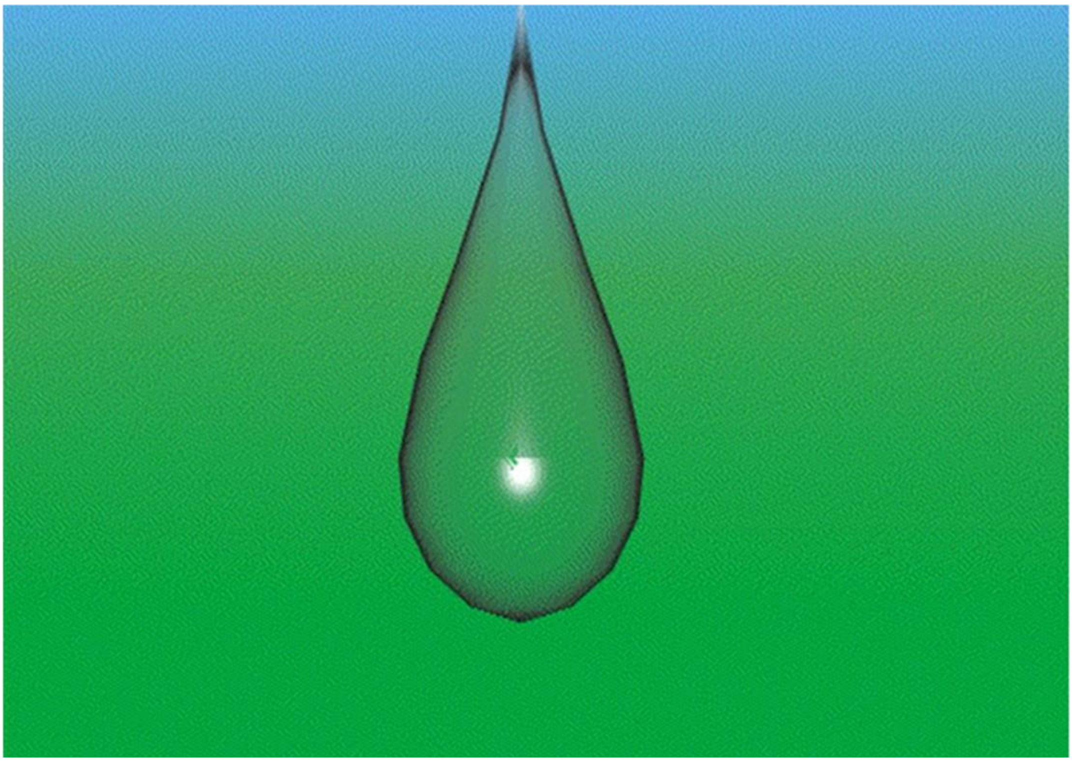
Ministry of Water

Commissioner of Water

State of Water Resources Report

Fiscal Year 2016/17

Final



Submitted to:
Commission of Water
15 UN Road Sentinel Park Building L.
Maseru Lesotho

Report compiled in September 2018

Executive summary

Despite the challenges encountered in acquisition of observed data, this report illustrates that all catchments had enough water to meet the needs of human and animal populations even though the Makhaleng catchment lost significant volume of water, i.e. 97% of its rainfall, through evapotranspiration. The Senqu catchment lost the lowest volume of water (65% of its rainfall) to evapotranspiration thereby leaving ample amount of water for the immediate downstream users. The Mohokare catchment lost 84% of its rainfall to evapotranspiration.

The amount of water available for further exploitation in the Senqu catchment in 2016/17 was 3.5 BCM while the exploited amount of water was 0.5 BCM. In the same year, the Makhaleng catchment had 0.16 BCM of water still available for further exploitation while the abstracted water was 0.005 BCM. On the other hand, the Mohokare catchment had 0.8 BCM of water available for further exploitation while the consumed water was approximately 0.02 BCM annually.

General recommendations are included in this report whose implementation is expected to improve the functioning of the structure of the Water Sector and Sanitation given the present institutional arrangement.

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List of abbreviations

BoS -	Bureaux of Statistics
CoW -	Commissioner of Water
DMS -	Drought Management Strategy
DoE -	Department of Environment
DRWS -	Department of Rural Water Supply
DWA -	Department of Water Affairs
DWIES-	Domestic Water and Industrial Effluent Standards (1998)
GNI -	Gross National Income
IWMP -	Industrial Wastewater Management Policy (2003)
IFR -	Instream Flow Requirements
IWRMS-	Integrated Water Resources Management Strategy
LEWA -	Lesotho Water and Electricity Authority
LHDA -	Lesotho Highlands Development Authority
LHWC -	Lesotho Highlands Water Commission
LHWP -	Lesotho Highlands Water Project
LLBWSS -	Lesotho Lowlands Bulk Water Supply Scheme
LLWSU -	Lesotho Lowlands Water Supply Unit
LWA -	Lesotho Water Act (2008)
LWSS -	Long-term Water and Sanitation Strategy (2016)
LWSSWQG -	Long-term Water and Sanitation Strategy and Water Quality Guidelines
LWSP -	Lesotho Water and Sanitation Policy
MA -	Metolong Authority
MDGs -	Millennium Development Goals
MW -	Ministry of Water
NSDP -	National Strategic Development Plan
ORASECOM -	Orange-Senqu River Basin Commission (ORASECOM) Agreement (2000)
SADC -	Southern African Development Community
SDGs -	Sustainable Development Goals
UNDP -	United Nations Development Program
WASCO -	Water and Sewerage Company
WDMS -	Water Demand Management Strategy
WRMPS -	Water Resources Management Policy and Strategy (1999)

WSS - Water and Sanitation Sector

1. Introduction

This chapter introduces the State of Water Resources Report including its objectives, contents, limitations and assumptions and intended audience.

Although ownership of water is vested in the Basotho Nation, the Government of Lesotho has the duty to ensure sustainable development of the resource in order to maximize socio-economic benefits for the country. It is within this context that the Government of Lesotho has been undertaking a reform of the legal framework and institutional arrangements of the Water and Sanitation Sector. A major step in the process was the adoption of the Lesotho Water and Sanitation Policy of 2007 and Water Act of 2008.

The Water Act provides for the management, protection, conservation, development and sustainable utilisation of water resources. One specific requirement of the Act is that a State of Water Resources Report is produced on an annual basis. This is the fourth report, and as such, it reports on the fiscal year of April 2016 to March 2017. Where appropriate and possible, this report also recapitulates on the last three years: April 2013 to March 2014; April 2014 to March 2015; and April 2015 to March 2016. The objective of the annual State of the Water Resources Report is to position the importance of water in the national development context, inform policy development and direction, assist in articulating work plans to integrate activities across the sector and to reflect progress relating to the strategies put in place in pursuit of the national development goals.

The report has a varied target readership including planners and decision-makers in Government and non-governmental organisations, international cooperating partners and even members of the public who wish to be informed about water resources of Lesotho.

Compilation of the report is the responsibility of the Office of the Commissioner of Water but it depends on the contributions from all the key stakeholders both within the Ministry of Water and outside it.

Following a brief setting of context in the following chapter, Chapter 3 provides a brief overview of the Water and Sanitation Sector in Lesotho while Chapter 4 presents water resources. Chapter 5 provides an overview of water demand for various uses during the period under review. Chapter 6 then outlines annual water balance by catchment. Chapter 7 draws conclusions from the report and makes recommendations to the Water Sector.

2. Context

This chapter provides a brief overview of the geographical and socio-economic context of the Kingdom of Lesotho, necessary for a better appreciation of the State of Water Resources Report.

