04	3.40	1.75	1.61	1.50	1.35	1.20	18.83	1.57
2003	1.12	1.47	4.08	6.62	7.51	7.36	5.58	4.22	3.53	2.92	2.42	1.99	48.82	4.07
2004	1.63	2.17	6.23	9.51	10.36	9.95	6.40	3.62	2.64	1.92	1.43	1.04	56.88	4.74
2005	0.79	0.90	5.07	12.32	9.93	4.00	3.46	2.85	2.19	1.68	1.31	0.98	45.49	3.79
2006	0.87	1.43	2.83	11.09	13.87	19.25	16.80	3.82	2.82	2.08	1.54	1.12	77.52	6.46
2007	0.80	2.96	28.21	31.65	11.04	7.28	4.31	3.57	2.69	1.96	1.47	1.12	97.07	8.09
2008	0.87	0.75	11.41	19.69	19.31	18.65	10.12	3.79	2.92	2.32	1.83	1.38	93.05	7.75
2009	1.05	1.03	1.16	13.44	14.47	4.01	4.63	3.93	2.91	2.14	1.61	1.20	51.59	4.30
2010	0.95	4.16	12.37	13.18	16.26	16.99	9.91	6.70	3.57	2.68	2.05	1.50	90.32	7.53
2011	1.06	1.01	13.48	26.61	16.02	5.26	5.60	4.66	3.42	2.50	1.86	1.38	82.84	6.90
2012	1.03	1.02	1.21	1.81	5.25	6.60	4.22	2.97	2.20	1.63	1.22	0.89	30.05	2.50
2013	0.64	0.73	8.68	13.89	9.09	7.34	5.99	3.65	2.80	2.14	1.64	1.23	57.80	4.82
2014	0.96	0.78	0.58	10.41	21.43	16.03	6.89	3.74	2.81	2.10	1.65	1.30	68.68	5.72

Appendix 10 Simulated surface runoff for Muzinga River in Mm^3

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total	Aver
1960	0.38	0.39	2.18	2.70	1.28	1.07	1.12	1.04	0.79	0.65	0.55	0.50	12.64	1.05
1961	0.47	0.61	0.78	1.22	2.32	3.71	2.77	0.96	0.75	0.58	0.47	0.37	14.99	1.25
1962	0.28	0.37	1.81	2.15	2.22	2.54	1.43	0.94	0.74	0.59	0.46	0.35	13.87	1.16
1963	0.27	0.49	0.68	1.78	2.12	1.09	0.76	0.59	0.47	0.38	0.31	0.26	9.19	0.77
1964	0.21	0.28	1.26	1.98	1.30	0.81	0.75	0.64	0.52	0.42	0.32	0.25	8.73	0.73
1965	0.21	0.35	0.44	0.52	1.69	1.79	0.85	0.77	0.63	0.52	0.43	0.33	8.53	0.71
1966	0.26	0.25	0.46	2.05	2.50	2.10	1.76	0.85	0.76	0.62	0.55	0.49	12.65	1.05
1967	0.40	0.36	0.38	0.40	0.45	0.49	0.55	0.60	0.53	0.45	0.35	0.27	5.24	0.44
1968	0.21	0.38	1.12	1.64	1.23	2.54	2.76	1.08	0.78	0.61	0.47	0.36	13.19	1.10
1969	0.31	0.33	5.51	6.57	1.76	0.98	1.24	1.21	0.74	0.59	0.48	0.37	20.08	1.67
1970	0.27	0.36	0.93	2.04	1.92	1.01	0.80	0.90	0.92	0.67	0.52	0.37	10.71	0.89
1971	0.27	0.77	1.82	3.82	3.16	1.38	1.37	0.89	0.68	0.51	0.38	0.28	15.34	1.28
1972	0.22	0.22	0.34	0.78	1.03	0.86	0.72	0.61	0.47	0.38	0.33	0.28	6.24	0.52
1973	0.26	0.85	2.38	3.49	4.60	5.57	3.45	1.13	0.86	0.67	0.53	0.46	24.24	2.02
1974	0.39	0.43	1.86	2.28	2.38	2.21	1.05	0.94	0.71	0.54	0.42	0.32	13.54	1.13
1975	0.29	0.31	0.76	1.32	2.06	5.63	4.83	0.95	0.75	0.58	0.43	0.32	18.23	1.52
1976	0.26	0.28	0.73	0.91	3.01	3.73	1.50	0.79	0.58	0.45	0.40	0.38	13.02	1.08
1977	0.34	0.46	1.24	2.97	3.47	3.72	3.62	1.82	0.88	0.69	0.53	0.39	20.14	1.68
1978	0.35	0.49	1.75	1.90	1.47	1.89	1.33	0.78	0.59	0.49	0.46	0.38	11.87	0.99
1979	0.39	0.41	0.57	0.80	2.26	2.36	0.99	0.86	0.67	0.52	0.43	0.38	10.65	0.89
1980	0.40	0.44	2.35	3.49	3.85	3.47	1.50	0.92	0.71	0.54	0.42	0.35	18.42	1.53
1981	0.31	0.46	1.02	1.33	1.38	1.24	0.89	0.77	0.62	0.49	0.40	0.32	9.23	0.77
1982	0.36	0.42	0.44	0.47	0.49	0.62	0.64	0.50	0.42	0.37	0.35	0.29	5.37	0.45
1983	0.24	0.23	0.62	0.71	0.54	1.65	1.70	0.69	0.55	0.45	0.38	0.33	8.11	0.68
1984	0.28	0.36	0.91	2.62	2.82	2.60	2.20	0.84	0.68	0.56	0.44	0.34	14.66	1.22
1985	0.28	0.34	1.26	4.33	4.15	1.40	1.11	1.01	0.74	0.54	0.41	0.30	15.86	1.32
1986	0.60	0.73	1.38	2.27	1.62	0.87	0.67	0.50	0.37	0.29	0.22	0.18	9.70	0.81
1987	0.17	0.18	1.05	1.48	1.69	3.25	3.12	1.47	0.78	0.60	0.47	0.36	14.61	1.22
1988	0.61	0.84	0.82	1.69	3.71	3.04	1.13	0.97	0.74	0.55	0.43	0.34	14.87	1.24
1989	0.33	0.43	1.99	4.22	3.88	1.89	0.94	0.80	0.63	0.49	0.38	0.30	16.27	1.36
1990	0.23	0.19	0.24	0.43	0.58	1.00	1.04	0.57	0.43	0.32	0.25	0.20	5.48	0.46
1991	0.16	0.13	0.21	0.41	0.44	0.35	0.31	0.27	0.22	0.18	0.15	0.11	2.93	0.24
1992	0.08	0.12	0.52	0.62	1.63	2.12	1.04	0.65	0.49	0.40	0.35	0.29	8.30	0.69
1993	0.21	0.51	0.96	1.91	1.80	0.80	0.63	0.49	0.38	0.30	0.23	0.18	8.39	0.70
1994	0.17	0.17	0.33	0.50	0.54	0.55	0.50	0.43	0.36	0.30	0.25	0.21	4.30	0.36
1995	0.18	0.16	1.36	1.53	1.34	1.50	0.78	0.79	0.77	0.62	0.50	0.38	9.91	0.83
1996	0.28	0.35	1.21	3.94	4.76	3.15	1.90	0.97	0.72	0.52	0.39	0.35	18.53	1.54
1997	0.39	0.45	0.55	3.19	3.30	1.30	1.29	0.72	0.52	0.40	0.32	0.25	12.68	1.06
1998	0.23	0.41	1.28	3.38	4.06	2.88	1.71	0.88	0.68	0.52	0.42	0.34	16.79	1.40
1999	0.28	0.40	0.58	1.01	1.82	3.71	3.20	1.05	0.86	0.76	0.62	0.47	14.78	1.23
2000	0.39	0.49	0.79	0.84	4.23	5.63	2.22	0.84	0.65	0.53	0.45	0.36	17.41	1.45
2001	0.27	0.29	1.34	1.52	0.70	0.68	0.66	0.60	0.49	0.40	0.33	0.26	7.55	0.63
2002	0.20	0.18	0.16	0.24	0.28	0.65	0.73	0.38	0.35	0.32	0.29	0.26	4.03	0.34
2003	0.24	0.31	0.87	1.42	1.61	1.58	1.20	0.90	0.76	0.63	0.52	0.43	10.46	0.87
2004	0.35	0.47	1.33	2.04	2.22	2.13	1.37	0.78	0.56	0.41	0.31	0.22	12.19	1.02
2005	0.17	0.19	1.09	2.64	2.13	0.86	0.74	0.61	0.47	0.36	0.28	0.21	9.75	0.81
2006	0.19	0.31	0.61	2.38	2.97	4.13	3.60	0.82	0.60	0.45	0.33	0.24	16.61	1.38
2007	0.17	0.63	6.04	6.78	2.36	1.56	0.92	0.77	0.58	0.42	0.32	0.24	20.80	1.73
2008	0.19	0.16	2.45	4.22	4.14	4.00	2.17	0.81	0.63	0.50	0.39	0.29	19.94	1.66
2009	0.22	0.22	0.25	2.88	3.10	0.86	0.99	0.84	0.62	0.46	0.34	0.26	11.05	0.92
2010	0.20	0.89	2.65	2.82	3.48	3.64	2.12	1.44	0.77	0.57	0.44	0.32	19.35	1.61
2011	0.23	0.22	2.89	5.70	3.43	1.13	1.20	1.00	0.73	0.53	0.40	0.30	17.75	1.48
2012	0.22	0.22	0.26	0.39	1.13	1.41	0.90	0.64	0.47	0.35	0.26	0.19	6.44	0.54
2013	0.14	0.16	1.86	2.98	1.95	1.57	1.28	0.78	0.60	0.46	0.35	0.26	12.39	1.03
2014	0.20	0.17	0.13	2.23	4.59	3.44	1.48	0.80	0.60	0.45	0.35	0.28	14.72	1.23

Appendix 11 Simulated surface runoff for Nyamukombe River in Mm^3

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total	Aver
1960	2.03	2.08	11.76	14.60	6.92	5.80	6.04	5.60	4.26	3.51	2.95	2.72	68.25	5.69
1961	2.55	3.28	4.19	6.58	12.50	20.06	14.93	5.20	4.05	3.12	2.51	1.98	80.97	6.75
1962	1.53	1.98	9.78	11.60	11.97	13.72	7.70	5.07	4.00	3.16	2.51	1.89	74.92	6.24
1963	1.47	2.62	3.67	9.64	11.44	5.86	4.12	3.18	2.53	2.03	1.67	1.39	49.62	4.13
1964	1.14	1.51	6.79	10.67	7.04	4.36	4.07	3.43	2.81	2.24	1.74	1.35	47.15	3.93
1965	1.13	1.89	2.38	2.79	9.14	9.67	4.61	4.18	3.39	2.83	2.30	1.77	46.09	3.84
1966	1.40	1.35	2.50	11.05	13.51	11.35	9.52	4.61	4.08	3.37	2.94	2.65	68.33	5.69
1967	2.18	1.94	2.06	2.17	2.43	2.64	2.97	3.22	2.87	2.42	1.91	1.47	28.27	2.36
1968	1.13	2.07	6.05	8.87	6.63	13.70	14.92	5.84	4.23	3.29	2.55	1.95	71.22	5.93
1969	1.68	1.78	29.74	35.48	9.51	5.29	6.67	6.51	4.01	3.16	2.61	2.00	108.45	9.04
1970	1.45	1.95	5.00	11.03	10.38	5.44	4.34	4.88	4.97	3.61	2.78	2.00	57.84	4.82
1971	1.48	4.17	9.84	20.63	17.07	7.48	7.38	4.78	3.68	2.74	2.06	1.52	82.84	6.90
1972	1.20	1.18	1.83	4.20	5.56	4.62	3.88	3.27	2.56	2.08	1.80	1.52	33.70	2.81
1973	1.41	4.61	12.87	18.83	24.81	30.06	18.61	6.12	4.63	3.60	2.87	2.46	130.89	10.91
1974	2.12	2.35	10.05	12.32	12.85	11.96	5.65	5.07	3.82	2.91	2.26	1.74	73.10	6.09
1975	1.54	1.67	4.11	7.15	11.12	30.42	26.07	5.15	4.07	3.12	2.35	1.70	98.47	8.21
1976	1.40	1.51	3.96	4.90	16.23	20.14	8.12	4.27	3.15	2.44	2.15	2.04	70.31	5.86
1977	1.85	2.50	6.69	16.05	18.73	20.11	19.57	9.81	4.73	3.73	2.86	2.12	108.77	9.06
1978	1.89	2.67	9.47	10.28	7.92	10.19	7.16	4.20	3.16	2.66	2.46	2.06	64.12	5.34
1979	2.10	2.21	3.09	4.34	12.21	12.74	5.35	4.62	3.61	2.82	2.34	2.07	57.49	4.79
1980	2.14	2.36	12.70	18.85	20.77	18.74	8.07	4.95	3.85	2.90	2.25	1.87	99.44	8.29
1981	1.69	2.47	5.49	7.16	7.46	6.68	4.82	4.17	3.35	2.64	2.15	1.75	49.83	4.15
1982	1.92	2.28	2.39	2.55	2.67	3.34	3.45	2.71	2.24	1.98	1.87	1.58	28.98	2.41
1983	1.30	1.25	3.33	3.85	2.93	8.92	9.19	3.73	2.99	2.43	2.06	1.78	43.77	3.65
1984	1.52	1.95	4.92	14.16	15.20	14.04	11.86	4.56	3.69	3.01	2.39	1.85	79.16	6.60
1985	1.49	1.81	6.82	23.39	22.43	7.57	5.97	5.44	3.98	2.94	2.20	1.60	85.65	7.14
1986	3.24	3.92	7.45	12.28	8.76	4.67	3.62	2.68	2.01	1.54	1.20	0.98	52.36	4.36
1987	0.91	0.97	5.67	8.02	9.11	17.53	16.84	7.95	4.21	3.25	2.53	1.94	78.92	6.58
1988	3.30	4.53	4.42	9.13	20.05	16.40	6.11	5.25	3.97	2.99	2.30	1.83	80.28	6.69
1989	1.80	2.35	10.74	22.79	20.95	10.21	5.07	4.31	3.38	2.62	2.06	1.60	87.87	7.32
1990	1.22	1.03	1.28	2.34	3.13	5.42	5.64	3.09	2.30	1.75	1.35	1.07	29.62	2.47
1991	0.86	0.70	1.15	2.19	2.37	1.88	1.68	1.45	1.18	0.96	0.78	0.61	15.82	1.32
1992	0.44	0.64	2.81	3.33	8.81	11.45	5.63	3.49	2.63	2.16	1.90	1.57	44.85	3.74
1993	1.15	2.73	5.21	10.30	9.72	4.30	3.40	2.62	2.05	1.60	1.25	0.97	45.31	3.78
1994	0.89	0.93	1.77	2.68	2.94	2.99	2.67	2.34	1.97	1.60	1.34	1.12	23.23	1.94
1995	0.95	0.84	7.32	8.27	7.22	8.12	4.19	4.27	4.17	3.35	2.70	2.07	53.49	4.46
1996	1.51	1.89	6.53	21.27	25.71	17.00	10.26	5.25	3.88	2.81	2.08	1.87	100.07	8.34
1997	2.09	2.41	2.98	17.20	17.81	7.01	6.99	3.88	2.83	2.16	1.72	1.37	68.45	5.70
1998	1.22	2.21	6.93	18.28	21.95	15.57	9.21	4.75	3.66	2.79	2.25	1.83	90.64	7.55
1999	1.52	2.17	3.15	5.47	9.83	20.05	17.26	5.69	4.67	4.13	3.36	2.52	79.81	6.65
2000	2.11	2.67	4.27	4.51	22.85	30.42	11.98	4.52	3.49	2.84	2.44	1.94	94.04	7.84
2001	1.48	1.59	7.22	8.18	3.79	3.68	3.56	3.23	2.65	2.17	1.80	1.40	40.75	3.40
2002	1.08	0.96	0.89	1.29	1.54	3.52	3.94	2.03	1.86	1.73	1.56	1.38	21.79	1.82
2003	1.29	1.70	4.72	7.66	8.69	8.51	6.46	4.88	4.09	3.38	2.80	2.30	56.49	4.71
2004	1.89	2.51	7.20	11.01	11.98	11.51	7.40	4.19	3.05	2.22	1.65	1.20	65.82	5.49
2005	0.91	1.05	5.87	14.26	11.49	4.63	4.01	3.29	2.54	1.95	1.52	1.14	52.64	4.39
2006	1.01	1.65	3.27	12.83	16.05	22.28	19.44	4.42	3.26	2.41	1.79	1.30	89.71	7.48
2007	0.93	3.42	32.64	36.63	12.77	8.43	4.99	4.14	3.11	2.27	1.71	1.29	112.33	9.36
2008	1.01	0.87	13.21	22.78	22.35	21.58	11.72	4.38	3.38	2.69	2.12	1.59	107.68	8.97
2009	1.21	1.19	1.34	15.56	16.75	4.64	5.36	4.55	3.37	2.48	1.86	1.39	59.70	4.97
2010	1.10	4.81	14.31	15.25	18.82	19.66	11.47	7.75	4.13	3.10	2.37	1.74	104.52	8.71
2011	1.22	1.17	15.60	30.79	18.54	6.09	6.47	5.39	3.95	2.89	2.15	1.60	95.86	7.99
2012	1.19	1.18	1.40	2.10	6.08	7.63	4.89	3.44	2.54	1.88	1.41	1.03	34.77	2.90
2013	0.75	0.85	10.04	16.07	10.51	8.49	6.93	4.22	3.23	2.47	1.89	1.42	66.89	5.57
2014	1.11	0.90	0.68	12.04	24.80	18.55	7.97	4.32	3.25	2.43	1.91	1.50	79.47	6.62