Lesotho is a land-locked mountainous country completely surrounded by South Africa, between the latitudes of 28.5° and 30.7° South and the longitudes of 27° and 29.5° East. It has a total area of 30 350km^2**.** As can be seen in Figure 2-1, altitude varies from 1500m to 3482m. Lesotho is the only country in the world that is entirely situated above 1000m in altitude. The climate is temperate with cool to cold winters and hot, wet summers into mid-autumn. Mean annual rainfall averaged over the entire country is just below 800mm and varies from less than 300mm in the western lowlands to 1600mm in the north-eastern highlands, during which rivers are in high-flows (Plate 2-1). Up to 85% of the rainfall can fall between October and April. The mountainous regions receive snow during in winter.

Plate 2-1: Mokhotlong River tributary of Senqu River (viewed from 29°18'41.49"S, 29°6'49.16"E)

Lesotho is located entirely within the Senqu-Orange River basin. The major catchments in Lesotho are:

- The Senqu drains an area of approximately two thirds of Lesotho (i.e. 24,485 km^2). This catchment has the total area of 21 689 km^2 in both Lesotho and South Africa excluding the Makhaleng Catchment area, but with Makhaleng catchment included, Senqu has an area of 24 485 km^2 as it leaves the border of Lesotho. The Senqu River originates in the extreme

north of the country and leaves Lesotho at its confluence with the Makhaleng River at the Morifi village in Mohale’s Hoek District near Moyeni in Quthing District.

- The Makhaleng, with a catchment area of 2 988 km^2 (upstream of its confluence with the Senqu River), originates in the vicinity of Mount Machache and leaves the country near Mohale's Hoek.
- The Mohokare marks the border of Lesotho with South Africa and has a catchment area of 13 370 km^2 (both in Lesotho and South Africa), as it leaves the border of Lesotho. It springs from Mount Aux Sources, and leaves Lesotho near the Bolikela village in Mafeteng.

Wetlands are to be found in all of Lesotho’s agro-ecological zones with a total area of approximately 96,381 hectares. They are comprised of palustrine, lacustrine (Plate **2-2**, Plate **2-3** and Plate **2-4**) and riverine wetlands with the high altitude lacustrine ones the most dominant and critical in terms of hydrological functioning of the Senqu River. The Letšeng-la-Letsie wetland (Plate **2-5**) in the Quthing district was designated as a RAMSAR site by the Government as part of its accession to the RAMSAR Convention.

Plate 2-2: *‘Muela Dam*

Surface water resources of Lesotho are estimated at over 3026MCM/yr. Renewable groundwater resources are estimated at 341MCM/yr (TAMS, 1996).

Major dam/weir structures have been constructed in the framework of Phase I of LHWP:

- Katse Dam in the central Maloti Mountains was completed in May 1997. It is a concrete double arch dam, 185 m high, with 710m crest length and a storage capacity of 1,950Mkm^3. It impounds the Malibamatšo River catchment (1866 km^2);
- Mohale Dam is a concrete faced rockfill dam, 145m high, with 540m crest length, and was completed in 2002 (LHDA, 2003). It impounds the Senqunyane River catchment (938 km^2) and has a storage capacity of 860Mm^3;
- Matsoku Weir, a mass concrete gravity structure, 19m high, with 180 m long, diverts floodwater in excess of the compensation flow through the Matsoku tunnel. This tunnel discharges up to 55 m^{3}s^{-1} into Katse Reservoir
- 'Muela Dam, a concrete arch dam, 55 m high, 6 Mm^3 capacity dam acts as the tail pond of the 'Muela hydropower station, and was completed in 1998 (LHDA, 2009).
- Plans for construction of Polihali Dam under Phase II of LHWP are advanced.

Construction of another dam under the Lesotho Lowlands Bulk Water Supply Scheme, the Metolong Dam, was completed in 2015 (Ministry of Water, 2017). It is a 73m high, 53MCM roller-compacted concrete dam, constructed for bulk water supply to areas that include Berea, Maseru, Roma, Mazenod and Morija.

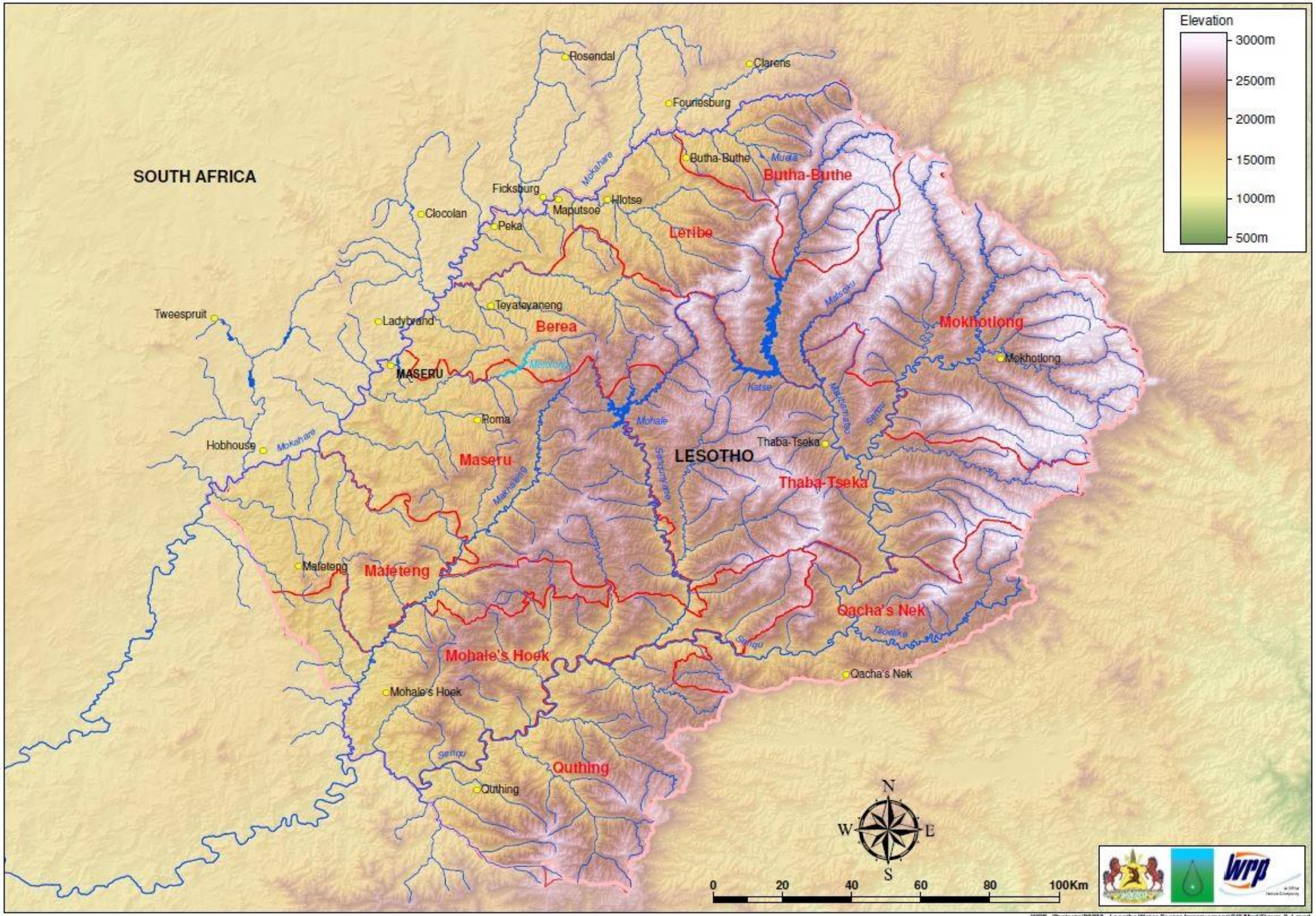
According to the 2006 population census, the population of Lesotho was 1,876,633 in 2006. Also according to the 2016 population census, the population of Lesotho was 2,007,201. These two population censuses give the annual growth rate 0.06%. Interpolation from this rate implies a population of 1,966,957 in 2013, 1,979,416 in 2014, and 1,991,954 in 2015. Population density in 2016 was 66 inhabitants/km^2 as opposed to 61 inhabitants/km^2 in 2006, and 58.4% of the population is rural in 2016 as opposed to 82% in 2006. The proportion, even the absolute number of rural population is in decline, largely as a result of rural to urban migration.

The lowland area is the most populated and intensively cultivated zone followed by the foothills, the mountains and the Senqu river valley. Lesotho was ranked 160 out of 188 countries in the 2015 UNDP Human Development Report. Per capita Gross National Income (GNI) was estimated at USD3.319. Over 59.7% of the population was ranked below national poverty line.

Plate 2-3: *Katse Dam*

Plate 2-4: *Metolong Dam*

Plate 2-5: *Letšeng-La-Letsie*



WRP: /Projects/P0276 - Lesotho Water Sector Improvement/GIS/Mxd/Figure 2-1.mxd

Figure 2-1: Kingdom of Lesotho – Key features

3. The Water and Sanitation Sector

This chapter provides an overview of the history of the Water and Sanitation Sector, policy and legal framework, institutional arrangements, as well as current activities.

3.1 Introduction

Water resources surveys in Lesotho started in 1960s in the Ministry of Works performed by the then Hydrological Surveys Division of the Ministry of Public Works, which later became a fully-fledged Department of Hydrological and Meteorological Services in 1974 (LMS, 2013), later in 1988 attaining the name of Department of Water Affairs upon introduction of other divisions that are concerned with Water Resources, Water Rights and Pollution Control, the Groundwater Division that started as the groundwater project, and the Lesotho Meteorological Services that budded off as an independent sister Department in 2000. The Department of Water Affairs existed under different ministries of: Water, Energy and Mining; Natural Resources; Meteorology, Energy and Water; and Water (Balek, 1977; Tanor, et al., 2014). The Ministry responsible for water now has the office of the Commissioner of Water that coordinates activities of all the sectoral departments and parastatals that include the Department of Water Affairs (DWA), Department of Rural Water Supply (DWRS), Water and Sewerage Company (WASCO), Lesotho Highlands Development Authority (LHDA), Metolong Authority (MA), Lesotho Water and Electricity Authority (LEWA), and the Lesotho Lowlands Water Supply Unit (LLWSU).

The Commissioner of Water (CoW) was established under section 8 of the Act (Water Act 2008) and according to subsection 2 paragraph (f) of this section, CoW should produce an annual water resources report. Thus far, two reports have been produced, the first report covered a period of April 2010 to March 2011 and the second report covered April 2011 to March 2013. They were based on fiscal years rather than hydrologic years. The third (this) report covers a period of three years (April 2013 to March 2016).

The main aim of the report is to position the importance of water in the national development context, inform policy development and direction, assist in articulating work plans to integrate activities across the water sector, and to reflect progress relating to the strategies put in place in pursuit of the national development goals. This report is meant to provide an assessment of the state of water resources in Lesotho for both surface water and groundwater. The report also proposes review of strategies for data collection and management for supporting the subsequent reporting.

This report provides information that forms input into the national water resources planning process and what challenges continuously crop up that can affect either the quantity or quality of water as well as sanitation issues. These factors are embraced by the Water and Sanitation Policy (2007), Water Act 2008 and the Long-term Water and Sanitation Strategy (2016).

3.2 Policy and legal background

The country has been doing a major water resources management reform since 1995 which brought about the Water Resources Management Policy and Strategy (1999), Industrial Wastewater Management Policy 2003, and Domestic Water and Industrial Effluent Standards (1998). The Water Resources Management Policy is updated every five years to incorporate changes in the sector with

time. The last update was in 2007 as the Water and Sanitation Policy and a year later the Government published Water Act (2008). The Act makes provisions for: management, protection, conservation, development, and sustainable use of water resources. The principles of integrated water resource management are enshrined in both the policy and the Act.

The Water and Sanitation Sector is currently guided by the Lesotho Water and Sanitation Policy of 2007 and governed by the Lesotho Water Act (2008). The Policy covers all aspects of water resources, from protection and conservation, water and sanitation services, transboundary issues and stakeholder involvement through to institutional arrangements. The Long-term Water and Sanitation Strategy (2016) was also formulated to enhance the implementation of Water Act, and the Water and Sanitation Policy (2007). The Water Act (2008) establishes the office of Commissioner of Water, and mandates the Commissioner to:

- provide policy direction to, and coordinate the Water and Sanitation Sector,
- implement the Water and Sanitation Policy
- develop strategies and plans, and ensure their implementation
- be custodian of national water resources data
- produce state of water resources reports
- carry out such regulatory activities in respect to water resources as are provided for under the Water Act
- advise the Minister concerning the management and utilization of water resources

The Water and Sanitation Sector aligns itself with other national, regional and international policy and legal framework. These include Vision 2020, National Strategic Development Plan (NSDP), the Environment Act (2008), the Revised SADC Protocol on Shared Water Courses (2000), the Orange-Senqu River Basin Commission (ORASECOM) Agreement (2000), the Southern African Development Community (SADC) Regional Water Policy (2006), the SADC Regional Water Strategy (2007) and Millennium Development Goals (MDGs) from 2000 to 2015, and Sustainable Development Goals (SDGs) from 2016 to 2030.

The sector policy and legal framework is implemented through a number of tools, including Water Demand Management Strategy, Drought Management Strategy, Integrated Water Resources Management Strategy, the Long-term Water and Sanitation Strategy and Water Quality Guidelines.

3.3 Institutional Arrangements

Institutions within the Water and Sanitation Sector of Lesotho are presented in Figure 3-1 and their responsibilities in Figure 3-2. Official documentation on explicit statement of the vision, mission and mandate of the Water and Sanitation Sector of Lesotho has not been available to the consultant during compilation of this report. Based on the Lesotho Long-term Water and Sanitation Strategy 2014 (COW, 2014), one can deduce the mandate of the Ministry responsible for water as to manage water resources and provide water and sanitation services for socio-economic development of Lesotho. The Water and Sanitation Sector in Lesotho is coordinated by the Ministry of Water through the Commissioner of Water. In 2014, Commissioner of Water developed a Long-Term Strategy for the Water and Sanitation Sector designed to ensure that water is used for the benefit of all. The strategy deals with amongst others urban water supply, rural water supply and sanitation services. The function of water resource management is undertaken by the Department of Water Affairs (DWA) that collects, keeps and provides records, information, results of monitoring activities research and analyses to the Commissioner of Water's office (CoW) who acts as the

custodian of raw water resources. Raw water abstraction is licensed by DWA. Implementation of rural water supplies to rural areas is implemented by the Department of Rural Water Supply (DRWS), with the intended operations and maintenance of these schemes being the responsibility of local authorities and local committees (COW, 2014). Provision of potable water supply to urban areas is currently undertaken by WASCO under the service provision license issued by the Lesotho Electricity and Water Authority (LEWA). The Lesotho Highlands Development Authority (LHDA) is implementing, operating and maintaining the portion of the Lesotho Highlands Water Project in Lesotho, which consists of three (3) dams, a weir, appurtenant infrastructure, the raw water conveyance system to South Africa and the Muela hydropower. (LEWA, 2017).