Appendix 12 Simulated surface runoff for Mambezi River in Mm^3

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total	Aver
1960	1.76	1.80	10.16	12.61	5.98	5.01	5.22	4.84	3.68	3.03	2.55	2.35	58.99	4.92
1961	2.21	2.84	3.62	5.69	10.80	17.33	12.91	4.49	3.50	2.70	2.17	1.71	69.97	5.83
1962	1.32	1.71	8.45	10.03	10.34	11.86	6.66	4.39	3.46	2.73	2.17	1.63	64.75	5.40
1963	1.27	2.27	3.17	8.33	9.89	5.07	3.56	2.75	2.19	1.75	1.44	1.20	42.88	3.57
1964	0.98	1.30	5.86	9.22	6.08	3.77	3.52	2.97	2.43	1.94	1.50	1.17	40.75	3.40
1965	0.98	1.63	2.05	2.41	7.90	8.36	3.99	3.61	2.93	2.44	1.99	1.53	39.83	3.32
1966	1.21	1.16	2.16	9.55	11.68	9.81	8.22	3.99	3.52	2.91	2.54	2.29	59.05	4.92
1967	1.88	1.67	1.78	1.87	2.10	2.28	2.56	2.78	2.48	2.09	1.65	1.27	24.43	2.04
1968	0.98	1.78	5.23	7.66	5.73	11.84	12.90	5.05	3.65	2.84	2.20	1.69	61.55	5.13
1969	1.45	1.54	25.70	30.67	8.22	4.57	5.77	5.63	3.47	2.73	2.26	1.73	93.72	7.81
1970	1.26	1.69	4.32	9.53	8.97	4.70	3.75	4.22	4.30	3.12	2.40	1.73	49.98	4.17
1971	1.28	3.61	8.50	17.83	14.75	6.46	6.38	4.13	3.18	2.37	1.78	1.31	71.59	5.97
1972	1.04	1.02	1.58	3.63	4.80	4.00	3.35	2.82	2.22	1.80	1.56	1.31	29.13	2.43
1973	1.22	3.98	11.12	16.27	21.44	25.98	16.08	5.29	4.00	3.11	2.48	2.13	113.11	9.43
1974	1.83	2.03	8.68	10.65	11.11	10.33	4.88	4.38	3.30	2.51	1.96	1.51	63.18	5.26
1975	1.33	1.44	3.55	6.18	9.61	26.29	22.53	4.45	3.51	2.70	2.03	1.47	85.09	7.09
1976	1.21	1.31	3.42	4.24	14.02	17.40	7.02	3.69	2.72	2.11	1.85	1.76	60.76	5.06
1977	1.60	2.16	5.78	13.87	16.19	17.38	16.92	8.47	4.09	3.23	2.47	1.83	94.00	7.83
1978	1.63	2.30	8.18	8.89	6.84	8.80	6.19	3.63	2.73	2.30	2.13	1.78	55.41	4.62
1979	1.82	1.91	2.67	3.75	10.55	11.01	4.62	3.99	3.12	2.44	2.02	1.78	49.68	4.14
1980	1.85	2.04	10.98	16.29	17.95	16.19	6.98	4.28	3.33	2.50	1.95	1.61	85.94	7.16
1981	1.46	2.14	4.75	6.19	6.45	5.77	4.16	3.60	2.90	2.28	1.85	1.51	43.06	3.59
1982	1.66	1.97	2.07	2.20	2.31	2.89	2.98	2.34	1.94	1.71	1.62	1.36	25.04	2.09
1983	1.13	1.08	2.88	3.33	2.54	7.71	7.95	3.23	2.58	2.10	1.78	1.54	37.83	3.15
1984	1.32	1.69	4.26	12.24	13.14	12.13	10.25	3.94	3.19	2.60	2.06	1.60	68.41	5.70
1985	1.29	1.57	5.90	20.21	19.39	6.54	5.16	4.70	3.44	2.54	1.90	1.38	74.02	6.17
1986	2.80	3.39	6.44	10.61	7.57	4.04	3.13	2.32	1.73	1.33	1.04	0.85	45.25	3.77
1987	0.79	0.83	4.90	6.93	7.87	15.15	14.55	6.87	3.64	2.81	2.19	1.67	68.20	5.68
1988	2.85	3.92	3.82	7.89	17.33	14.18	5.28	4.54	3.43	2.58	1.99	1.58	69.38	5.78
1989	1.56	2.03	9.28	19.69	18.11	8.82	4.38	3.72	2.92	2.27	1.78	1.38	75.94	6.33
1990	1.05	0.89	1.11	2.02	2.71	4.68	4.87	2.67	1.99	1.51	1.17	0.92	25.60	2.13
1991	0.74	0.61	1.00	1.90	2.05	1.63	1.45	1.25	1.02	0.83	0.68	0.52	13.67	1.14
1992	0.38	0.55	2.43	2.87	7.61	9.90	4.87	3.01	2.27	1.86	1.64	1.36	38.76	3.23
1993	1.00	2.36	4.50	8.90	8.40	3.71	2.94	2.27	1.77	1.39	1.08	0.84	39.16	3.26
1994	0.77	0.80	1.53	2.32	2.54	2.58	2.31	2.02	1.70	1.38	1.15	0.96	20.08	1.67
1995	0.82	0.73	6.33	7.15	6.24	7.02	3.62	3.69	3.61	2.90	2.34	1.79	46.23	3.85
1996	1.31	1.63	5.65	18.38	22.22	14.69	8.87	4.54	3.35	2.43	1.80	1.62	86.48	7.21
1997	1.80	2.09	2.57	14.87	15.40	6.06	6.04	3.35	2.45	1.86	1.48	1.19	59.16	4.93
1998	1.06	1.91	5.99	15.80	18.97	13.45	7.96	4.11	3.16	2.41	1.94	1.58	78.33	6.53
1999	1.31	1.88	2.72	4.73	8.49	17.33	14.91	4.91	4.03	3.57	2.90	2.18	68.97	5.75
2000	1.83	2.31	3.69	3.90	19.75	26.29	10.35	3.90	3.01	2.46	2.11	1.67	81.27	6.77
2001	1.28	1.37	6.24	7.07	3.28	3.18	3.08	2.79	2.29	1.88	1.55	1.21	35.22	2.93
2002	0.93	0.83	0.77	1.12	1.33	3.04	3.40	1.75	1.61	1.50	1.35	1.20	18.83	1.57
2003	1.12	1.47	4.08	6.62	7.51	7.36	5.58	4.22	3.53	2.92	2.42	1.99	48.82	4.07
2004	1.63	2.17	6.23	9.51	10.36	9.95	6.40	3.62	2.64	1.92	1.43	1.04	56.88	4.74
2005	0.79	0.90	5.07	12.32	9.93	4.00	3.46	2.85	2.19	1.68	1.31	0.98	45.49	3.79
2006	0.87	1.43	2.83	11.09	13.87	19.25	16.80	3.82	2.82	2.08	1.54	1.12	77.52	6.46
2007	0.80	2.96	28.21	31.65	11.04	7.28	4.31	3.57	2.69	1.96	1.47	1.12	97.07	8.09
2008	0.87	0.75	11.41	19.69	19.31	18.65	10.12	3.79	2.92	2.32	1.83	1.38	93.05	7.75
2009	1.05	1.03	1.16	13.44	14.47	4.01	4.63	3.93	2.91	2.14	1.61	1.20	51.59	4.30
2010	0.95	4.16	12.37	13.18	16.26	16.99	9.91	6.70	3.57	2.68	2.05	1.50	90.32	7.53
2011	1.06	1.01	13.48	26.61	16.02	5.26	5.60	4.66	3.42	2.50	1.86	1.38	82.84	6.90
2012	1.03	1.02	1.21	1.81	5.25	6.60	4.22	2.97	2.20	1.63	1.22	0.89	30.05	2.50
2013	0.64	0.73	8.68	13.89	9.09	7.34	5.99	3.65	2.80	2.14	1.64	1.23	57.80	4.82
2014	0.96	0.78	0.58	10.41	21.43	16.03	6.89	3.74	2.81	2.10	1.65	1.30	68.68	5.72

Appendix 13 Simulated surface runoff for Rwera River in Mm^3

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total	Aver
1960	1.21	1.23	6.97	8.65	4.10	3.44	3.58	3.32	2.52	2.08	1.75	1.61	40.45	3.37
1961	1.51	1.95	2.48	3.90	7.41	11.89	8.85	3.08	2.40	1.85	1.49	1.17	47.98	4.00
1962	0.91	1.18	5.80	6.87	7.09	8.13	4.57	3.01	2.37	1.87	1.49	1.12	44.40	3.70
1963	0.87	1.56	2.17	5.71	6.78	3.47	2.44	1.88	1.50	1.20	0.99	0.82	29.40	2.45
1964	0.67	0.89	4.02	6.32	4.17	2.59	2.41	2.03	1.67	1.33	1.03	0.80	27.94	2.33
1965	0.67	1.12	1.41	1.65	5.42	5.73	2.73	2.48	2.01	1.67	1.36	1.05	27.31	2.28
1966	0.83	0.80	1.48	6.55	8.01	6.73	5.64	2.73	2.42	2.00	1.75	1.57	40.49	3.37
1967	1.29	1.15	1.22	1.28	1.44	1.56	1.76	1.91	1.70	1.43	1.13	0.87	16.75	1.40
1968	0.67	1.22	3.59	5.26	3.93	8.12	8.84	3.46	2.50	1.95	1.51	1.16	42.20	3.52
1969	0.99	1.05	17.63	21.03	5.64	3.13	3.96	3.86	2.38	1.87	1.55	1.18	64.26	5.36
1970	0.86	1.16	2.96	6.54	6.15	3.22	2.57	2.89	2.95	2.14	1.65	1.18	34.27	2.86
1971	0.87	2.47	5.83	12.23	10.11	4.43	4.38	2.83	2.18	1.63	1.22	0.90	49.09	4.09
1972	0.71	0.70	1.09	2.49	3.29	2.74	2.30	1.94	1.52	1.23	1.07	0.90	19.97	1.66
1973	0.84	2.73	7.63	11.16	14.70	17.81	11.03	3.63	2.74	2.13	1.70	1.46	77.56	6.46
1974	1.26	1.39	5.95	7.30	7.62	7.09	3.35	3.00	2.26	1.72	1.34	1.03	43.32	3.61
1975	0.91	0.99	2.43	4.24	6.59	18.03	15.45	3.05	2.41	1.85	1.39	1.01	58.35	4.86
1976	0.83	0.90	2.35	2.91	9.62	11.93	4.81	2.53	1.87	1.44	1.27	1.21	41.66	3.47
1977	1.10	1.48	3.97	9.51	11.10	11.92	11.60	5.81	2.81	2.21	1.70	1.26	64.46	5.37
1978	1.12	1.58	5.61	6.09	4.69	6.04	4.24	2.49	1.87	1.58	1.46	1.22	37.99	3.17
1979	1.25	1.31	1.83	2.57	7.23	7.55	3.17	2.74	2.14	1.67	1.39	1.22	34.07	2.84
1980	1.27	1.40	7.53	11.17	12.31	11.10	4.78	2.93	2.28	1.72	1.33	1.11	58.93	4.91
1981	1.00	1.47	3.25	4.24	4.42	3.96	2.85	2.47	1.99	1.57	1.27	1.04	29.53	2.46
1982	1.14	1.35	1.42	1.51	1.58	1.98	2.04	1.61	1.33	1.17	1.11	0.93	17.17	1.43
1983	0.77	0.74	1.97	2.28	1.74	5.29	5.45	2.21	1.77	1.44	1.22	1.06	25.94	2.16
1984	0.90	1.16	2.92	8.39	9.01	8.32	7.03	2.70	2.19	1.78	1.42	1.09	46.91	3.91
1985	0.89	1.07	4.04	13.86	13.29	4.49	3.54	3.22	2.36	1.74	1.31	0.95	50.75	4.23
1986	1.92	2.32	4.41	7.28	5.19	2.77	2.15	1.59	1.19	0.91	0.71	0.58	31.03	2.59
1987	0.54	0.57	3.36	4.75	5.40	10.39	9.98	4.71	2.49	1.92	1.50	1.15	46.77	3.90
1988	1.96	2.69	2.62	5.41	11.88	9.72	3.62	3.11	2.35	1.77	1.36	1.08	47.57	3.96
1989	1.07	1.39	6.36	13.50	12.42	6.05	3.00	2.55	2.00	1.55	1.22	0.95	52.07	4.34
1990	0.72	0.61	0.76	1.39	1.86	3.21	3.34	1.83	1.36	1.04	0.80	0.63	17.55	1.46
1991	0.51	0.42	0.68	1.30	1.40	1.12	0.99	0.86	0.70	0.57	0.46	0.36	9.37	0.78
1992	0.26	0.38	1.66	1.97	5.22	6.79	3.34	2.07	1.56	1.28	1.12	0.93	26.58	2.21
1993	0.68	1.62	3.09	6.11	5.76	2.55	2.02	1.55	1.22	0.95	0.74	0.58	26.85	2.24
1994	0.53	0.55	1.05	1.59	1.74	1.77	1.58	1.38	1.17	0.95	0.79	0.66	13.77	1.15
1995	0.56	0.50	4.34	4.90	4.28	4.81	2.48	2.53	2.47	1.99	1.60	1.23	31.70	2.64
1996	0.90	1.12	3.87	12.60	15.23	10.07	6.08	3.11	2.30	1.67	1.24	1.11	59.30	4.94
1997	1.24	1.43	1.76	10.20	10.56	4.15	4.14	2.30	1.68	1.28	1.02	0.81	40.56	3.38
1998	0.72	1.31	4.11	10.83	13.01	9.22	5.46	2.82	2.17	1.65	1.33	1.08	53.71	4.48
1999	0.90	1.29	1.87	3.24	5.82	11.88	10.23	3.37	2.76	2.45	1.99	1.49	47.29	3.94
2000	1.25	1.58	2.53	2.67	13.54	18.03	7.10	2.68	2.07	1.68	1.45	1.15	55.73	4.64
2001	0.87	0.94	4.28	4.85	2.25	2.18	2.11	1.91	1.57	1.29	1.07	0.83	24.15	2.01
2002	0.64	0.57	0.53	0.77	0.91	2.08	2.33	1.20	1.10	1.03	0.92	0.82	12.91	1.08
2003	0.77	1.01	2.80	4.54	5.15	5.04	3.83	2.89	2.42	2.00	1.66	1.36	33.47	2.79
2004	1.12	1.49	4.27	6.52	7.10	6.82	4.39	2.48	1.81	1.32	0.98	0.71	39.00	3.25
2005	0.54	0.62	3.48	8.45	6.81	2.74	2.37	1.95	1.50	1.15	0.90	0.67	31.19	2.60
2006	0.60	0.98	1.94	7.60	9.51	13.20	11.52	2.62	1.93	1.43	1.06	0.77	53.16	4.43
2007	0.55	2.03	19.34	21.71	7.57	4.99	2.96	2.45	1.85	1.35	1.01	0.76	66.56	5.55
2008	0.60	0.52	7.83	13.50	13.24	12.79	6.94	2.60	2.00	1.59	1.26	0.94	63.81	5.32
2009	0.72	0.71	0.79	9.22	9.93	2.75	3.18	2.70	1.99	1.47	1.10	0.82	35.38	2.95
2010	0.65	2.85	8.48	9.04	11.15	11.65	6.79	4.60	2.45	1.84	1.41	1.03	61.93	5.16
2011	0.72	0.69	9.25	18.24	10.98	3.61	3.84	3.19	2.34	1.71	1.28	0.95	56.80	4.73
2012	0.71	0.70	0.83	1.24	3.60	4.52	2.89	2.04	1.51	1.12	0.84	0.61	20.60	1.72
2013	0.44	0.50	5.95	9.53	6.23	5.03	4.10	2.50	1.92	1.47	1.12	0.84	39.64	3.30
2014	0.66	0.54	0.40	7.14	14.69	10.99	4.72	2.56	1.93	1.44	1.13	0.89	47.09	3.92