a) DWA – Department of Water Affairs

Despite its origin as the Hydrological Surveys Division in the Ministry of Works in early 1960s, the Department of Water Affairs (DWA) was established as a fully-fledged department in 1988 under the Ministry of Water, Energy and Mining. The role of water resource management is played by the DWA. The organization monitors national water resources, stores and provides records, information, and analyses to the Commissioner of Water. DWA is not involved in raw or treated water production but rather licenses raw water abstraction and usage.

b) CoW – Commissioner of Water

Water Act (2008) establishes the Commissioner of Water's office (CoW) to act as the custodian of raw water resources of Lesotho (Lesotho Government, 2008). The Office of the Commissioner of Water, currently within the Ministry of Water, is mandated to promote coordination of programs and activities within the water sector (Government of Lesotho 2007). The Commissioner is responsible for the Water Sector: policy, planning and strategy; performance and evaluation; asset management; and dam safety. Additionally, the Commissioner overseas two parastatals: the Lesotho Highlands Water Development Authority (LHDA) and WASCO.

c) LEWA – Lesotho Electricity and Water Authority

Lesotho Electricity and Water Authority (LEWA) was established through the Lesotho Electricity Authority (LEA) Act. No. 12 of 2002 as amended. The Institution takes a lead role in developing technical aspects of regulatory thinking of the urban water and sewerage sub-sector regulation with particular emphasis on safety, security and quality of supply, and development and implementation of technical rules and codes. The Institution contributes to wider aspects of regulatory policy development including the relationship between economic regulation and technical aspects of urban water and sewerage systems development and operation.

d) LHWC – Lesotho Highlands Water Commission

The Lesotho Highlands Water Commission (formerly the Joint Permanent Technical Commission) was established by the Lesotho Highlands Water Project Treaty of 1986 signed between Lesotho and South Africa on the implementation of the Lesotho Highlands Water Project (LHWP).

The Lesotho Highlands Water Commission (LHWC) is composed of two delegations, one from each Party to the Treaty (Lesotho and South Africa). Each party has nominated three representatives constituting its delegation as well as an alternate for each of the nominated representatives. The two delegations are independent and report directly to their respective governments. The LHWC as a body reports to the two governments, through their Designated Authorities (the Ministry of Water

in Lesotho and the Department of Water and Sanitation in South Africa). The LHWC is being coordinated by the Secretariat, which provides administrative support to both delegations and is the channel of communication between the LHWC and the outside world.

e) WASCO – Water and Sewerage Company (Pty) Ltd

Water and Sewerage Company (WASCO) is established under the Water and Sewerage Company (Propriety) Limited (Establishment and Vesting) Act (2010), to supply potable water and treat wastewater. Raw water abstraction from the natural environment by WASCO is permitted by the Department of Water Affairs whereas the disposal of treated wastewater into the environment is licensed (according to Environment Act, 2008) whereas the service provision that entails: treatment, distribution to users and collection and treatment of wastewater are licensed by LEWA. Provision of potable water and sewerage services to urban areas is undertaken by WASCO under the Composite Water and Sewerage Services License issued by the Lesotho Electricity and Water Authority (LEWA) as the regulator. WASCO operates several river intake works, boreholes for abstraction of raw water for treatment, and their associated transmission and distribution networks and service reservoirs. Subsequently, WASCO collects, transports and treats the wastewater for safe disposal into the environment through the sewerage system. WASCO is responsible for the provision of urban water supply and sanitation services and regulating water treatment plants. This entity is also responsible for the Maseru and Metolong water treatment plants. Other plants include the Pitseng area with abstractions from the Mphosong River in the Leribe district as well as other water treatment facilities that have been constructed throughout Lesotho in the gazetted towns of Roma, Botha-Bothe, Hlotse, Maputsoe, Tejatejaneng, Mapoteng, Morija, Semonkong, Mafeteng, Mohale's Hoek, Moyeni, Qacha's Nek, Thaba-Tseka and Mokhotlong.

f) DRWS – Department of Rural Water Supply

Department of Rural Water Supply is responsible for provision of water supply and sanitation in rural and some peri-urban areas (TAMS, 1996). Implementation of rural water supplies to small settlements is done by the Department of Rural Water Supply (DRWS), with the operation and maintenance of these schemes intended to be the responsibility of local authorities and local committees.

g) LHWP – Lesotho Highlands Water Project

The Lesotho Highlands Water Project (LHWP) is an ongoing water supply project with a hydropower component, developed in partnership between the governments of Lesotho and South Africa, being implemented by the LHDA in Lesotho and the TCTA in South Africa, under the supervision of the LHWC. It comprises a system of several large dams and tunnels throughout Lesotho and South Africa. In Lesotho, it involves the rivers Malibamatšo, Matsoku, Senqunyane and Senqu. In South Africa, it involves the Vaal River. It is Africa's largest water transfer scheme.

The purpose of the project is to provide Lesotho with a source of income in exchange for the provision of water to the central Gauteng province where the majority of industrial and mining activities occur in South Africa, as well as to generate hydroelectric power for Lesotho.

h) LHDA – Lesotho Highlands Development Authority

The Lesotho Highlands Development Authority (LHDA) was established through the Order No 23 of 1986 as amended, to implement, operate and maintain the Lesotho Highlands Water Project

dams, weir and appurtenant structures (Katse, Matsoku, 'Muela and Mohale), raw water conveyance system and the 'Muela hydropower scheme within Lesotho. The LHDA was set up to implement, operate and maintain that part of the Lesotho Highlands Water Project (LHWP) that falls within the borders of Lesotho.

i) LLWSU – Lesotho Lowlands Water Supply Unit

The Lesotho Lowlands Water Supply Unit (LLWSU) was established by Cabinet Memorandum in 2002 with the mandate to the implementation of the Lesotho Lowlands Water Supply Project (LLWSP), now in accordance with the provisions of the Lesotho Water and Sanitation Policy (2007). The LLWSU is the arm of the Government of Lesotho, in the Ministry of Water that is responsible for implementation of the long-term programme of water resources development within the Lesotho Lowlands (by way of bulk water supply infrastructure development) known as the LLWSP. LLWSU is mandated to secure long-term potable bulk water supplies in the lowlands of Lesotho to support socio-economic development and to assist in poverty reduction and health improvements.

j) MA - Metolong Authority

The Metolong Authority (MA) is the Authority established through the Metolong Authority Act, 15 of 2010 to implement the Metolong Dam and Water Supply Programme MA has been responsible for implementation of the fast-tracked Zone 4 &5 of the Lesotho Lowlands Water Supply Project (LLWSP). The MA was responsible for the design and construction of the Metolong Dam, water treatment plant and the conveyance system, which upon completion, the operation of the infrastructure would be handed over to WASCO.

k) NGOs

Several non-governmental organizations (NGOs) also contribute to water provision services alongside the Department of Rural Water Supply.

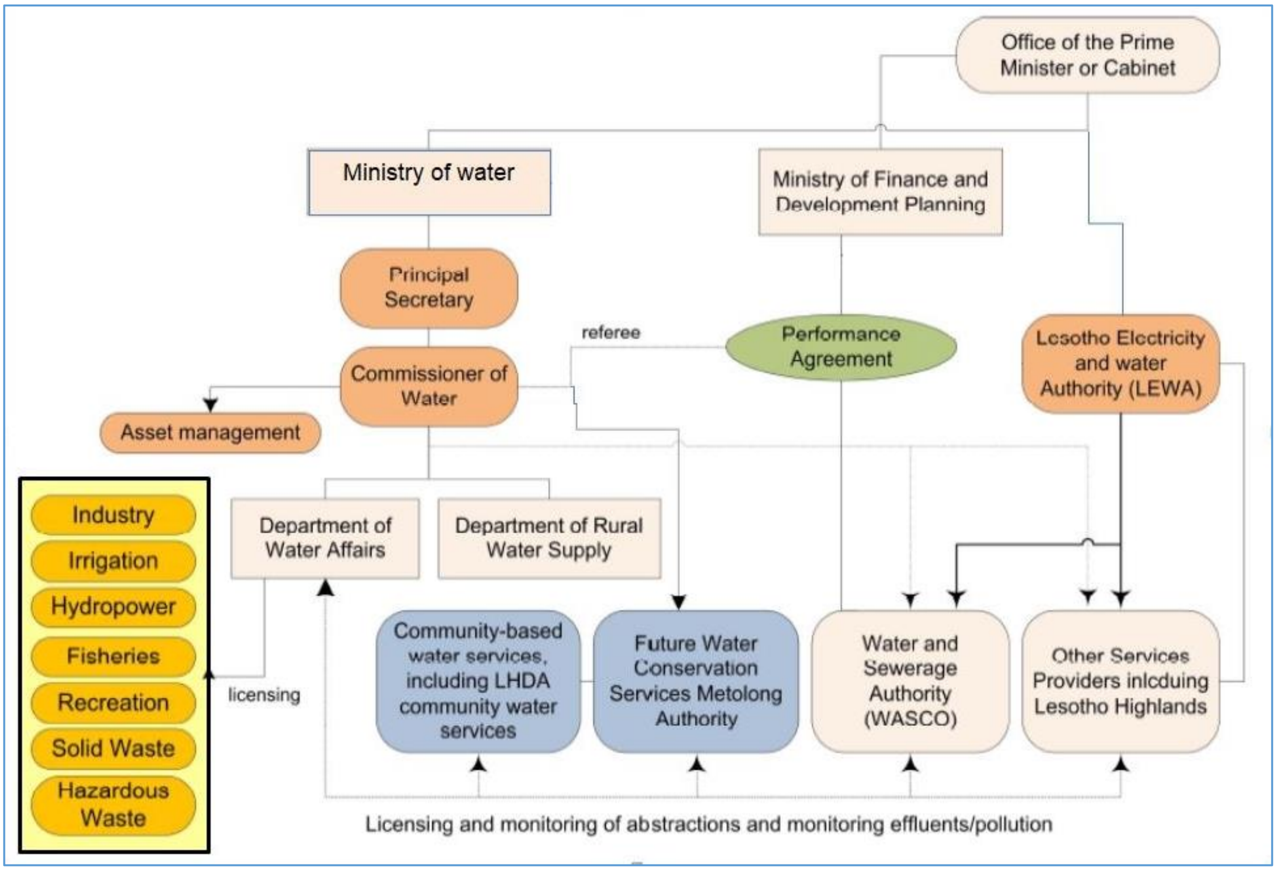


Figure 3-1: Institutional arrangements in the Water and Sanitation Sector.

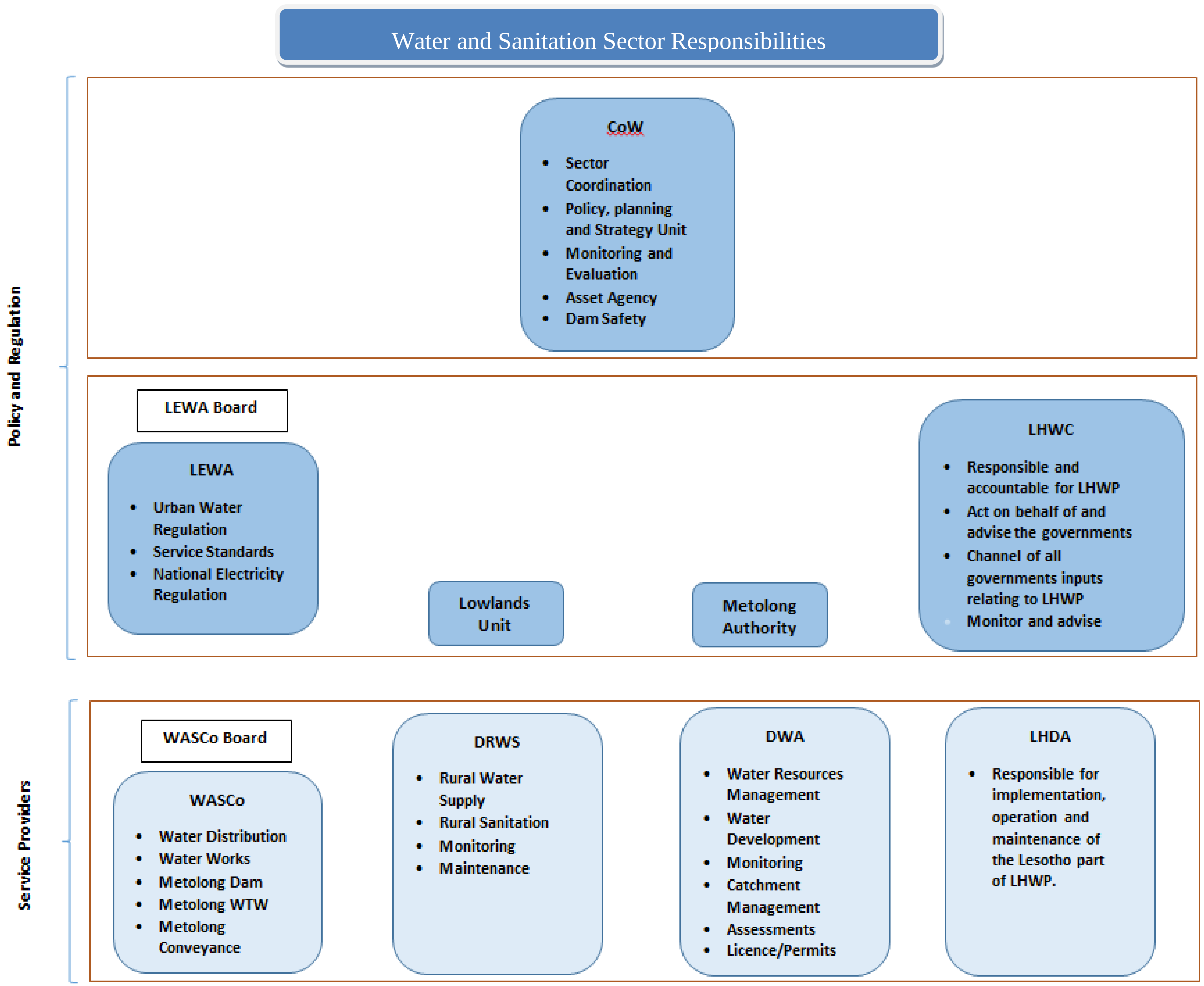


Figure 3-2: Institutional roles. Adapted from the Ministry of Water (formerly Ministry of Energy, Meteorology and Water Affairs), 2013

3.4 Sector Programmes and Projects

3.4.1 Motivation for continued improvements in water management in Lesotho

The Lesotho Water and Sanitation Policy of 2007 has to be updated every five years to incorporate new changes within the sector. The policy is based on Integrated Water Resources Management approach. The policy is in line with the Agenda 21, Dublin Principles, Helsinki Rules, Johannesburg Plan of Implementation, Southern African Vision for Water and Environment, SADC Protocol on Shared Water courses, third SADC Regional Strategic Action Plan (RSAP-III) and ORASECOM programme. The policy is driven by the following policy statements:

- Water resources management
- Water supply and sanitation services
- Water and environment
- Trans boundary water resources
- A sector-wide approach
- Stakeholder Involvement
- Institutional arrangements and legislative framework

The policy is a paradigm shift in the water resources management in Lesotho. Some of the strategies form part of the projects which have to be implemented. One project which has been completed is the water quality guidelines and standards for different water uses. This forms part of the indicators to measure the success of the policy. One of the problems the policy has to address is the unaccounted for water quantity. The policy can decide on the acceptable limit of this percentage. This is the amount of water that is lost and increase expenses to the utility company – bearing in mind that water has an economic value, the policy has to incorporate this concern as well.