Appendix 14 Simulated surface runoff for Honde headwaters in Mm^3

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1960	0.21	0.20	0.77	0.99	0.59	0.53	0.51	0.45	0.34	0.25	0.18	0.15
1961	0.14	0.18	0.25	0.41	0.71	1.22	1.08	0.52	0.36	0.24	0.16	0.11
1962	0.07	0.09	0.55	0.74	0.77	0.87	0.62	0.49	0.35	0.24	0.16	0.09
1963	0.06	0.12	0.21	0.58	0.76	0.50	0.36	0.24	0.17	0.12	0.08	0.05
1964	0.04	0.06	0.36	0.63	0.53	0.40	0.34	0.27	0.20	0.14	0.08	0.05
1965	0.04	0.08	0.13	0.18	0.55	0.65	0.41	0.35	0.26	0.19	0.13	0.08
1966	0.05	0.05	0.13	0.65	0.88	0.71	0.65	0.45	0.36	0.27	0.20	0.16
1967	0.12	0.10	0.11	0.13	0.15	0.17	0.20	0.22	0.20	0.16	0.10	0.06
1968	0.03	0.08	0.31	0.53	0.50	0.96	1.05	0.53	0.38	0.25	0.16	0.10
1969	0.08	0.09	2.29	2.67	0.72	0.51	0.52	0.49	0.32	0.22	0.16	0.10
1970	0.05	0.08	0.26	0.65	0.72	0.49	0.38	0.35	0.35	0.27	0.18	0.10
1971	0.06	0.19	0.53	1.38	1.31	0.61	0.57	0.43	0.29	0.19	0.11	0.06
1972	0.04	0.04	0.09	0.24	0.36	0.37	0.32	0.25	0.17	0.12	0.09	0.06
1973	0.06	0.22	0.74	1.20	1.79	2.28	1.46	0.57	0.43	0.29	0.20	0.15
1974	0.12	0.12	0.57	0.78	0.78	0.79	0.55	0.45	0.31	0.21	0.13	0.08
1975	0.06	0.08	0.21	0.42	0.71	2.21	2.04	0.51	0.36	0.24	0.15	0.08
1976	0.05	0.07	0.20	0.30	1.14	1.35	0.61	0.41	0.26	0.17	0.13	0.12
1977	0.10	0.13	0.36	1.00	1.19	1.38	1.38	0.74	0.48	0.33	0.21	0.12
1978	0.09	0.15	0.54	0.67	0.58	0.67	0.53	0.37	0.24	0.18	0.15	0.11
1979	0.10	0.12	0.18	0.27	0.78	0.89	0.49	0.39	0.27	0.19	0.13	0.10
1980	0.11	0.14	0.79	1.20	1.42	1.29	0.64	0.49	0.34	0.22	0.14	0.10
1981	0.08	0.13	0.30	0.45	0.53	0.52	0.41	0.32	0.24	0.16	0.11	0.08
1982	0.08	0.12	0.15	0.17	0.18	0.22	0.24	0.19	0.14	0.11	0.10	0.07
1983	0.05	0.05	0.16	0.22	0.21	0.54	0.62	0.34	0.24	0.17	0.12	0.09
1984	0.07	0.09	0.26	0.87	1.01	0.91	0.84	0.46	0.33	0.23	0.16	0.10
1985	0.07	0.08	0.36	1.61	1.64	0.62	0.55	0.47	0.32	0.20	0.12	0.07
1986	0.14	0.21	0.44	0.75	0.65	0.43	0.30	0.19	0.12	0.07	0.04	0.02
1987	0.02	0.03	0.28	0.47	0.61	1.14	1.09	0.61	0.42	0.28	0.18	0.11
1988	0.16	0.26	0.31	0.58	1.23	1.13	0.59	0.47	0.33	0.21	0.13	0.09
1989	0.08	0.13	0.63	1.49	1.42	0.77	0.50	0.38	0.27	0.18	0.12	0.07
1990	0.04	0.03	0.05	0.13	0.21	0.35	0.39	0.25	0.16	0.10	0.06	0.03
1991	0.02	0.01	0.04	0.12	0.16	0.13	0.11	0.08	0.06	0.03	0.02	0.01
1992	0.00	0.01	0.13	0.20	0.54	0.74	0.48	0.32	0.21	0.15	0.11	0.08
1993	0.04	0.11	0.27	0.63	0.69	0.41	0.28	0.19	0.13	0.08	0.05	0.02
1994	0.02	0.03	0.08	0.16	0.21	0.23	0.20	0.16	0.12	0.08	0.06	0.04
1995	0.03	0.02	0.37	0.49	0.48	0.58	0.40	0.36	0.33	0.26	0.18	0.11
1996	0.06	0.08	0.34	1.43	1.82	1.14	0.78	0.52	0.34	0.21	0.13	0.09
1997	0.11	0.15	0.19	1.19	1.30	0.54	0.52	0.33	0.20	0.13	0.09	0.05
1998	0.04	0.10	0.37	1.18	1.50	1.02	0.69	0.48	0.32	0.21	0.14	0.10
1999	0.07	0.11	0.18	0.34	0.61	1.27	1.20	0.55	0.43	0.34	0.24	0.15
2000	0.11	0.14	0.25	0.31	1.71	2.08	0.78	0.45	0.30	0.22	0.16	0.11
2001	0.06	0.07	0.38	0.51	0.33	0.31	0.28	0.24	0.18	0.13	0.09	0.05
2002	0.03	0.03	0.02	0.05	0.08	0.18	0.23	0.16	0.13	0.11	0.09	0.07
2003	0.06	0.09	0.26	0.46	0.60	0.62	0.52	0.42	0.32	0.24	0.17	0.12
2004	0.09	0.12	0.38	0.66	0.72	0.70	0.58	0.40	0.25	0.15	0.09	0.04
2005	0.02	0.03	0.29	0.84	0.82	0.46	0.36	0.26	0.18	0.11	0.07	0.04
2006	0.03	0.07	0.18	0.80	1.05	1.62	1.52	0.44	0.28	0.17	0.10	0.05
2007	0.02	0.14	2.46	2.79	0.83	0.65	0.50	0.37	0.24	0.15	0.09	0.05
2008	0.03	0.02	0.84	1.48	1.67	1.65	0.90	0.44	0.29	0.20	0.13	0.08
2009	0.04	0.04	0.06	1.05	1.20	0.40	0.44	0.38	0.26	0.16	0.10	0.05
2010	0.03	0.22	0.83	1.01	1.36	1.34	0.73	0.61	0.41	0.26	0.17	0.09
2011	0.05	0.04	1.05	2.18	1.45	0.59	0.56	0.46	0.31	0.19	0.12	0.06
2012	0.04	0.04	0.06	0.12	0.34	0.49	0.40	0.28	0.18	0.11	0.06	0.03
2013	0.01	0.02	0.58	0.98	0.75	0.66	0.56	0.39	0.26	0.17	0.11	0.06
2014	0.03	0.02	0.01	0.46	1.07	1.02	0.66	0.43	0.28	0.17	0.11	0.07
2015	0.04	0.04	0.07	0.25	0.81	0.93	0.65	0.56	0.38	0.24	0.14	0.08
2016	0.05	0.05	0.63	0.73	0.20	0.11	0.06	0.03	0.01	0.00	0.00	0.00

Appendix 15 Simulated surface runoff for Manana River in Mm^3

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1960	0.21	0.20	0.77	0.99	0.59	0.53	0.51	0.45	0.34	0.25	0.18	0.15
1961	0.14	0.18	0.25	0.41	0.71	1.22	1.08	0.52	0.36	0.24	0.16	0.11
1962	0.07	0.09	0.55	0.74	0.77	0.87	0.62	0.49	0.35	0.24	0.16	0.09
1963	0.06	0.12	0.21	0.58	0.76	0.50	0.36	0.24	0.17	0.12	0.08	0.05
1964	0.04	0.06	0.36	0.63	0.53	0.40	0.34	0.27	0.20	0.14	0.08	0.05
1965	0.04	0.08	0.13	0.18	0.55	0.65	0.41	0.35	0.26	0.19	0.13	0.08
1966	0.05	0.05	0.13	0.65	0.88	0.71	0.65	0.45	0.36	0.27	0.20	0.16
1967	0.12	0.10	0.11	0.13	0.15	0.17	0.20	0.22	0.20	0.16	0.10	0.06
1968	0.03	0.08	0.31	0.53	0.50	0.96	1.05	0.53	0.38	0.25	0.16	0.10
1969	0.08	0.09	2.29	2.67	0.72	0.51	0.52	0.49	0.32	0.22	0.16	0.10
1970	0.05	0.08	0.26	0.65	0.72	0.49	0.38	0.35	0.35	0.27	0.18	0.10
1971	0.06	0.19	0.53	1.38	1.31	0.61	0.57	0.43	0.29	0.19	0.11	0.06
1972	0.04	0.04	0.09	0.24	0.36	0.37	0.32	0.25	0.17	0.12	0.09	0.06
1973	0.06	0.22	0.74	1.20	1.79	2.28	1.46	0.57	0.43	0.29	0.20	0.15
1974	0.12	0.12	0.57	0.78	0.78	0.79	0.55	0.45	0.31	0.21	0.13	0.08
1975	0.06	0.08	0.21	0.42	0.71	2.21	2.04	0.51	0.36	0.24	0.15	0.08
1976	0.05	0.07	0.20	0.30	1.14	1.35	0.61	0.41	0.26	0.17	0.13	0.12
1977	0.10	0.13	0.36	1.00	1.19	1.38	1.38	0.74	0.48	0.33	0.21	0.12
1978	0.09	0.15	0.54	0.67	0.58	0.67	0.53	0.37	0.24	0.18	0.15	0.11
1979	0.10	0.12	0.18	0.27	0.78	0.89	0.49	0.39	0.27	0.19	0.13	0.10
1980	0.11	0.14	0.79	1.20	1.42	1.29	0.64	0.49	0.34	0.22	0.14	0.10
1981	0.08	0.13	0.30	0.45	0.53	0.52	0.41	0.32	0.24	0.16	0.11	0.08
1982	0.08	0.12	0.15	0.17	0.18	0.22	0.24	0.19	0.14	0.11	0.10	0.07
1983	0.05	0.05	0.16	0.22	0.21	0.54	0.62	0.34	0.24	0.17	0.12	0.09
1984	0.07	0.09	0.26	0.87	1.01	0.91	0.84	0.46	0.33	0.23	0.16	0.10
1985	0.07	0.08	0.36	1.61	1.64	0.62	0.55	0.47	0.32	0.20	0.12	0.07
1986	0.14	0.21	0.44	0.75	0.65	0.43	0.30	0.19	0.12	0.07	0.04	0.02
1987	0.02	0.03	0.28	0.47	0.61	1.14	1.09	0.61	0.42	0.28	0.18	0.11
1988	0.16	0.26	0.31	0.58	1.23	1.13	0.59	0.47	0.33	0.21	0.13	0.09
1989	0.08	0.13	0.63	1.49	1.42	0.77	0.50	0.38	0.27	0.18	0.12	0.07
1990	0.04	0.03	0.05	0.13	0.21	0.35	0.39	0.25	0.16	0.10	0.06	0.03
1991	0.02	0.01	0.04	0.12	0.16	0.13	0.11	0.08	0.06	0.03	0.02	0.01
1992	0.00	0.01	0.13	0.20	0.54	0.74	0.48	0.32	0.21	0.15	0.11	0.08
1993	0.04	0.11	0.27	0.63	0.69	0.41	0.28	0.19	0.13	0.08	0.05	0.02
1994	0.02	0.03	0.08	0.16	0.21	0.23	0.20	0.16	0.12	0.08	0.06	0.04
1995	0.03	0.02	0.37	0.49	0.48	0.58	0.40	0.36	0.33	0.26	0.18	0.11
1996	0.06	0.08	0.34	1.43	1.82	1.14	0.78	0.52	0.34	0.21	0.13	0.09
1997	0.11	0.15	0.19	1.19	1.30	0.54	0.52	0.33	0.20	0.13	0.09	0.05
1998	0.04	0.10	0.37	1.18	1.50	1.02	0.69	0.48	0.32	0.21	0.14	0.10
1999	0.07	0.11	0.18	0.34	0.61	1.27	1.20	0.55	0.43	0.34	0.24	0.15
2000	0.11	0.14	0.25	0.31	1.71	2.08	0.78	0.45	0.30	0.22	0.16	0.11
2001	0.06	0.07	0.38	0.51	0.33	0.31	0.28	0.24	0.18	0.13	0.09	0.05
2002	0.03	0.03	0.02	0.05	0.08	0.18	0.23	0.16	0.13	0.11	0.09	0.07
2003	0.06	0.09	0.26	0.46	0.60	0.62	0.52	0.42	0.32	0.24	0.17	0.12
2004	0.09	0.12	0.38	0.66	0.72	0.70	0.58	0.40	0.25	0.15	0.09	0.04
2005	0.02	0.03	0.29	0.84	0.82	0.46	0.36	0.26	0.18	0.11	0.07	0.04
2006	0.03	0.07	0.18	0.80	1.05	1.62	1.52	0.44	0.28	0.17	0.10	0.05
2007	0.02	0.14	2.46	2.79	0.83	0.65	0.50	0.37	0.24	0.15	0.09	0.05
2008	0.03	0.02	0.84	1.48	1.67	1.65	0.90	0.44	0.29	0.20	0.13	0.08
2009	0.04	0.04	0.06	1.05	1.20	0.40	0.44	0.38	0.26	0.16	0.10	0.05
2010	0.03	0.22	0.83	1.01	1.36	1.34	0.73	0.61	0.41	0.26	0.17	0.09
2011	0.05	0.04	1.05	2.18	1.45	0.59	0.56	0.46	0.31	0.19	0.12	0.06
2012	0.04	0.04	0.06	0.12	0.34	0.49	0.40	0.28	0.18	0.11	0.06	0.03
2013	0.01	0.02	0.58	0.98	0.75	0.66	0.56	0.39	0.26	0.17	0.11	0.06
2014	0.03	0.02	0.01	0.46	1.07	1.02	0.66	0.43	0.28	0.17	0.11	0.07
2015	0.04	0.04	0.07	0.25	0.81	0.93	0.65	0.56	0.38	0.24	0.14	0.08
2016	0.05	0.05	0.63	0.73	0.20	0.11	0.06	0.03	0.01	0.00	0.00	0.00