The country has three main catchments (Senqu, Mohokare and Makhaleng Catchments), the water resources management should be based on these areas. This would improve the database management. The district local authorities can be mandated to monitor the sub-catchments within their districts and the management can be trickled to users at community level.

3.4.2 Recent and current Water and Sanitation Sector activities

This section presents the list of completed (since 2013), on-going and future water and sanitation projects in Lesotho. The Government of the Kingdom of Lesotho together with assistance from the Development Partners continuously support the endeavour for this country to achieve the Millennium Development Goals (alternatively the Sustainable Development Goals) through development of supporting legislature and policy frameworks. This support comes amongst others as technical assistance to water sector as well as grants to finance policy development studies. In brief, activities related to this assistance are itemized as follows:

- Technical Assistance (TA) to Water Sector, that reviewed the following legislature, policies and strategies:
    - Water and Sanitation Policy 2007 (Completed in 2007), Water Act 2008 (Completed in 2008); and operationalization of LTWSS (ongoing)
    - Long Term Water and Sanitation Strategy (Completed in 2014 and Gazetted in 2016)

- Hermony/ Ralintši Integrated Water Recourses Management (IWRM) (Completed in 2016)
- Implementation of the Long Term Water and Sanitation Strategy – Key Focus Area Three - Water and Sanitation Sector Policy Support Programme: the Programme will support the Water Sector in implementing the Water and Sanitation Policy for improving water and sanitation services (on-going)

- Wetland Restoration and Conservation Project (WRCP): the protection program for wetlands located at Khalong la Lithunya, Koti Sephola and Letšeng-La-Letsie. The project ran from 2010 up to 2013. The wetlands were equipped with gauging stations which could be helpful in evaluating the hydrological functioning of the wetlands (Completed in September 2013).
- Draft Water Quality Guidelines and Standards (Fichtner, 2013): development of the draft national water quality guidelines and standards was completed in 2013.
- Watercourses Classification Framework and Environmental Flows (completed in December 2017)
- Update of the Lowlands Water Supply Design Study of 2008 (Ongoing)
- Metolong Dam and Water Supply Programme (ongoing)
- Compilation of State of Water Resources report 2013/14 – 2015/16 and template for future reports (Regular reports; also ongoing in 2017).
- Hydraulic Modelling: Development of a Hydraulic Network Analysis Model incorporating optimized operating costs, Integrated Asset Management for Maseru and areas served by the Metolong Dam (WASCO, 2014) (Completed in 2013).
- Tertiary Lines: To assess the existing water supply and sanitation services; design and supervise construction of MDWSP tertiary pipelines, reservoirs and transfer of the water to demand centres; and upgrade the existing reticulation infrastructure (ongoing)
- The LHWP Phase 2: Phase II of the LHWP is underway.
- Lesotho Lowlands Water Supply Scheme: it categorises the project areas into 8 Zones. Updates of the 2008 designs of Water Supply Programme (Ongoing since 2015).

As part of the planned future initiatives on water resources, the following projects are envisaged:

- Development of Water and Sanitation Strategic Master Plan
- Development of the Water and Sanitation Communication Strategy
- Construction of multipurpose dams
- Transfer of water to Botswana

Water resources are developed, managed and protected by the Ministry of Water and CoW is a public officer within the Ministry. The Ministry allocates river, well and spring waters to users through water-use permits. The water-use permits are renewed after five years and do not guarantee the full supply of water resources within that period and in drought periods, and the permitted abstraction quantity does not change. The rural water supply is achieved through the Department of Rural Water Supply which is mainly focussed on development, maintenance and rehabilitation of groundwater resources.

3.5 Strategy to address problematic gap relative to current state

Effective coordination of the Water and Sanitation Sector requires participation of all major stakeholders in executing an accurately focused strategy to address the current state. Data

management is critical for accurate information for purposes of timely decision-making and planning. To that end, the data collection instruments inclusive of human element play a pivotal role to indicate periodic state of the watercourses and trigger a requisite response to maintain the healthy state. Analysis of the collected data and its timely inclusion in management meetings for quick decision-making, review of sector policies, monitoring of activities implemented by stakeholders across the sector and evaluation of the planned impact should form the strategic focus of the Commissioner of Water's office.

Some of the rivers gauging stations have data-collection challenges that range from shortage of field-based staff (hydrometric observers), non-operational and vandalized staff-gauges, inaccurate observers records, and unpaid hydrometric observers and stations guards. Procedures to determine common parameters and data formats within the Water Sector should be harmonized for common reporting. Figure 3-3 below depicts the proposed strategy framework amenable to the prevailing sectoral challenges.