Appendix 16 Simulated surface runoff for Nyachere River in Mm^3

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1960	0.50	0.47	1.84	2.37	1.41	1.26	1.21	1.08	0.81	0.60	0.46	0.41
1961	0.37	0.45	0.62	0.99	1.71	2.95	2.61	1.24	0.86	0.58	0.42	0.29
1962	0.18	0.23	1.34	1.78	1.87	2.08	1.50	1.17	0.83	0.58	0.41	0.26
1963	0.17	0.31	0.52	1.41	1.82	1.21	0.86	0.58	0.40	0.28	0.21	0.15
1964	0.10	0.16	0.86	1.52	1.28	0.96	0.82	0.64	0.47	0.33	0.22	0.14
1965	0.10	0.20	0.33	0.44	1.32	1.57	1.00	0.84	0.63	0.47	0.34	0.23
1966	0.15	0.14	0.31	1.57	2.12	1.72	1.55	1.08	0.86	0.65	0.51	0.43
1967	0.32	0.27	0.29	0.32	0.37	0.42	0.48	0.54	0.49	0.38	0.26	0.17
1968	0.10	0.21	0.76	1.29	1.21	2.31	2.53	1.26	0.91	0.62	0.42	0.27
1969	0.21	0.23	5.50	6.42	1.74	1.24	1.25	1.17	0.78	0.54	0.41	0.27
1970	0.15	0.21	0.63	1.56	1.74	1.19	0.90	0.83	0.85	0.66	0.45	0.27
1971	0.16	0.47	1.29	3.33	3.16	1.48	1.37	1.03	0.71	0.45	0.29	0.17
1972	0.11	0.12	0.22	0.57	0.88	0.88	0.76	0.59	0.41	0.29	0.23	0.18
1973	0.16	0.55	1.80	2.91	4.32	5.47	3.49	1.37	1.03	0.71	0.50	0.39
1974	0.31	0.32	1.39	1.88	1.87	1.91	1.32	1.08	0.75	0.50	0.34	0.22
1975	0.17	0.21	0.53	1.01	1.71	5.32	4.92	1.23	0.86	0.58	0.37	0.22
1976	0.15	0.18	0.50	0.74	2.74	3.25	1.46	0.99	0.63	0.42	0.34	0.31
1977	0.26	0.32	0.88	2.42	2.88	3.33	3.31	1.79	1.14	0.80	0.53	0.34
1978	0.26	0.37	1.32	1.62	1.40	1.61	1.29	0.90	0.58	0.44	0.39	0.30
1979	0.27	0.31	0.43	0.66	1.87	2.13	1.17	0.94	0.66	0.46	0.34	0.28
1980	0.29	0.34	1.91	2.89	3.43	3.12	1.53	1.17	0.81	0.53	0.36	0.26
1981	0.22	0.32	0.74	1.10	1.29	1.26	0.98	0.77	0.57	0.40	0.29	0.21
1982	0.22	0.31	0.37	0.41	0.44	0.54	0.57	0.45	0.34	0.27	0.26	0.20
1983	0.14	0.13	0.39	0.54	0.51	1.30	1.49	0.82	0.57	0.41	0.32	0.25
1984	0.19	0.23	0.64	2.10	2.43	2.19	2.02	1.10	0.78	0.57	0.40	0.26
1985	0.18	0.22	0.88	3.88	3.95	1.49	1.32	1.12	0.77	0.49	0.32	0.18
1986	0.35	0.52	1.06	1.80	1.58	1.05	0.71	0.45	0.28	0.18	0.11	0.07
1987	0.07	0.09	0.68	1.12	1.47	2.74	2.62	1.47	1.02	0.68	0.46	0.30
1988	0.42	0.65	0.75	1.40	2.97	2.73	1.41	1.13	0.79	0.51	0.34	0.24
1989	0.22	0.32	1.53	3.60	3.44	1.86	1.21	0.92	0.64	0.44	0.30	0.20
1990	0.12	0.08	0.14	0.32	0.50	0.85	0.94	0.60	0.38	0.24	0.15	0.09
1991	0.06	0.03	0.10	0.29	0.38	0.32	0.26	0.20	0.13	0.09	0.05	0.02
1992	0.00	0.04	0.32	0.49	1.30	1.77	1.16	0.78	0.50	0.36	0.29	0.21
1993	0.12	0.28	0.67	1.51	1.65	0.98	0.69	0.46	0.31	0.20	0.13	0.07
1994	0.06	0.08	0.20	0.38	0.51	0.55	0.48	0.39	0.29	0.21	0.15	0.11
1995	0.08	0.06	0.90	1.18	1.17	1.39	0.96	0.86	0.80	0.62	0.45	0.30
1996	0.17	0.20	0.82	3.45	4.40	2.77	1.87	1.24	0.83	0.51	0.32	0.25
1997	0.29	0.37	0.47	2.86	3.14	1.30	1.25	0.79	0.49	0.32	0.22	0.15
1998	0.12	0.26	0.91	2.85	3.61	2.47	1.67	1.14	0.77	0.51	0.36	0.26
1999	0.19	0.27	0.45	0.82	1.48	3.06	2.89	1.32	1.02	0.83	0.62	0.40
2000	0.29	0.36	0.62	0.75	4.11	5.01	1.90	1.08	0.73	0.53	0.41	0.29
2001	0.18	0.18	0.92	1.22	0.80	0.74	0.67	0.57	0.43	0.32	0.23	0.15
2002	0.09	0.08	0.07	0.12	0.19	0.44	0.56	0.38	0.32	0.28	0.23	0.19
2003	0.16	0.22	0.63	1.12	1.44	1.49	1.26	1.02	0.78	0.58	0.44	0.33
2004	0.24	0.31	0.94	1.59	1.74	1.70	1.39	0.95	0.59	0.36	0.22	0.12
2005	0.07	0.09	0.72	2.02	1.98	1.11	0.87	0.64	0.42	0.28	0.18	0.10
2006	0.08	0.18	0.45	1.94	2.53	3.89	3.63	1.05	0.67	0.42	0.26	0.15
2007	0.07	0.35	5.93	6.73	2.00	1.56	1.21	0.89	0.58	0.36	0.22	0.13
2008	0.08	0.06	2.02	3.57	4.02	3.97	2.17	1.05	0.70	0.49	0.34	0.21
2009	0.13	0.12	0.16	2.53	2.89	0.98	1.05	0.92	0.64	0.40	0.25	0.15
2010	0.09	0.53	2.01	2.44	3.28	3.24	1.74	1.46	0.99	0.64	0.43	0.26
2011	0.14	0.11	2.53	5.24	3.50	1.41	1.35	1.11	0.76	0.47	0.30	0.18
2012	0.10	0.10	0.16	0.29	0.83	1.19	0.97	0.68	0.43	0.26	0.16	0.08
2013	0.03	0.05	1.39	2.36	1.81	1.58	1.35	0.94	0.63	0.41	0.27	0.16
2014	0.10	0.06	0.02	1.10	2.57	2.45	1.60	1.03	0.66	0.42	0.29	0.19
2015	0.11	0.11	0.17	0.61	1.96	2.23	1.56	1.35	0.92	0.59	0.37	0.22
2016	0.14	0.13	1.52	1.76	0.50	0.28	0.15	0.07	0.03	0.00	0.00	0.00

Appendix 17 Simulated surface runoff for Nyarusha River in Mm^3

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1960	0.34	0.31	1.23	1.58	0.94	0.84	0.81	0.72	0.54	0.40	0.31	0.27
1961	0.25	0.30	0.41	0.66	1.14	1.97	1.74	0.83	0.58	0.39	0.28	0.19
1962	0.12	0.16	0.89	1.19	1.24	1.39	1.00	0.78	0.56	0.39	0.27	0.17
1963	0.11	0.21	0.35	0.94	1.21	0.81	0.57	0.38	0.27	0.19	0.14	0.10
1964	0.07	0.11	0.58	1.01	0.85	0.64	0.54	0.43	0.31	0.22	0.15	0.09
1965	0.07	0.14	0.22	0.29	0.88	1.05	0.66	0.56	0.42	0.32	0.23	0.15
1966	0.10	0.09	0.21	1.05	1.41	1.15	1.04	0.72	0.57	0.43	0.34	0.29
1967	0.22	0.18	0.19	0.21	0.25	0.28	0.32	0.36	0.33	0.25	0.17	0.11
1968	0.07	0.14	0.51	0.86	0.81	1.54	1.68	0.84	0.60	0.41	0.28	0.18
1969	0.14	0.15	3.67	4.28	1.16	0.83	0.83	0.78	0.52	0.36	0.27	0.18
1970	0.10	0.14	0.42	1.04	1.16	0.79	0.60	0.56	0.57	0.44	0.30	0.18
1971	0.10	0.31	0.86	2.22	2.10	0.98	0.91	0.69	0.47	0.30	0.19	0.11
1972	0.07	0.08	0.15	0.38	0.59	0.59	0.51	0.39	0.27	0.20	0.16	0.12
1973	0.10	0.37	1.20	1.94	2.88	3.65	2.33	0.91	0.69	0.47	0.33	0.26
1974	0.21	0.21	0.93	1.25	1.25	1.27	0.88	0.72	0.50	0.33	0.23	0.15
1975	0.11	0.14	0.35	0.67	1.14	3.54	3.28	0.82	0.57	0.39	0.25	0.15
1976	0.10	0.12	0.34	0.49	1.82	2.17	0.97	0.66	0.42	0.28	0.23	0.21
1977	0.18	0.21	0.59	1.61	1.92	2.22	2.21	1.19	0.76	0.53	0.36	0.22
1978	0.17	0.25	0.88	1.08	0.93	1.07	0.86	0.60	0.39	0.29	0.26	0.20
1979	0.18	0.20	0.29	0.44	1.25	1.42	0.78	0.63	0.44	0.30	0.23	0.19
1980	0.19	0.23	1.27	1.93	2.29	2.08	1.02	0.78	0.54	0.35	0.24	0.18
1981	0.15	0.22	0.50	0.73	0.86	0.84	0.65	0.52	0.38	0.26	0.19	0.14
1982	0.15	0.21	0.24	0.27	0.29	0.36	0.38	0.30	0.22	0.18	0.17	0.13
1983	0.09	0.09	0.26	0.36	0.34	0.87	1.00	0.55	0.38	0.27	0.21	0.17
1984	0.13	0.16	0.42	1.40	1.62	1.46	1.35	0.73	0.52	0.38	0.26	0.17
1985	0.12	0.15	0.59	2.58	2.63	0.99	0.88	0.75	0.52	0.33	0.21	0.12
1986	0.23	0.35	0.71	1.20	1.05	0.70	0.48	0.30	0.19	0.12	0.07	0.05
1987	0.05	0.06	0.45	0.75	0.98	1.83	1.75	0.98	0.68	0.46	0.31	0.20
1988	0.28	0.43	0.50	0.93	1.98	1.82	0.94	0.76	0.52	0.34	0.23	0.16
1989	0.15	0.21	1.02	2.40	2.29	1.24	0.81	0.61	0.43	0.29	0.20	0.13
1990	0.08	0.05	0.09	0.21	0.33	0.56	0.62	0.40	0.25	0.16	0.10	0.06
1991	0.04	0.02	0.07	0.19	0.26	0.22	0.17	0.13	0.09	0.06	0.03	0.01
1992	0.00	0.02	0.22	0.32	0.86	1.18	0.77	0.52	0.33	0.24	0.19	0.14
1993	0.08	0.19	0.45	1.01	1.10	0.65	0.46	0.30	0.20	0.14	0.08	0.05
1994	0.04	0.05	0.13	0.25	0.34	0.37	0.32	0.26	0.20	0.14	0.10	0.07
1995	0.05	0.04	0.60	0.78	0.78	0.93	0.64	0.58	0.53	0.42	0.30	0.20
1996	0.11	0.13	0.55	2.30	2.93	1.84	1.24	0.83	0.55	0.34	0.21	0.17
1997	0.20	0.24	0.31	1.91	2.09	0.87	0.83	0.53	0.33	0.21	0.15	0.10
1998	0.08	0.17	0.61	1.90	2.41	1.65	1.11	0.76	0.51	0.34	0.24	0.17
1999	0.13	0.18	0.30	0.55	0.99	2.04	1.93	0.88	0.68	0.55	0.41	0.26
2000	0.19	0.24	0.41	0.50	2.74	3.34	1.27	0.72	0.49	0.35	0.27	0.19
2001	0.12	0.12	0.62	0.82	0.53	0.49	0.45	0.38	0.29	0.21	0.16	0.10
2002	0.06	0.05	0.04	0.08	0.13	0.30	0.38	0.25	0.21	0.18	0.15	0.12
2003	0.11	0.15	0.42	0.75	0.96	0.99	0.84	0.68	0.52	0.39	0.29	0.22
2004	0.16	0.20	0.63	1.06	1.16	1.13	0.93	0.64	0.40	0.24	0.15	0.08
2005	0.04	0.06	0.48	1.35	1.32	0.74	0.58	0.42	0.28	0.18	0.12	0.07
2006	0.05	0.12	0.30	1.29	1.69	2.59	2.42	0.70	0.45	0.28	0.17	0.10
2007	0.05	0.23	3.95	4.49	1.34	1.04	0.80	0.59	0.39	0.24	0.15	0.09
2008	0.05	0.04	1.34	2.38	2.68	2.65	1.44	0.70	0.47	0.33	0.23	0.14
2009	0.08	0.08	0.11	1.69	1.93	0.65	0.70	0.61	0.42	0.27	0.17	0.10
2010	0.06	0.36	1.34	1.62	2.19	2.16	1.16	0.97	0.66	0.43	0.28	0.17
2011	0.09	0.08	1.68	3.50	2.33	0.94	0.90	0.74	0.50	0.32	0.20	0.12
2012	0.07	0.07	0.11	0.19	0.55	0.80	0.65	0.46	0.29	0.18	0.11	0.05
2013	0.02	0.03	0.93	1.57	1.21	1.05	0.90	0.63	0.42	0.28	0.18	0.11
2014	0.07	0.04	0.02	0.74	1.71	1.63	1.07	0.69	0.44	0.28	0.19	0.13
2015	0.08	0.07	0.11	0.40	1.31	1.49	1.04	0.90	0.61	0.39	0.25	0.15
2016	0.09	0.09	1.01	1.17	0.33	0.19	0.10	0.05	0.02	0.00	0.00	0.00

Appendix 18 Simulated surface runoff for Mukondwe River in Mm^3

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1960	0.17	0.16	0.61	0.79	0.47	0.42	0.40	0.36	0.27	0.20	0.15	0.14
1961	0.12	0.15	0.21	0.33	0.57	0.98	0.87	0.41	0.29	0.19	0.14	0.10
1962	0.06	0.08	0.45	0.59	0.62	0.69	0.50	0.39	0.28	0.19	0.14	0.09
1963	0.06	0.10	0.17	0.47	0.61	0.40	0.29	0.19	0.13	0.09	0.07	0.05
1964	0.03	0.05	0.29	0.51	0.43	0.32	0.27	0.21	0.16	0.11	0.07	0.05
1965	0.03	0.07	0.11	0.15	0.44	0.52	0.33	0.28	0.21	0.16	0.11	0.08
1966	0.05	0.05	0.10	0.52	0.71	0.57	0.52	0.36	0.29	0.22	0.17	0.14
1967	0.11	0.09	0.10	0.11	0.12	0.14	0.16	0.18	0.16	0.13	0.09	0.06
1968	0.03	0.07	0.25	0.43	0.40	0.77	0.84	0.42	0.30	0.21	0.14	0.09
1969	0.07	0.08	1.83	2.14	0.58	0.41	0.42	0.39	0.26	0.18	0.14	0.09
1970	0.05	0.07	0.21	0.52	0.58	0.40	0.30	0.28	0.28	0.22	0.15	0.09
1971	0.05	0.16	0.43	1.11	1.05	0.49	0.46	0.34	0.24	0.15	0.10	0.06
1972	0.04	0.04	0.07	0.19	0.29	0.29	0.25	0.20	0.14	0.10	0.08	0.06
1973	0.05	0.18	0.60	0.97	1.44	1.82	1.16	0.46	0.34	0.24	0.17	0.13
1974	0.10	0.11	0.46	0.63	0.62	0.64	0.44	0.36	0.25	0.17	0.11	0.07
1975	0.06	0.07	0.18	0.34	0.57	1.77	1.64	0.41	0.29	0.19	0.12	0.07
1976	0.05	0.06	0.17	0.25	0.91	1.08	0.49	0.33	0.21	0.14	0.11	0.10
1977	0.09	0.11	0.29	0.81	0.96	1.11	1.10	0.60	0.38	0.27	0.18	0.11
1978	0.09	0.12	0.44	0.54	0.47	0.54	0.43	0.30	0.19	0.15	0.13	0.10
1979	0.09	0.10	0.14	0.22	0.62	0.71	0.39	0.31	0.22	0.15	0.11	0.09
1980	0.10	0.11	0.64	0.96	1.14	1.04	0.51	0.39	0.27	0.18	0.12	0.09
1981	0.07	0.11	0.25	0.37	0.43	0.42	0.33	0.26	0.19	0.13	0.10	0.07
1982	0.07	0.10	0.12	0.14	0.15	0.18	0.19	0.15	0.11	0.09	0.09	0.07
1983	0.05	0.04	0.13	0.18	0.17	0.43	0.50	0.27	0.19	0.14	0.11	0.08
1984	0.06	0.08	0.21	0.70	0.81	0.73	0.67	0.37	0.26	0.19	0.13	0.09
1985	0.06	0.07	0.29	1.29	1.32	0.50	0.44	0.37	0.26	0.16	0.11	0.06
1986	0.12	0.17	0.35	0.60	0.53	0.35	0.24	0.15	0.09	0.06	0.04	0.02
1987	0.02	0.03	0.23	0.37	0.49	0.91	0.87	0.49	0.34	0.23	0.15	0.10
1988	0.14	0.22	0.25	0.47	0.99	0.91	0.47	0.38	0.26	0.17	0.11	0.08
1989	0.07	0.11	0.51	1.20	1.15	0.62	0.40	0.31	0.21	0.15	0.10	0.07
1990	0.04	0.03	0.05	0.11	0.17	0.28	0.31	0.20	0.13	0.08	0.05	0.03
1991	0.02	0.01	0.03	0.10	0.13	0.11	0.09	0.07	0.04	0.03	0.02	0.01
1992	0.00	0.01	0.11	0.16	0.43	0.59	0.39	0.26	0.17	0.12	0.10	0.07
1993	0.04	0.09	0.22	0.50	0.55	0.33	0.23	0.15	0.10	0.07	0.04	0.02
1994	0.02	0.03	0.07	0.13	0.17	0.18	0.16	0.13	0.10	0.07	0.05	0.04
1995	0.03	0.02	0.30	0.39	0.39	0.46	0.32	0.29	0.27	0.21	0.15	0.10
1996	0.06	0.07	0.27	1.15	1.47	0.92	0.62	0.41	0.28	0.17	0.11	0.08
1997	0.10	0.12	0.16	0.95	1.05	0.43	0.42	0.26	0.16	0.11	0.07	0.05
1998	0.04	0.09	0.30	0.95	1.20	0.82	0.56	0.38	0.26	0.17	0.12	0.09
1999	0.06	0.09	0.15	0.27	0.49	1.02	0.96	0.44	0.34	0.28	0.21	0.13
2000	0.10	0.12	0.21	0.25	1.37	1.67	0.63	0.36	0.24	0.18	0.14	0.10
2001	0.06	0.06	0.31	0.41	0.27	0.25	0.22	0.19	0.14	0.11	0.08	0.05
2002	0.03	0.03	0.02	0.04	0.06	0.15	0.19	0.13	0.11	0.09	0.08	0.06
2003	0.05	0.07	0.21	0.37	0.48	0.50	0.42	0.34	0.26	0.19	0.15	0.11
2004	0.08	0.10	0.31	0.53	0.58	0.57	0.46	0.32	0.20	0.12	0.07	0.04
2005	0.02	0.03	0.24	0.67	0.66	0.37	0.29	0.21	0.14	0.09	0.06	0.03
2006	0.03	0.06	0.15	0.65	0.84	1.30	1.21	0.35	0.22	0.14	0.09	0.05
2007	0.02	0.12	1.98	2.24	0.67	0.52	0.40	0.30	0.19	0.12	0.07	0.04
2008	0.03	0.02	0.67	1.19	1.34	1.32	0.72	0.35	0.23	0.16	0.11	0.07
2009	0.04	0.04	0.05	0.84	0.96	0.33	0.35	0.31	0.21	0.13	0.08	0.05
2010	0.03	0.18	0.67	0.81	1.09	1.08	0.58	0.49	0.33	0.21	0.14	0.09
2011	0.05	0.04	0.84	1.75	1.17	0.47	0.45	0.37	0.25	0.16	0.10	0.06
2012	0.03	0.03	0.05	0.10	0.28	0.40	0.32	0.23	0.14	0.09	0.05	0.03
2013	0.01	0.02	0.46	0.79	0.60	0.53	0.45	0.31	0.21	0.14	0.09	0.05
2014	0.03	0.02	0.01	0.37	0.86	0.82	0.53	0.34	0.22	0.14	0.10	0.06
2015	0.04	0.04	0.06	0.20	0.65	0.74	0.52	0.45	0.31	0.20	0.12	0.07
2016	0.05	0.04	0.51	0.59	0.17	0.09	0.05	0.02	0.01	0.00	0.00	0.00

Appendix 19 Simulated surface runoff for Matinedza River in Mm^3

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1960	0.15	0.14	0.54	0.69	0.41	0.37	0.35	0.32	0.24	0.18	0.14	0.12
1961	0.11	0.13	0.18	0.29	0.50	0.86	0.76	0.36	0.25	0.17	0.12	0.08
1962	0.05	0.07	0.39	0.52	0.54	0.61	0.44	0.34	0.24	0.17	0.12	0.08
1963	0.05	0.09	0.15	0.41	0.53	0.35	0.25	0.17	0.12	0.08	0.06	0.04
1964	0.03	0.05	0.25	0.44	0.37	0.28	0.24	0.19	0.14	0.10	0.06	0.04
1965	0.03	0.06	0.10	0.13	0.38	0.46	0.29	0.24	0.18	0.14	0.10	0.07
1966	0.04	0.04	0.09	0.46	0.62	0.50	0.45	0.32	0.25	0.19	0.15	0.13
1967	0.09	0.08	0.08	0.09	0.11	0.12	0.14	0.16	0.14	0.11	0.08	0.05
1968	0.03	0.06	0.22	0.38	0.35	0.67	0.74	0.37	0.26	0.18	0.12	0.08
1969	0.06	0.07	1.60	1.87	0.51	0.36	0.36	0.34	0.23	0.16	0.12	0.08
1970	0.04	0.06	0.18	0.46	0.51	0.35	0.26	0.24	0.25	0.19	0.13	0.08
1971	0.05	0.14	0.38	0.97	0.92	0.43	0.40	0.30	0.21	0.13	0.08	0.05
1972	0.03	0.03	0.07	0.17	0.26	0.26	0.22	0.17	0.12	0.09	0.07	0.05
1973	0.05	0.16	0.52	0.85	1.26	1.60	1.02	0.40	0.30	0.21	0.15	0.11
1974	0.09	0.09	0.41	0.55	0.55	0.56	0.39	0.31	0.22	0.15	0.10	0.06
1975	0.05	0.06	0.15	0.29	0.50	1.55	1.43	0.36	0.25	0.17	0.11	0.06
1976	0.04	0.05	0.15	0.21	0.80	0.95	0.43	0.29	0.18	0.12	0.10	0.09
1977	0.08	0.09	0.26	0.70	0.84	0.97	0.97	0.52	0.33	0.23	0.16	0.10
1978	0.08	0.11	0.39	0.47	0.41	0.47	0.37	0.26	0.17	0.13	0.11	0.09
1979	0.08	0.09	0.13	0.19	0.55	0.62	0.34	0.27	0.19	0.13	0.10	0.08
1980	0.08	0.10	0.56	0.84	1.00	0.91	0.44	0.34	0.24	0.15	0.10	0.08
1981	0.07	0.09	0.22	0.32	0.38	0.37	0.29	0.23	0.17	0.12	0.08	0.06
1982	0.07	0.09	0.11	0.12	0.13	0.16	0.17	0.13	0.10	0.08	0.07	0.06
1983	0.04	0.04	0.11	0.16	0.15	0.38	0.44	0.24	0.17	0.12	0.09	0.07
1984	0.06	0.07	0.19	0.61	0.71	0.64	0.59	0.32	0.23	0.16	0.12	0.08
1985	0.05	0.06	0.26	1.13	1.15	0.43	0.39	0.33	0.23	0.14	0.09	0.05
1986	0.10	0.15	0.31	0.53	0.46	0.30	0.21	0.13	0.08	0.05	0.03	0.02
1987	0.02	0.03	0.20	0.33	0.43	0.80	0.76	0.43	0.30	0.20	0.14	0.09
1988	0.12	0.19	0.22	0.41	0.87	0.80	0.41	0.33	0.23	0.15	0.10	0.07
1989	0.07	0.09	0.45	1.05	1.00	0.54	0.35	0.27	0.19	0.13	0.09	0.06
1990	0.03	0.02	0.04	0.09	0.15	0.25	0.27	0.17	0.11	0.07	0.04	0.03
1991	0.02	0.01	0.03	0.09	0.11	0.09	0.08	0.06	0.04	0.03	0.02	0.01
1992	0.00	0.01	0.09	0.14	0.38	0.52	0.34	0.23	0.15	0.11	0.08	0.06
1993	0.03	0.08	0.19	0.44	0.48	0.29	0.20	0.13	0.09	0.06	0.04	0.02
1994	0.02	0.02	0.06	0.11	0.15	0.16	0.14	0.11	0.09	0.06	0.04	0.03
1995	0.02	0.02	0.26	0.34	0.34	0.41	0.28	0.25	0.23	0.18	0.13	0.09
1996	0.05	0.06	0.24	1.01	1.28	0.81	0.54	0.36	0.24	0.15	0.09	0.07
1997	0.09	0.11	0.14	0.84	0.92	0.38	0.36	0.23	0.14	0.09	0.06	0.04
1998	0.04	0.08	0.26	0.83	1.05	0.72	0.49	0.33	0.22	0.15	0.11	0.08
1999	0.06	0.08	0.13	0.24	0.43	0.89	0.84	0.39	0.30	0.24	0.18	0.12
2000	0.08	0.11	0.18	0.22	1.20	1.46	0.55	0.32	0.21	0.15	0.12	0.08
2001	0.05	0.05	0.27	0.36	0.23	0.22	0.20	0.17	0.13	0.09	0.07	0.04
2002	0.03	0.02	0.02	0.04	0.06	0.13	0.16	0.11	0.09	0.08	0.07	0.05
2003	0.05	0.06	0.18	0.33	0.42	0.44	0.37	0.30	0.23	0.17	0.13	0.10
2004	0.07	0.09	0.27	0.46	0.51	0.49	0.41	0.28	0.17	0.11	0.07	0.04
2005	0.02	0.03	0.21	0.59	0.58	0.32	0.25	0.19	0.12	0.08	0.05	0.03
2006	0.02	0.05	0.13	0.57	0.74	1.13	1.06	0.31	0.19	0.12	0.08	0.04
2007	0.02	0.10	1.73	1.96	0.58	0.45	0.35	0.26	0.17	0.10	0.07	0.04
2008	0.02	0.02	0.59	1.04	1.17	1.16	0.63	0.31	0.21	0.14	0.10	0.06
2009	0.04	0.04	0.05	0.74	0.84	0.29	0.31	0.27	0.19	0.12	0.07	0.04
2010	0.03	0.16	0.59	0.71	0.96	0.95	0.51	0.43	0.29	0.19	0.12	0.07
2011	0.04	0.03	0.74	1.53	1.02	0.41	0.39	0.33	0.22	0.14	0.09	0.05
2012	0.03	0.03	0.05	0.08	0.24	0.35	0.28	0.20	0.13	0.08	0.05	0.02
2013	0.01	0.01	0.40	0.69	0.53	0.46	0.39	0.27	0.18	0.12	0.08	0.05
2014	0.03	0.02	0.01	0.32	0.75	0.71	0.47	0.30	0.19	0.12	0.08	0.06
2015	0.03	0.03	0.05	0.18	0.57	0.65	0.45	0.39	0.27	0.17	0.11	0.07
2016	0.04	0.04	0.44	0.51	0.14	0.08	0.04	0.02	0.01	0.00	0.00	0.00