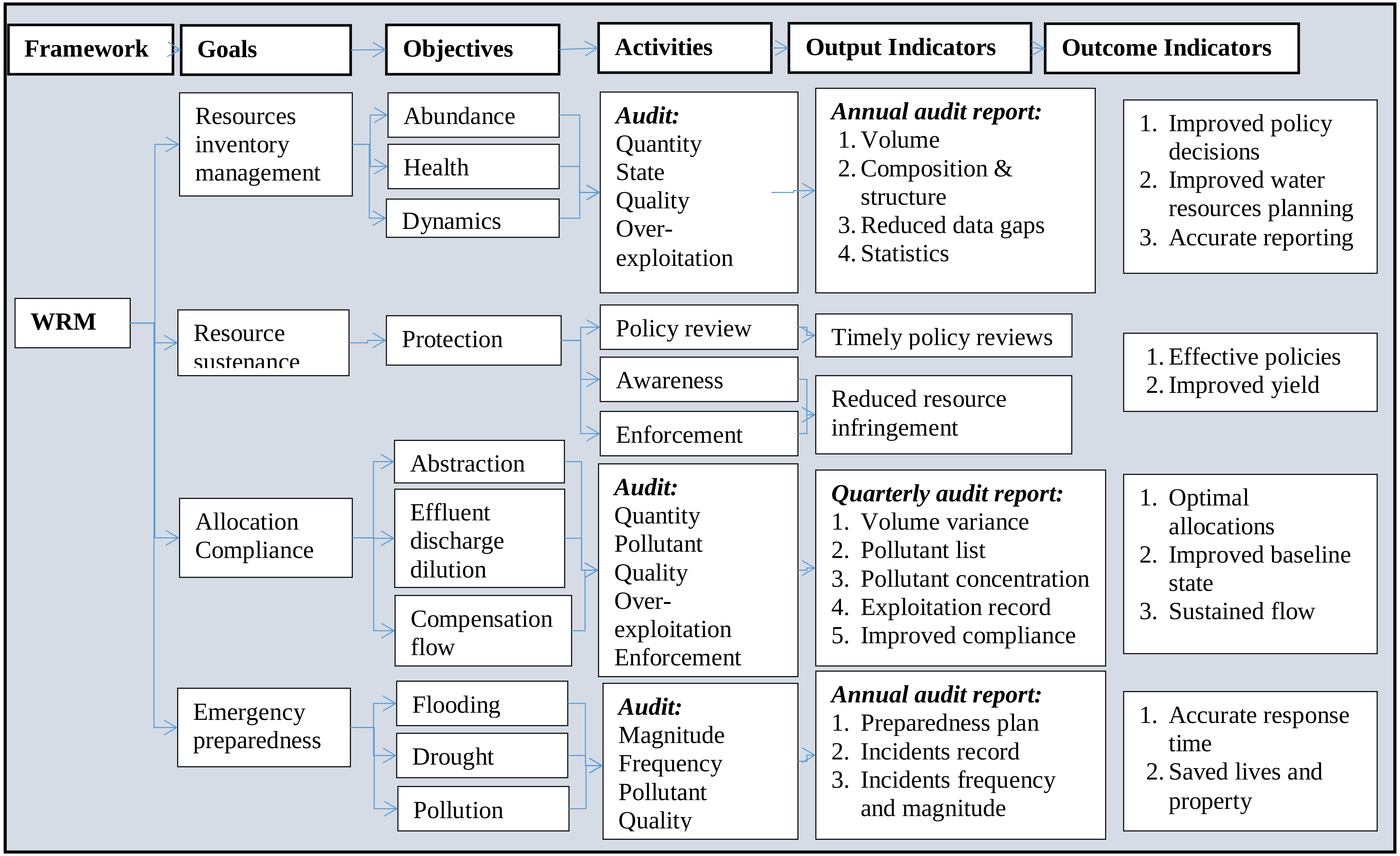


Figure 3-3: Proposed strategy to address water resources management challenges

4. Climate and Water Resources

This chapter provides an overview of climate and water resources during the period under review.

4.1 Water resources parameters

An accurate assessment of the water resources depends on the quantity and quality of the data that describes it. The status of the data collection networks is therefore also described in this chapter.

The following water resources parameters are reported on in the rest of this chapter:

- Weather data: temperature, wind speed, relative humidity, precipitation and evapotranspiration
- River discharge
- Lake / reservoir level and volume
- Water quality
- Groundwater levels
- Spring discharges
- Wetlands

4.2 Data Collection Networks

Lesotho has abundant water resources and as such should be monitored to maintain and enhance their reliable availability. Water resources status can be determined through water quality measurements and water quantity assessments. The number of active data collection stations for the key water resources parameters are summarised in Table 4-1.

Table 4-1: Operational water resources data collection network

Type of Measurement	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17
Climate Stations								
Multi-parameter	42	42	42	42	37	37	37	37
Precipitation only	50	50	50	50	53	53	53	53
Surface water								
River discharge	69	69	69	69	69	69	69	69
Lake/reservoir level	3	3	3	3	3	3	3	3
Lake/reservoir quality	-	-	-	-	14	14	14	14
River water quality	152	10	10	10	50	50	50	50
Groundwater								
Observation boreholes	72	72	72	72	66	63	63	60
Springs	162	162	162	162	155	152	150	147
Wetlands								
Discharge	0	13	13	13	0	0	0	0

Distributions of the above operational data collection networks of the Department of Water Affairs, Lesotho Meteorological Services[1] and Lesotho Highlands Development Authority, are shown in Figure 4-1.

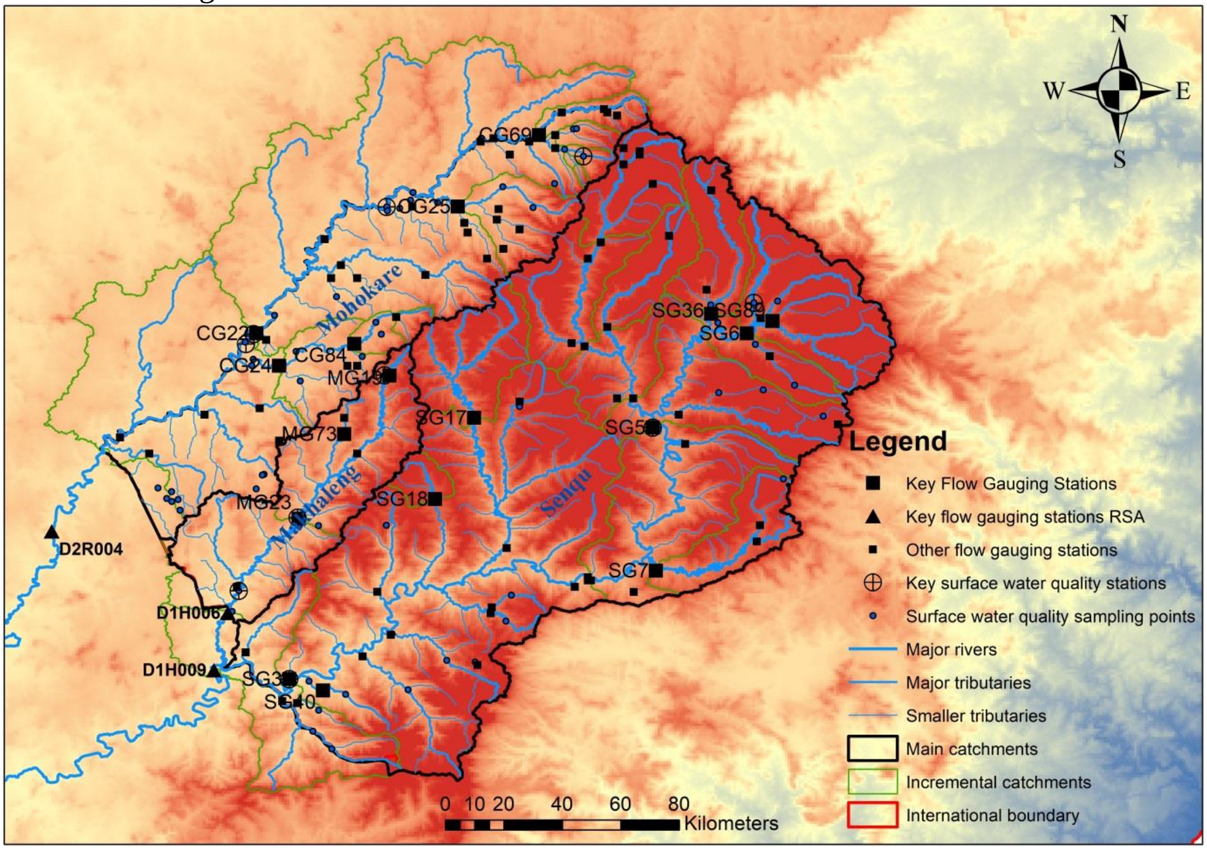


Figure 4-1: Lesotho catchments and key surface water resources monitoring points

4.3 Climate

The meteorological data that was used in the study includes the catchment rainfall as the input to the hydrological system, and evaporation / evapo-transpiration to describe the loss from the system. Evaporation losses from the water resources system was calculated within the WEAP model from temperature, relative humidity, wind speed and solar-radiation that is derived from the catchment cloud fraction.

Monthly meteorological data (Rainfall, temperature, wind speed and humidity) for the catchments was obtained from two sources: 1) Lesotho Meteorological services (LMS) and 2) the NASA Goddard Earth Sciences (GES) Data and Information Services Center (DISC) (NASA, 2015) satellite. The rainfall data were used to determine annual rainfall received over each major catchment area, the country, and non-catchment landscape area with Lesotho. This rainfall was represented both as millimetres per year and million cubic meters (MCM) per year, but built from the input monthly total rainfall.