Appendix 20 Simulated surface runoff for Duru River in Mm^3

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1960	1.78	1.67	6.53	8.38	4.98	4.48	4.29	3.83	2.86	2.13	1.64	1.43
1961	1.33	1.59	2.18	3.51	6.05	10.46	9.26	4.39	3.06	2.06	1.48	1.01
1962	0.65	0.83	4.74	6.31	6.61	7.38	5.31	4.16	2.96	2.06	1.44	0.92
1963	0.59	1.09	1.85	5.01	6.45	4.29	3.04	2.04	1.43	1.00	0.73	0.54
1964	0.37	0.56	3.06	5.38	4.54	3.40	2.89	2.28	1.67	1.17	0.77	0.49
1965	0.36	0.72	1.15	1.56	4.66	5.55	3.53	2.96	2.23	1.67	1.22	0.80
1966	0.53	0.50	1.10	5.58	7.50	6.09	5.50	3.84	3.03	2.31	1.81	1.53
1967	1.15	0.94	1.02	1.14	1.31	1.49	1.70	1.90	1.75	1.35	0.93	0.59
1968	0.35	0.75	2.70	4.58	4.30	8.18	8.95	4.48	3.21	2.19	1.48	0.97
1969	0.73	0.82	19.48	22.73	6.16	4.40	4.41	4.15	2.76	1.92	1.44	0.94
1970	0.54	0.73	2.23	5.54	6.16	4.21	3.20	2.96	3.01	2.35	1.59	0.94
1971	0.56	1.65	4.57	11.80	11.18	5.23	4.85	3.66	2.50	1.60	1.02	0.61
1972	0.39	0.41	0.79	2.03	3.11	3.12	2.71	2.09	1.45	1.04	0.83	0.63
1973	0.55	1.94	6.37	10.30	15.29	19.38	12.37	4.85	3.64	2.51	1.78	1.39
1974	1.10	1.12	4.93	6.65	6.63	6.75	4.69	3.81	2.67	1.77	1.20	0.78
1975	0.61	0.73	1.87	3.57	6.06	18.83	17.42	4.35	3.04	2.05	1.32	0.78
1976	0.54	0.64	1.78	2.61	9.69	11.52	5.18	3.52	2.22	1.49	1.21	1.10
1977	0.93	1.14	3.11	8.56	10.21	11.80	11.72	6.33	4.05	2.83	1.89	1.19
1978	0.91	1.31	4.69	5.74	4.96	5.69	4.55	3.18	2.07	1.56	1.38	1.06
1979	0.97	1.09	1.54	2.33	6.62	7.55	4.16	3.32	2.34	1.61	1.21	0.98
1980	1.03	1.21	6.77	10.25	12.15	11.03	5.40	4.14	2.87	1.87	1.26	0.93
1981	0.79	1.15	2.64	3.90	4.57	4.46	3.46	2.74	2.01	1.40	1.02	0.74
1982	0.79	1.09	1.30	1.45	1.55	1.91	2.02	1.61	1.19	0.97	0.90	0.69
1983	0.48	0.47	1.39	1.92	1.79	4.61	5.29	2.90	2.03	1.46	1.12	0.88
1984	0.68	0.83	2.25	7.45	8.62	7.75	7.15	3.89	2.76	2.00	1.40	0.93
1985	0.65	0.78	3.12	13.73	13.97	5.27	4.68	3.96	2.74	1.75	1.12	0.65
1986	1.23	1.83	3.76	6.38	5.59	3.70	2.52	1.59	1.00	0.64	0.39	0.26
1987	0.24	0.31	2.40	3.98	5.21	9.70	9.29	5.21	3.60	2.42	1.65	1.07
1988	1.49	2.29	2.66	4.95	10.51	9.68	4.99	4.02	2.78	1.82	1.21	0.84
1989	0.79	1.13	5.44	12.74	12.18	6.58	4.28	3.25	2.28	1.54	1.05	0.69
1990	0.42	0.29	0.48	1.13	1.78	3.00	3.32	2.12	1.33	0.85	0.54	0.33
1991	0.20	0.11	0.36	1.03	1.36	1.15	0.92	0.71	0.48	0.31	0.18	0.07
1992	0.01	0.13	1.14	1.72	4.59	6.29	4.09	2.74	1.76	1.28	1.03	0.75
1993	0.41	0.99	2.37	5.36	5.86	3.47	2.43	1.61	1.09	0.72	0.45	0.26
1994	0.22	0.28	0.70	1.35	1.81	1.96	1.71	1.37	1.04	0.73	0.53	0.38
1995	0.27	0.21	3.18	4.17	4.13	4.93	3.39	3.06	2.82	2.21	1.59	1.05
1996	0.61	0.71	2.91	12.21	15.57	9.80	6.61	4.40	2.93	1.82	1.14	0.89
1997	1.04	1.30	1.66	10.14	11.11	4.61	4.43	2.80	1.74	1.13	0.78	0.53
1998	0.43	0.92	3.22	10.08	12.80	8.76	5.90	4.05	2.73	1.81	1.29	0.92
1999	0.67	0.95	1.61	2.91	5.24	10.85	10.24	4.68	3.63	2.93	2.18	1.41
2000	1.01	1.29	2.20	2.64	14.57	17.76	6.73	3.84	2.58	1.87	1.46	1.01
2001	0.63	0.64	3.27	4.34	2.84	2.62	2.38	2.03	1.53	1.12	0.83	0.53
2002	0.32	0.27	0.24	0.44	0.67	1.57	2.00	1.35	1.13	0.98	0.81	0.66
2003	0.57	0.79	2.21	3.96	5.08	5.28	4.47	3.60	2.75	2.07	1.56	1.16
2004	0.85	1.09	3.32	5.63	6.17	6.01	4.94	3.38	2.10	1.29	0.79	0.43
2005	0.23	0.33	2.54	7.17	7.02	3.91	3.09	2.25	1.50	0.98	0.64	0.36
2006	0.28	0.65	1.59	6.86	8.96	13.77	12.85	3.73	2.36	1.49	0.93	0.52
2007	0.25	1.24	20.99	23.84	7.10	5.51	4.28	3.14	2.06	1.27	0.79	0.48
2008	0.28	0.21	7.14	12.64	14.23	14.07	7.67	3.72	2.49	1.74	1.20	0.74
2009	0.45	0.43	0.57	8.96	10.23	3.46	3.73	3.26	2.25	1.41	0.89	0.53
2010	0.34	1.89	7.11	8.63	11.62	11.49	6.16	5.18	3.50	2.27	1.51	0.91
2011	0.48	0.40	8.95	18.57	12.39	5.01	4.78	3.95	2.68	1.68	1.06	0.64
2012	0.37	0.35	0.57	1.03	2.95	4.23	3.44	2.42	1.52	0.94	0.56	0.29
2013	0.10	0.17	4.91	8.36	6.42	5.60	4.78	3.34	2.22	1.46	0.95	0.58
2014	0.35	0.23	0.09	3.91	9.10	8.66	5.66	3.65	2.35	1.50	1.02	0.68
2015	0.40	0.39	0.61	2.14	6.94	7.89	5.52	4.78	3.27	2.07	1.31	0.80
2016	0.49	0.46	5.37	6.22	1.76	0.99	0.53	0.26	0.09	0.02	0.00	0.00

Appendix 21 Simulated surface runoff for Nyamakanga River in Mm^3

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1960	0.38	0.36	1.39	1.79	1.08	0.97	0.94	0.84	0.64	0.50	0.41	0.37
1961	0.33	0.38	0.50	0.78	1.32	2.33	2.05	0.94	0.67	0.47	0.36	0.27
1962	0.18	0.21	1.04	1.38	1.43	1.58	1.14	0.90	0.65	0.48	0.36	0.25
1963	0.17	0.27	0.43	1.10	1.41	0.95	0.68	0.47	0.35	0.28	0.23	0.18
1964	0.13	0.16	0.69	1.19	1.01	0.76	0.66	0.53	0.41	0.31	0.23	0.17
1965	0.13	0.20	0.28	0.38	1.04	1.23	0.80	0.68	0.52	0.42	0.33	0.23
1966	0.16	0.14	0.27	1.23	1.64	1.34	1.20	0.85	0.68	0.54	0.44	0.38
1967	0.29	0.23	0.25	0.28	0.32	0.37	0.42	0.47	0.44	0.36	0.27	0.20
1968	0.13	0.20	0.62	1.02	0.96	1.78	1.94	0.98	0.72	0.51	0.37	0.26
1969	0.20	0.21	4.16	4.85	1.34	0.96	0.97	0.91	0.62	0.46	0.37	0.26
1970	0.16	0.19	0.51	1.21	1.35	0.93	0.72	0.67	0.69	0.56	0.40	0.26
1971	0.16	0.39	1.00	2.60	2.44	1.11	1.03	0.79	0.56	0.38	0.27	0.19
1972	0.13	0.12	0.20	0.47	0.71	0.72	0.63	0.50	0.36	0.29	0.25	0.21
1973	0.18	0.46	1.40	2.32	3.36	4.12	2.63	1.03	0.79	0.56	0.42	0.35
1974	0.28	0.27	1.07	1.45	1.49	1.49	0.99	0.82	0.59	0.42	0.31	0.22
1975	0.18	0.19	0.43	0.80	1.33	4.11	3.79	0.93	0.67	0.47	0.33	0.22
1976	0.16	0.17	0.41	0.59	2.10	2.49	1.14	0.78	0.51	0.37	0.32	0.30
1977	0.25	0.28	0.70	1.85	2.28	2.60	2.50	1.35	0.87	0.62	0.44	0.30
1978	0.23	0.31	1.02	1.25	1.09	1.24	1.00	0.71	0.48	0.39	0.36	0.29
1979	0.26	0.27	0.36	0.53	1.45	1.65	0.92	0.74	0.54	0.40	0.32	0.27
1980	0.28	0.30	1.47	2.21	2.67	2.41	1.15	0.89	0.63	0.44	0.32	0.25
1981	0.22	0.28	0.59	0.87	1.01	0.99	0.77	0.62	0.47	0.36	0.28	0.22
1982	0.22	0.28	0.31	0.35	0.38	0.46	0.49	0.40	0.32	0.28	0.28	0.22
1983	0.16	0.15	0.33	0.45	0.43	1.04	1.18	0.67	0.49	0.37	0.31	0.26
1984	0.20	0.22	0.52	1.62	1.87	1.75	1.60	0.83	0.61	0.46	0.35	0.25
1985	0.18	0.20	0.70	2.95	3.00	1.15	1.02	0.87	0.62	0.42	0.29	0.19
1986	0.31	0.43	0.84	1.39	1.23	0.82	0.57	0.38	0.26	0.20	0.16	0.12
1987	0.11	0.11	0.55	0.90	1.16	2.21	2.09	1.11	0.78	0.54	0.39	0.28
1988	0.36	0.52	0.60	1.08	2.34	2.15	1.06	0.86	0.62	0.43	0.31	0.23
1989	0.22	0.28	1.19	2.78	2.64	1.39	0.92	0.71	0.51	0.37	0.28	0.21
1990	0.14	0.10	0.13	0.28	0.43	0.70	0.76	0.51	0.34	0.25	0.19	0.14
1991	0.10	0.06	0.11	0.27	0.35	0.30	0.26	0.21	0.17	0.14	0.12	0.09
1992	0.05	0.05	0.28	0.42	1.03	1.40	0.93	0.63	0.43	0.34	0.29	0.23
1993	0.14	0.25	0.54	1.18	1.29	0.78	0.56	0.39	0.28	0.22	0.17	0.12
1994	0.10	0.10	0.19	0.33	0.44	0.48	0.42	0.35	0.29	0.23	0.19	0.16
1995	0.12	0.09	0.71	0.93	0.93	1.10	0.77	0.70	0.65	0.53	0.40	0.28
1996	0.18	0.19	0.65	2.63	3.42	2.18	1.41	0.94	0.64	0.42	0.29	0.24
1997	0.27	0.32	0.39	2.19	2.40	1.02	0.98	0.63	0.41	0.30	0.23	0.18
1998	0.15	0.24	0.72	2.18	2.84	1.96	1.26	0.87	0.60	0.42	0.33	0.25
1999	0.19	0.24	0.38	0.66	1.16	2.43	2.28	1.00	0.79	0.65	0.51	0.34
2000	0.25	0.30	0.50	0.59	3.13	3.88	1.53	0.82	0.57	0.44	0.37	0.27
2001	0.18	0.17	0.73	0.96	0.65	0.60	0.55	0.48	0.38	0.31	0.25	0.18
2002	0.12	0.10	0.08	0.13	0.19	0.40	0.49	0.36	0.31	0.29	0.26	0.22
2003	0.19	0.22	0.51	0.89	1.13	1.17	0.99	0.80	0.62	0.49	0.39	0.31
2004	0.23	0.27	0.74	1.23	1.35	1.31	1.08	0.75	0.48	0.32	0.23	0.15
2005	0.10	0.11	0.58	1.57	1.54	0.87	0.69	0.52	0.37	0.27	0.21	0.14
2006	0.11	0.18	0.38	1.50	1.95	3.04	2.82	0.80	0.53	0.36	0.25	0.17
2007	0.10	0.30	4.49	5.18	1.61	1.17	0.92	0.69	0.47	0.32	0.23	0.16
2008	0.11	0.08	1.55	2.72	3.16	3.10	1.63	0.80	0.55	0.41	0.31	0.21
2009	0.14	0.13	0.15	1.94	2.22	0.79	0.84	0.74	0.53	0.36	0.25	0.18
2010	0.12	0.44	1.55	1.87	2.57	2.53	1.31	1.10	0.76	0.51	0.37	0.24
2011	0.14	0.12	1.93	3.97	2.66	1.10	1.04	0.87	0.60	0.40	0.28	0.19
2012	0.12	0.11	0.15	0.26	0.68	0.96	0.79	0.57	0.38	0.26	0.19	0.13
2013	0.07	0.08	1.08	1.82	1.41	1.23	1.05	0.74	0.51	0.36	0.27	0.18
2014	0.12	0.08	0.04	0.86	1.99	1.90	1.26	0.82	0.54	0.37	0.28	0.21
2015	0.14	0.12	0.16	0.50	1.53	1.73	1.22	1.05	0.73	0.49	0.33	0.22
2016	0.15	0.13	1.17	1.36	0.42	0.26	0.16	0.11	0.08	0.06	0.05	0.03

Appendix 22 Simulated surface runoff for Mupenga River in Mm^3

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1960	2.41	2.25	8.83	11.33	6.74	6.06	5.81	5.18	3.87	2.88	2.23	1.94
1961	1.79	2.16	2.95	4.75	8.18	14.15	12.53	5.93	4.14	2.79	2.00	1.37
1962	0.88	1.12	6.41	8.54	8.94	9.98	7.18	5.63	4.00	2.79	1.95	1.24
1963	0.80	1.47	2.50	6.77	8.73	5.81	4.12	2.76	1.93	1.36	0.99	0.72
1964	0.50	0.76	4.14	7.27	6.14	4.59	3.91	3.08	2.26	1.59	1.05	0.66
1965	0.49	0.98	1.56	2.12	6.31	7.51	4.78	4.01	3.01	2.27	1.65	1.08
1966	0.71	0.67	1.49	7.55	10.14	8.24	7.44	5.19	4.10	3.12	2.45	2.06
1967	1.56	1.27	1.38	1.54	1.78	2.01	2.30	2.57	2.36	1.83	1.26	0.80
1968	0.48	1.02	3.66	6.19	5.81	11.07	12.10	6.06	4.34	2.96	2.00	1.31
1969	0.99	1.10	26.36	30.76	8.34	5.95	5.97	5.61	3.73	2.60	1.95	1.28
1970	0.73	0.99	3.02	7.49	8.33	5.69	4.34	4.00	4.07	3.18	2.15	1.27
1971	0.75	2.23	6.18	15.97	15.12	7.07	6.56	4.96	3.38	2.17	1.38	0.82
1972	0.53	0.55	1.07	2.75	4.21	4.22	3.66	2.83	1.96	1.40	1.13	0.85
1973	0.74	2.63	8.62	13.93	20.69	26.22	16.74	6.56	4.93	3.40	2.41	1.88
1974	1.49	1.51	6.67	9.00	8.96	9.13	6.34	5.16	3.61	2.39	1.62	1.06
1975	0.82	0.99	2.53	4.83	8.21	25.47	23.57	5.89	4.12	2.77	1.79	1.06
1976	0.73	0.87	2.41	3.53	13.11	15.59	7.00	4.76	3.01	2.01	1.63	1.48
1977	1.26	1.54	4.21	11.58	13.82	15.97	15.86	8.56	5.48	3.82	2.56	1.61
1978	1.23	1.77	6.34	7.77	6.71	7.70	6.16	4.30	2.80	2.11	1.86	1.43
1979	1.31	1.47	2.08	3.15	8.96	10.22	5.62	4.50	3.17	2.18	1.64	1.33
1980	1.40	1.64	9.16	13.87	16.44	14.93	7.31	5.60	3.88	2.53	1.71	1.26
1981	1.07	1.55	3.57	5.28	6.18	6.03	4.68	3.70	2.72	1.90	1.38	1.00
1982	1.07	1.47	1.76	1.96	2.10	2.58	2.74	2.18	1.61	1.31	1.22	0.94
1983	0.66	0.64	1.88	2.59	2.42	6.23	7.16	3.92	2.75	1.97	1.51	1.20
1984	0.92	1.12	3.05	10.08	11.67	10.49	9.67	5.26	3.74	2.71	1.90	1.25
1985	0.87	1.06	4.22	18.57	18.91	7.13	6.33	5.36	3.71	2.36	1.51	0.88
1986	1.66	2.48	5.09	8.63	7.57	5.01	3.41	2.16	1.35	0.86	0.53	0.35
1987	0.33	0.41	3.25	5.39	7.05	13.13	12.56	7.05	4.87	3.27	2.23	1.45
1988	2.02	3.09	3.60	6.70	14.23	13.09	6.75	5.44	3.77	2.46	1.64	1.14
1989	1.08	1.53	7.35	17.24	16.48	8.90	5.79	4.40	3.08	2.09	1.42	0.94
1990	0.56	0.39	0.65	1.53	2.40	4.05	4.49	2.86	1.80	1.16	0.73	0.45
1991	0.27	0.15	0.48	1.40	1.84	1.55	1.25	0.96	0.65	0.41	0.25	0.09
1992	0.01	0.17	1.55	2.33	6.21	8.50	5.54	3.71	2.39	1.73	1.39	1.01
1993	0.56	1.34	3.20	7.25	7.93	4.70	3.29	2.18	1.47	0.97	0.61	0.35
1994	0.30	0.38	0.94	1.83	2.46	2.65	2.32	1.85	1.40	0.99	0.72	0.51
1995	0.36	0.29	4.30	5.64	5.59	6.67	4.59	4.13	3.81	2.99	2.15	1.42
1996	0.82	0.96	3.93	16.52	21.06	13.26	8.94	5.95	3.96	2.46	1.54	1.20
1997	1.41	1.76	2.24	13.72	15.03	6.23	5.99	3.79	2.35	1.53	1.06	0.72
1998	0.59	1.24	4.35	13.64	17.32	11.85	7.98	5.48	3.69	2.44	1.74	1.25
1999	0.91	1.29	2.18	3.93	7.09	14.68	13.86	6.33	4.91	3.96	2.95	1.90
2000	1.37	1.74	2.97	3.57	19.71	24.02	9.10	5.20	3.49	2.52	1.97	1.37
2001	0.86	0.87	4.43	5.87	3.84	3.54	3.23	2.75	2.07	1.52	1.12	0.72
2002	0.43	0.36	0.32	0.59	0.90	2.12	2.70	1.82	1.53	1.33	1.10	0.89
2003	0.77	1.06	3.00	5.36	6.88	7.15	6.05	4.87	3.72	2.80	2.11	1.57
2004	1.15	1.47	4.49	7.61	8.35	8.13	6.68	4.58	2.84	1.75	1.07	0.59
2005	0.31	0.44	3.43	9.70	9.50	5.30	4.18	3.05	2.04	1.33	0.87	0.49
2006	0.37	0.88	2.16	9.29	12.12	18.63	17.39	5.04	3.20	2.02	1.25	0.70
2007	0.34	1.68	28.40	32.25	9.61	7.45	5.78	4.25	2.79	1.72	1.07	0.64
2008	0.38	0.29	9.67	17.10	19.26	19.03	10.37	5.03	3.37	2.36	1.63	1.01
2009	0.60	0.58	0.78	12.13	13.85	4.68	5.05	4.41	3.05	1.91	1.21	0.72
2010	0.45	2.56	9.62	11.67	15.72	15.54	8.34	7.01	4.74	3.07	2.04	1.23
2011	0.65	0.54	12.11	25.13	16.76	6.78	6.46	5.34	3.63	2.27	1.44	0.86
2012	0.49	0.48	0.77	1.39	3.99	5.72	4.65	3.27	2.06	1.27	0.76	0.39
2013	0.14	0.23	6.65	11.31	8.69	7.58	6.47	4.51	3.00	1.98	1.29	0.78
2014	0.48	0.31	0.12	5.28	12.31	11.72	7.66	4.93	3.18	2.04	1.38	0.91
2015	0.54	0.52	0.82	2.90	9.39	10.68	7.46	6.47	4.42	2.80	1.77	1.08
2016	0.66	0.63	7.26	8.42	2.38	1.34	0.72	0.35	0.13	0.02	0.00	0.00

Appendix 23 Simulated surface runoff for Mtarazi River in Mm^3

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1960	1.22	1.14	4.45	5.72	3.40	3.06	2.93	2.61	1.95	1.45	1.12	0.98
1961	0.90	1.09	1.49	2.40	4.13	7.14	6.32	2.99	2.09	1.41	1.01	0.69
1962	0.45	0.56	3.23	4.31	4.51	5.03	3.62	2.84	2.02	1.41	0.99	0.63
1963	0.40	0.74	1.26	3.42	4.40	2.93	2.08	1.39	0.98	0.69	0.50	0.37
1964	0.25	0.39	2.09	3.67	3.10	2.32	1.97	1.55	1.14	0.80	0.53	0.33
1965	0.25	0.49	0.79	1.07	3.18	3.79	2.41	2.02	1.52	1.14	0.83	0.54
1966	0.36	0.34	0.75	3.81	5.12	4.16	3.75	2.62	2.07	1.57	1.23	1.04
1967	0.78	0.64	0.70	0.78	0.90	1.01	1.16	1.30	1.19	0.92	0.63	0.40
1968	0.24	0.51	1.84	3.12	2.93	5.58	6.11	3.06	2.19	1.49	1.01	0.66
1969	0.50	0.56	13.30	15.51	4.21	3.00	3.01	2.83	1.88	1.31	0.98	0.64
1970	0.37	0.50	1.52	3.78	4.20	2.87	2.19	2.02	2.05	1.61	1.09	0.64
1971	0.38	1.13	3.12	8.05	7.63	3.57	3.31	2.50	1.71	1.09	0.70	0.41
1972	0.27	0.28	0.54	1.39	2.12	2.13	1.85	1.43	0.99	0.71	0.57	0.43
1973	0.38	1.33	4.35	7.03	10.43	13.23	8.44	3.31	2.49	1.71	1.21	0.95
1974	0.75	0.76	3.36	4.54	4.52	4.60	3.20	2.60	1.82	1.21	0.82	0.53
1975	0.41	0.50	1.28	2.44	4.14	12.85	11.89	2.97	2.08	1.40	0.90	0.53
1976	0.37	0.44	1.22	1.78	6.61	7.86	3.53	2.40	1.52	1.02	0.82	0.75
1977	0.64	0.78	2.12	5.84	6.97	8.05	8.00	4.32	2.76	1.93	1.29	0.81
1978	0.62	0.89	3.20	3.92	3.39	3.88	3.11	2.17	1.41	1.06	0.94	0.72
1979	0.66	0.74	1.05	1.59	4.52	5.15	2.84	2.27	1.60	1.10	0.83	0.67
1980	0.70	0.83	4.62	6.99	8.29	7.53	3.69	2.83	1.96	1.27	0.86	0.64
1981	0.54	0.78	1.80	2.66	3.12	3.04	2.36	1.87	1.37	0.96	0.69	0.50
1982	0.54	0.74	0.89	0.99	1.06	1.30	1.38	1.10	0.81	0.66	0.62	0.47
1983	0.33	0.32	0.95	1.31	1.22	3.14	3.61	1.98	1.39	1.00	0.76	0.60
1984	0.46	0.56	1.54	5.08	5.88	5.29	4.88	2.65	1.89	1.37	0.96	0.63
1985	0.44	0.53	2.13	9.37	9.53	3.60	3.19	2.70	1.87	1.19	0.76	0.44
1986	0.84	1.25	2.57	4.35	3.82	2.53	1.72	1.09	0.68	0.44	0.27	0.18
1987	0.16	0.21	1.64	2.72	3.56	6.62	6.34	3.55	2.46	1.65	1.12	0.73
1988	1.02	1.56	1.81	3.38	7.17	6.60	3.40	2.74	1.90	1.24	0.83	0.57
1989	0.54	0.77	3.71	8.69	8.31	4.49	2.92	2.22	1.55	1.05	0.72	0.47
1990	0.28	0.20	0.33	0.77	1.21	2.04	2.26	1.44	0.91	0.58	0.37	0.23
1991	0.14	0.08	0.24	0.71	0.93	0.78	0.63	0.49	0.33	0.21	0.12	0.05
1992	0.01	0.09	0.78	1.18	3.13	4.29	2.79	1.87	1.20	0.87	0.70	0.51
1993	0.28	0.68	1.61	3.66	4.00	2.37	1.66	1.10	0.74	0.49	0.31	0.18
1994	0.15	0.19	0.48	0.92	1.24	1.33	1.17	0.93	0.71	0.50	0.36	0.26
1995	0.18	0.14	2.17	2.84	2.82	3.36	2.31	2.09	1.92	1.51	1.08	0.71
1996	0.41	0.49	1.98	8.33	10.62	6.69	4.51	3.00	2.00	1.24	0.78	0.61
1997	0.71	0.89	1.13	6.92	7.58	3.14	3.02	1.91	1.19	0.77	0.53	0.36
1998	0.30	0.63	2.19	6.88	8.74	5.98	4.03	2.76	1.86	1.23	0.88	0.63
1999	0.46	0.65	1.10	1.98	3.58	7.41	6.99	3.19	2.48	2.00	1.49	0.96
2000	0.69	0.88	1.50	1.80	9.94	12.12	4.59	2.62	1.76	1.27	0.99	0.69
2001	0.43	0.44	2.23	2.96	1.93	1.79	1.63	1.39	1.04	0.77	0.57	0.36
2002	0.22	0.18	0.16	0.30	0.46	1.07	1.36	0.92	0.77	0.67	0.56	0.45
2003	0.39	0.54	1.51	2.70	3.47	3.61	3.05	2.45	1.88	1.41	1.06	0.79
2004	0.58	0.74	2.27	3.84	4.21	4.10	3.37	2.31	1.43	0.88	0.54	0.30
2005	0.16	0.22	1.73	4.89	4.79	2.67	2.11	1.54	1.03	0.67	0.44	0.25
2006	0.19	0.45	1.09	4.68	6.11	9.39	8.77	2.54	1.61	1.02	0.63	0.35
2007	0.17	0.85	14.32	16.26	4.85	3.76	2.92	2.14	1.41	0.86	0.54	0.32
2008	0.19	0.15	4.87	8.62	9.71	9.60	5.23	2.54	1.70	1.19	0.82	0.51
2009	0.30	0.29	0.39	6.12	6.98	2.36	2.55	2.22	1.54	0.96	0.61	0.36
2010	0.23	1.29	4.85	5.89	7.93	7.84	4.21	3.53	2.39	1.55	1.03	0.62
2011	0.33	0.27	6.11	12.67	8.45	3.42	3.26	2.69	1.83	1.14	0.72	0.44
2012	0.25	0.24	0.39	0.70	2.01	2.88	2.34	1.65	1.04	0.64	0.38	0.20
2013	0.07	0.12	3.35	5.70	4.38	3.82	3.26	2.28	1.51	1.00	0.65	0.39
2014	0.24	0.16	0.06	2.66	6.21	5.91	3.86	2.49	1.60	1.03	0.70	0.46
2015	0.27	0.26	0.41	1.46	4.74	5.39	3.76	3.27	2.23	1.41	0.89	0.54
2016	0.33	0.32	3.66	4.25	1.20	0.68	0.37	0.18	0.06	0.01	0.00	0.00

Appendix 24 Simulated surface runoff for Booyo River in Mm^3

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1960	0.63	0.59	2.30	2.96	1.76	1.58	1.52	1.35	1.01	0.75	0.58	0.51
1961	0.47	0.56	0.77	1.24	2.13	3.69	3.27	1.55	1.08	0.73	0.52	0.36
1962	0.23	0.29	1.67	2.23	2.33	2.60	1.87	1.47	1.04	0.73	0.51	0.32
1963	0.21	0.38	0.65	1.77	2.28	1.51	1.07	0.72	0.50	0.35	0.26	0.19
1964	0.13	0.20	1.08	1.90	1.60	1.20	1.02	0.80	0.59	0.41	0.27	0.17
1965	0.13	0.25	0.41	0.55	1.64	1.96	1.25	1.05	0.79	0.59	0.43	0.28
1966	0.19	0.18	0.39	1.97	2.65	2.15	1.94	1.35	1.07	0.81	0.64	0.54
1967	0.41	0.33	0.36	0.40	0.46	0.52	0.60	0.67	0.62	0.48	0.33	0.21
1968	0.13	0.26	0.95	1.62	1.52	2.89	3.16	1.58	1.13	0.77	0.52	0.34
1969	0.26	0.29	6.88	8.02	2.18	1.55	1.56	1.46	0.97	0.68	0.51	0.33
1970	0.19	0.26	0.79	1.95	2.17	1.48	1.13	1.04	1.06	0.83	0.56	0.33
1971	0.20	0.58	1.61	4.17	3.94	1.84	1.71	1.29	0.88	0.57	0.36	0.21
1972	0.14	0.14	0.28	0.72	1.10	1.10	0.96	0.74	0.51	0.37	0.29	0.22
1973	0.19	0.69	2.25	3.64	5.40	6.84	4.37	1.71	1.29	0.89	0.63	0.49
1974	0.39	0.39	1.74	2.35	2.34	2.38	1.66	1.35	0.94	0.62	0.42	0.28
1975	0.21	0.26	0.66	1.26	2.14	6.64	6.15	1.54	1.07	0.72	0.47	0.28
1976	0.19	0.23	0.63	0.92	3.42	4.07	1.83	1.24	0.78	0.53	0.43	0.39
1977	0.33	0.40	1.10	3.02	3.60	4.16	4.14	2.23	1.43	1.00	0.67	0.42
1978	0.32	0.46	1.66	2.03	1.75	2.01	1.61	1.12	0.73	0.55	0.49	0.37
1979	0.34	0.38	0.54	0.82	2.34	2.67	1.47	1.17	0.83	0.57	0.43	0.35
1980	0.36	0.43	2.39	3.62	4.29	3.89	1.91	1.46	1.01	0.66	0.45	0.33
1981	0.28	0.40	0.93	1.38	1.61	1.57	1.22	0.97	0.71	0.49	0.36	0.26
1982	0.28	0.38	0.46	0.51	0.55	0.67	0.71	0.57	0.42	0.34	0.32	0.25
1983	0.17	0.17	0.49	0.68	0.63	1.63	1.87	1.02	0.72	0.51	0.39	0.31
1984	0.24	0.29	0.80	2.63	3.04	2.74	2.52	1.37	0.98	0.71	0.49	0.33
1985	0.23	0.28	1.10	4.84	4.93	1.86	1.65	1.40	0.97	0.62	0.39	0.23
1986	0.43	0.65	1.33	2.25	1.97	1.31	0.89	0.56	0.35	0.23	0.14	0.09
1987	0.09	0.11	0.85	1.41	1.84	3.42	3.28	1.84	1.27	0.85	0.58	0.38
1988	0.53	0.81	0.94	1.75	3.71	3.42	1.76	1.42	0.98	0.64	0.43	0.30
1989	0.28	0.40	1.92	4.50	4.30	2.32	1.51	1.15	0.80	0.54	0.37	0.24
1990	0.15	0.10	0.17	0.40	0.63	1.06	1.17	0.75	0.47	0.30	0.19	0.12
1991	0.07	0.04	0.13	0.37	0.48	0.40	0.33	0.25	0.17	0.11	0.06	0.02
1992	0.00	0.05	0.40	0.61	1.62	2.22	1.44	0.97	0.62	0.45	0.36	0.26
1993	0.15	0.35	0.84	1.89	2.07	1.23	0.86	0.57	0.38	0.25	0.16	0.09
1994	0.08	0.10	0.25	0.48	0.64	0.69	0.61	0.48	0.37	0.26	0.19	0.13
1995	0.09	0.07	1.12	1.47	1.46	1.74	1.20	1.08	0.99	0.78	0.56	0.37
1996	0.21	0.25	1.03	4.31	5.49	3.46	2.33	1.55	1.03	0.64	0.40	0.31
1997	0.37	0.46	0.59	3.58	3.92	1.63	1.56	0.99	0.61	0.40	0.28	0.19
1998	0.15	0.32	1.14	3.56	4.52	3.09	2.08	1.43	0.96	0.64	0.46	0.33
1999	0.24	0.34	0.57	1.03	1.85	3.83	3.61	1.65	1.28	1.03	0.77	0.50
2000	0.36	0.46	0.77	0.93	5.14	6.27	2.37	1.36	0.91	0.66	0.51	0.36
2001	0.22	0.23	1.15	1.53	1.00	0.92	0.84	0.72	0.54	0.40	0.29	0.19
2002	0.11	0.09	0.08	0.15	0.24	0.55	0.70	0.48	0.40	0.35	0.29	0.23
2003	0.20	0.28	0.78	1.40	1.79	1.86	1.58	1.27	0.97	0.73	0.55	0.41
2004	0.30	0.38	1.17	1.99	2.18	2.12	1.74	1.19	0.74	0.46	0.28	0.15
2005	0.08	0.12	0.90	2.53	2.48	1.38	1.09	0.79	0.53	0.35	0.23	0.13
2006	0.10	0.23	0.56	2.42	3.16	4.86	4.54	1.32	0.83	0.53	0.33	0.18
2007	0.09	0.44	7.41	8.41	2.51	1.94	1.51	1.11	0.73	0.45	0.28	0.17
2008	0.10	0.08	2.52	4.46	5.02	4.96	2.71	1.31	0.88	0.62	0.42	0.26
2009	0.16	0.15	0.20	3.16	3.61	1.22	1.32	1.15	0.80	0.50	0.31	0.19
2010	0.12	0.67	2.51	3.04	4.10	4.05	2.18	1.83	1.24	0.80	0.53	0.32
2011	0.17	0.14	3.16	6.56	4.37	1.77	1.69	1.39	0.95	0.59	0.37	0.23
2012	0.13	0.12	0.20	0.36	1.04	1.49	1.21	0.85	0.54	0.33	0.20	0.10
2013	0.04	0.06	1.73	2.95	2.27	1.98	1.69	1.18	0.78	0.52	0.34	0.20
2014	0.13	0.08	0.03	1.38	3.21	3.06	2.00	1.29	0.83	0.53	0.36	0.24
2015	0.14	0.14	0.21	0.76	2.45	2.79	1.95	1.69	1.15	0.73	0.46	0.28
2016	0.17	0.16	1.90	2.20	0.62	0.35	0.19	0.09	0.03	0.01	0.00	0.00

Appendix 25 Simulated surface runoff for Ngarura River in Mm^3

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1960	1.87	1.74	6.83	8.77	5.22	4.69	4.50	4.01	2.99	2.23	1.72	1.50
1961	1.39	1.67	2.28	3.68	6.33	10.95	9.70	4.59	3.21	2.16	1.55	1.06
1962	0.68	0.86	4.96	6.61	6.92	7.72	5.56	4.36	3.10	2.16	1.51	0.96
1963	0.62	1.14	1.93	5.24	6.75	4.49	3.19	2.13	1.50	1.05	0.77	0.56
1964	0.38	0.59	3.20	5.63	4.75	3.56	3.03	2.38	1.75	1.23	0.81	0.51
1965	0.38	0.76	1.21	1.64	4.88	5.81	3.70	3.10	2.33	1.75	1.27	0.84
1966	0.55	0.52	1.16	5.84	7.85	6.38	5.76	4.02	3.17	2.42	1.89	1.60
1967	1.20	0.98	1.07	1.19	1.37	1.56	1.78	1.99	1.83	1.41	0.97	0.62
1968	0.37	0.79	2.83	4.79	4.50	8.57	9.37	4.69	3.36	2.29	1.55	1.01
1969	0.77	0.85	20.40	23.80	6.45	4.60	4.62	4.34	2.89	2.01	1.51	0.99
1970	0.57	0.76	2.33	5.80	6.45	4.40	3.36	3.10	3.15	2.46	1.67	0.98
1971	0.58	1.73	4.78	12.36	11.70	5.47	5.07	3.83	2.62	1.68	1.07	0.64
1972	0.41	0.43	0.83	2.13	3.26	3.27	2.84	2.19	1.51	1.09	0.87	0.66
1973	0.58	2.03	6.67	10.78	16.01	20.30	12.96	5.08	3.82	2.63	1.86	1.46
1974	1.15	1.17	5.16	6.97	6.94	7.07	4.91	3.99	2.79	1.85	1.26	0.82
1975	0.64	0.76	1.96	3.74	6.35	19.71	18.24	4.56	3.19	2.14	1.39	0.82
1976	0.56	0.67	1.87	2.73	10.14	12.06	5.42	3.68	2.33	1.56	1.26	1.15
1977	0.98	1.19	3.26	8.96	10.69	12.36	12.28	6.63	4.24	2.96	1.98	1.24
1978	0.95	1.37	4.91	6.01	5.20	5.96	4.77	3.33	2.16	1.63	1.44	1.11
1979	1.02	1.14	1.61	2.44	6.94	7.91	4.35	3.48	2.45	1.69	1.27	1.03
1980	1.08	1.27	7.09	10.73	12.73	11.55	5.66	4.34	3.01	1.96	1.32	0.98
1981	0.83	1.20	2.76	4.08	4.79	4.67	3.63	2.87	2.10	1.47	1.07	0.77
1982	0.83	1.14	1.36	1.51	1.63	2.00	2.12	1.68	1.25	1.02	0.95	0.73
1983	0.51	0.50	1.45	2.01	1.88	4.82	5.54	3.03	2.13	1.53	1.17	0.93
1984	0.71	0.87	2.36	7.80	9.03	8.11	7.49	4.07	2.89	2.10	1.47	0.97
1985	0.68	0.82	3.27	14.37	14.63	5.52	4.90	4.15	2.87	1.83	1.17	0.68
1986	1.29	1.92	3.94	6.68	5.86	3.88	2.64	1.67	1.05	0.67	0.41	0.27
1987	0.25	0.32	2.51	4.17	5.46	10.16	9.72	5.46	3.77	2.53	1.72	1.12
1988	1.56	2.39	2.78	5.18	11.01	10.13	5.22	4.21	2.92	1.90	1.27	0.88
1989	0.83	1.19	5.69	13.34	12.75	6.89	4.48	3.41	2.38	1.62	1.10	0.72
1990	0.44	0.31	0.51	1.18	1.86	3.14	3.47	2.22	1.40	0.90	0.56	0.35
1991	0.21	0.12	0.37	1.08	1.43	1.20	0.96	0.74	0.50	0.32	0.19	0.07
1992	0.01	0.14	1.20	1.80	4.80	6.58	4.29	2.87	1.85	1.34	1.08	0.78
1993	0.43	1.04	2.48	5.61	6.14	3.63	2.54	1.69	1.14	0.75	0.47	0.27
1994	0.23	0.29	0.73	1.42	1.90	2.05	1.79	1.43	1.09	0.76	0.56	0.40
1995	0.28	0.22	3.33	4.36	4.33	5.16	3.55	3.20	2.95	2.31	1.66	1.10
1996	0.64	0.75	3.04	12.79	16.30	10.26	6.92	4.61	3.07	1.90	1.19	0.93
1997	1.09	1.36	1.74	10.62	11.64	4.82	4.63	2.93	1.82	1.19	0.82	0.55
1998	0.45	0.96	3.37	10.56	13.41	9.17	6.18	4.24	2.86	1.89	1.35	0.97
1999	0.70	1.00	1.68	3.05	5.49	11.36	10.72	4.90	3.80	3.06	2.28	1.47
2000	1.06	1.35	2.30	2.76	15.26	18.59	7.04	4.02	2.70	1.95	1.53	1.06
2001	0.66	0.67	3.43	4.54	2.97	2.74	2.50	2.13	1.60	1.18	0.87	0.56
2002	0.33	0.28	0.25	0.46	0.70	1.64	2.09	1.41	1.18	1.03	0.85	0.69
2003	0.60	0.82	2.32	4.15	5.32	5.53	4.68	3.77	2.88	2.16	1.63	1.21
2004	0.89	1.14	3.48	5.89	6.46	6.29	5.17	3.54	2.20	1.35	0.83	0.45
2005	0.24	0.34	2.66	7.50	7.35	4.10	3.23	2.36	1.58	1.03	0.67	0.38
2006	0.29	0.68	1.67	7.19	9.38	14.42	13.46	3.90	2.48	1.56	0.97	0.54
2007	0.26	1.30	21.98	24.96	7.43	5.77	4.48	3.29	2.16	1.33	0.83	0.50
2008	0.30	0.22	7.48	13.23	14.90	14.73	8.03	3.89	2.61	1.82	1.26	0.78
2009	0.47	0.45	0.60	9.39	10.72	3.62	3.91	3.41	2.36	1.48	0.93	0.56
2010	0.35	1.98	7.45	9.03	12.16	12.03	6.45	5.42	3.67	2.38	1.58	0.95
2011	0.50	0.42	9.37	19.45	12.97	5.25	5.00	4.13	2.81	1.76	1.11	0.67
2012	0.38	0.37	0.59	1.07	3.09	4.43	3.60	2.53	1.59	0.98	0.59	0.30
2013	0.11	0.18	5.15	8.75	6.72	5.87	5.00	3.49	2.32	1.53	1.00	0.61
2014	0.37	0.24	0.09	4.09	9.53	9.07	5.92	3.82	2.46	1.58	1.07	0.71
2015	0.42	0.40	0.63	2.25	7.27	8.27	5.78	5.01	3.42	2.17	1.37	0.83
2016	0.51	0.48	5.62	6.52	1.84	1.04	0.56	0.27	0.10	0.02	0.00	0.00

Appendix 26 Simulated surface runoff for Ruda River in Mm^3

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1960	1.57	1.47	5.76	7.39	4.40	3.95	3.79	3.38	2.52	1.88	1.45	1.27
1961	1.17	1.41	1.92	3.10	5.34	9.23	8.17	3.87	2.70	1.82	1.30	0.89
1962	0.58	0.73	4.18	5.57	5.83	6.51	4.68	3.67	2.61	1.82	1.27	0.81
1963	0.52	0.96	1.63	4.42	5.69	3.79	2.69	1.80	1.26	0.89	0.65	0.47
1964	0.32	0.50	2.70	4.74	4.00	3.00	2.55	2.01	1.47	1.04	0.68	0.43
1965	0.32	0.64	1.02	1.38	4.11	4.90	3.12	2.61	1.96	1.48	1.07	0.70
1966	0.47	0.44	0.97	4.92	6.62	5.37	4.85	3.38	2.68	2.04	1.60	1.35
1967	1.01	0.83	0.90	1.01	1.16	1.31	1.50	1.68	1.54	1.19	0.82	0.52
1968	0.31	0.66	2.39	4.04	3.79	7.22	7.89	3.95	2.83	1.93	1.30	0.85
1969	0.65	0.72	17.19	20.06	5.44	3.88	3.89	3.66	2.44	1.70	1.27	0.83
1970	0.48	0.64	1.97	4.88	5.43	3.71	2.83	2.61	2.65	2.08	1.40	0.83
1971	0.49	1.46	4.03	10.41	9.86	4.61	4.28	3.23	2.21	1.41	0.90	0.54
1972	0.34	0.36	0.70	1.79	2.74	2.75	2.39	1.85	1.28	0.92	0.73	0.56
1973	0.49	1.71	5.62	9.09	13.49	17.10	10.92	4.28	3.22	2.22	1.57	1.23
1974	0.97	0.99	4.35	5.87	5.85	5.95	4.14	3.36	2.36	1.56	1.06	0.69
1975	0.54	0.64	1.65	3.15	5.35	16.61	15.37	3.84	2.68	1.81	1.17	0.69
1976	0.48	0.56	1.57	2.30	8.55	10.17	4.57	3.10	1.96	1.31	1.07	0.97
1977	0.82	1.00	2.75	7.55	9.01	10.41	10.34	5.58	3.58	2.49	1.67	1.05
1978	0.80	1.15	4.14	5.07	4.38	5.02	4.02	2.80	1.82	1.38	1.21	0.93
1979	0.86	0.96	1.36	2.05	5.85	6.66	3.67	2.93	2.07	1.42	1.07	0.87
1980	0.91	1.07	5.98	9.04	10.72	9.74	4.77	3.65	2.53	1.65	1.11	0.82
1981	0.70	1.01	2.33	3.44	4.03	3.93	3.06	2.42	1.77	1.24	0.90	0.65
1982	0.70	0.96	1.15	1.28	1.37	1.68	1.79	1.42	1.05	0.86	0.80	0.61
1983	0.43	0.42	1.23	1.69	1.58	4.06	4.67	2.56	1.79	1.29	0.99	0.78
1984	0.60	0.73	1.99	6.57	7.61	6.84	6.31	3.43	2.44	1.77	1.24	0.82
1985	0.57	0.69	2.75	12.11	12.33	4.65	4.13	3.50	2.42	1.54	0.99	0.57
1986	1.09	1.62	3.32	5.63	4.94	3.27	2.23	1.41	0.88	0.56	0.35	0.23
1987	0.21	0.27	2.12	3.51	4.60	8.56	8.19	4.60	3.18	2.13	1.45	0.95
1988	1.32	2.02	2.35	4.37	9.28	8.54	4.40	3.55	2.46	1.60	1.07	0.74
1989	0.70	1.00	4.80	11.24	10.75	5.80	3.78	2.87	2.01	1.36	0.93	0.61
1990	0.37	0.26	0.43	1.00	1.57	2.64	2.93	1.87	1.18	0.75	0.47	0.29
1991	0.18	0.10	0.31	0.91	1.20	1.01	0.81	0.63	0.42	0.27	0.16	0.06
1992	0.01	0.11	1.01	1.52	4.05	5.55	3.61	2.42	1.56	1.13	0.91	0.66
1993	0.37	0.87	2.09	4.73	5.17	3.06	2.14	1.42	0.96	0.63	0.40	0.23
1994	0.19	0.25	0.61	1.19	1.60	1.73	1.51	1.21	0.92	0.64	0.47	0.33
1995	0.23	0.19	2.80	3.68	3.64	4.35	2.99	2.70	2.49	1.95	1.40	0.92
1996	0.54	0.63	2.57	10.77	13.74	8.65	5.83	3.88	2.58	1.60	1.00	0.79
1997	0.92	1.15	1.46	8.95	9.80	4.06	3.90	2.47	1.53	1.00	0.69	0.47
1998	0.38	0.81	2.84	8.89	11.30	7.73	5.21	3.57	2.41	1.59	1.14	0.81
1999	0.59	0.84	1.42	2.57	4.62	9.58	9.04	4.13	3.20	2.58	1.92	1.24
2000	0.89	1.14	1.94	2.33	12.86	15.67	5.94	3.39	2.28	1.65	1.29	0.89
2001	0.56	0.57	2.89	3.83	2.50	2.31	2.10	1.79	1.35	0.99	0.73	0.47
2002	0.28	0.24	0.21	0.39	0.59	1.39	1.76	1.19	1.00	0.87	0.72	0.58
2003	0.50	0.69	1.95	3.49	4.48	4.66	3.95	3.17	2.43	1.82	1.38	1.02
2004	0.75	0.96	2.93	4.96	5.44	5.30	4.36	2.98	1.86	1.14	0.70	0.38
2005	0.21	0.29	2.24	6.32	6.20	3.45	2.72	1.99	1.33	0.87	0.57	0.32
2006	0.24	0.58	1.41	6.06	7.91	12.15	11.34	3.29	2.09	1.32	0.82	0.46
2007	0.22	1.09	18.52	21.03	6.27	4.86	3.77	2.77	1.82	1.12	0.70	0.42
2008	0.25	0.19	6.30	11.15	12.56	12.41	6.77	3.28	2.20	1.54	1.06	0.66
2009	0.39	0.38	0.51	7.91	9.03	3.05	3.29	2.88	1.99	1.25	0.79	0.47
2010	0.30	1.67	6.27	7.61	10.25	10.14	5.44	4.57	3.09	2.00	1.33	0.80
2011	0.42	0.36	7.90	16.39	10.93	4.42	4.22	3.48	2.37	1.48	0.94	0.56
2012	0.32	0.31	0.50	0.90	2.60	3.73	3.03	2.14	1.34	0.83	0.50	0.25
2013	0.09	0.15	4.34	7.37	5.66	4.94	4.22	2.94	1.95	1.29	0.84	0.51
2014	0.31	0.20	0.08	3.45	8.03	7.64	4.99	3.22	2.07	1.33	0.90	0.60
2015	0.35	0.34	0.53	1.89	6.12	6.97	4.87	4.22	2.88	1.83	1.16	0.70
2016	0.43	0.41	4.74	5.49	1.55	0.87	0.47	0.23	0.08	0.01	0.00	0.00