[1] Illustration of LMS data collection network shown in Figure 4.2

The data from the Lesotho Meteorological Services (LMS) is from the network of Automatic Weather Stations, Meteorological Stations, Agrometeorological Stations, Synoptic Weather Stations as well as Rainfall Stations country-wide (see Figure 4-2).

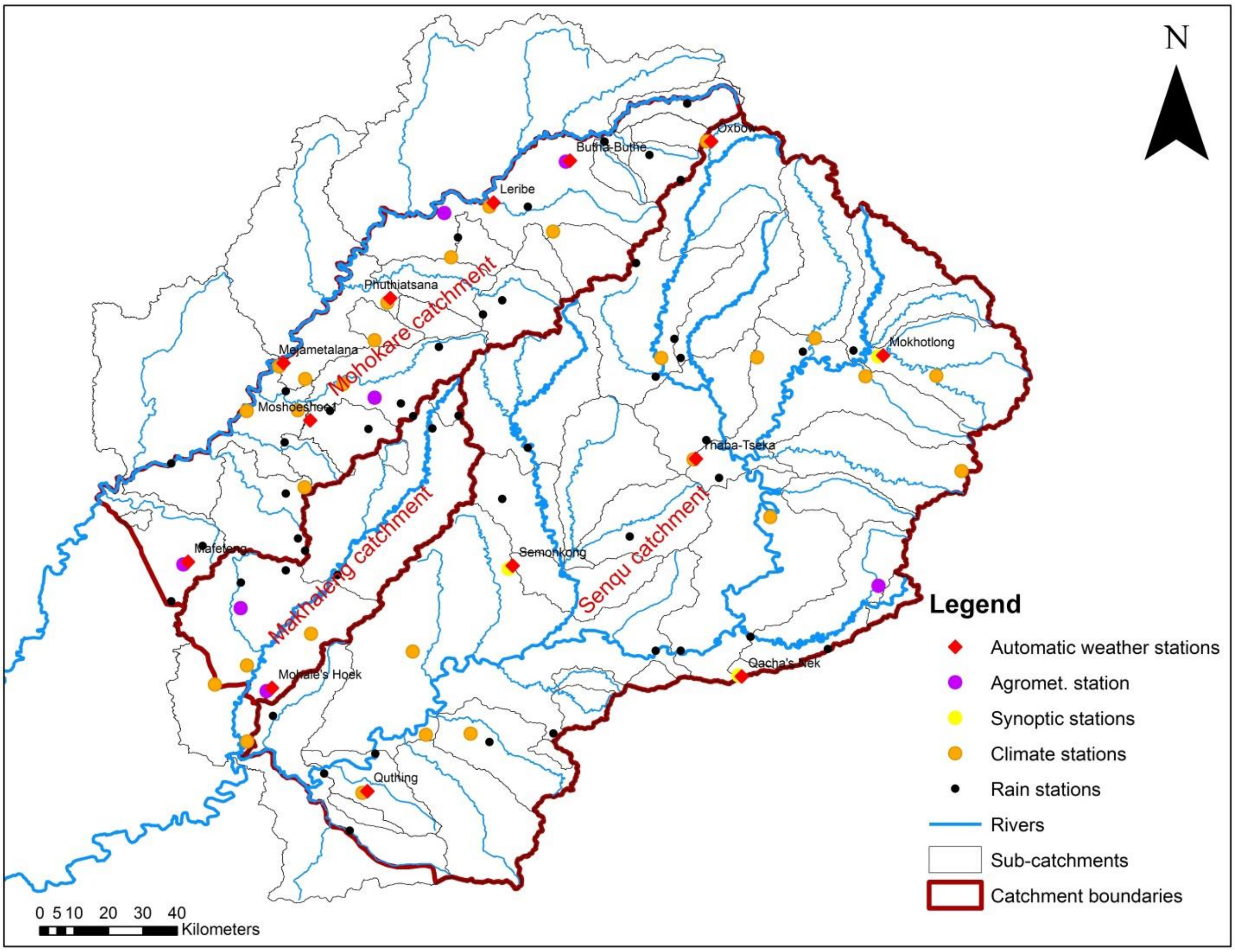


Figure 4-2: Weather stations types per catchment, operated by the LMS

The Lesotho Meteorological Stations (LMS) operates a total of 37 climate stations across the country in which temperature and precipitation observations are made. Of the 37 climate stations, 13 of them are Automatic Weather Stations (AWS) that measure and transmit data on various meteorological parameters such as rainfall, wind speed, wind direction, temperature, humidity and ambient pressure. Again, 8 of the 37 stations serve for agrometeorological purposes in which air temperature, soil temperature, precipitation, evaporation and sunshine duration are observed. The network of Agrometeorological Stations is mainly confined to the lowlands areas where most of the arable farming activities take place. There are also four synoptic stations in the country that are fully equipped with various sensors and equipment for various weather elements. The synoptic stations form part of the global observational system of the World Meteorological Organization and hence they routinely report complete observations of weather elements on daytime basis (due to staff shortage). Out of these, three of them, Maseru, Mokhotlong and Qacha’s Nek are registered with WMO. Lastly, LMS also operate 53 rainfall stations in which a station observer records cumulative rainfall amounts on daily basis (LMS, 2013).

Rainfall forms a direct input into the water resources system (hydrological cycle) whereas other weather elements (Table 4-2) are used to estimate evaporation as a loss from the system. Weather elements vary with space and time as illustrated in Table 4-2 below along with methods of patching any data may miss from the record. The recommended monitoring frequency and the instrumentation used are also presented. Table 4-2 below also presents the desired parameters to be recorded at every weather station.

Table 4-2: Meteorological elements and their measuring instrumentation

Elements		**Temporal variation**	**Spatial variation**	**Monitoring frequency**	**Instruments**
Precipitation	Rainfall (mm)	Time series	Isohyets	Daily or continuous	Rain gauge
	Snow (m)			Event based	Snow sensor, meter stick
	Hail (m, size)		-	Event based	Meter stick, callipers
Temperature (Degree Celsius)	Instantaneous		Spatial interpolation	Continuous	Thermometers, sensors
	Mean			Daily	
	Minimum			Daily	
	Maximum			Daily	
Wind	Speed (m/s)		Spatial interpolation	Continuous	Wind anemometer
	Direction (Degree)			Daily	Wind vane
Humidity	Absolute (m^3)		Spatial interpolation	Daily	Wet & dry bulb thermometers and sensors
	Relative (%)			Daily	
Solar radiation (Watts/m^2)			-	Continuous	Sensors
Sunshine (Hours)			-	Daily	Sunshine recorder
Evaporation (mm)	Open-water evaporation		-	Daily	Piche Evaporimeter, Sunken Evaporation Pan and Class A Land Pan Evaporimeter
	Evapotranspiration		Spatial interpolation	Daily	No direct instrumentation (requires a complete weather station)

In total, there are 90 operational rainfall stations in Lesotho (as per Figure 4-2). According to Marc, *et al.*, (2015), for the mountainous regions, the optimum density of rainfall stations that would yield accurate catchment rainfall derivation is 24 per 1000 km^2. Using this density, the number of recommended functional rainfall stations should be 720 and this should be evenly distributed across the country. The current number of rainfall stations (i.e. 90) is approximately 13% of the total number of required rainfall stations that is required in order to improve catchment rainfall estimates. This therefore implies that there is a need to use data from all the 90 functional rainfall stations in the country even though this number is below optimum.

The meteorological data that was used in the study catchments entails the rainfall (**Error! Reference source not found.**) and the applied evapotranspiration causal weather elements such as the cloud cover, temperature (minimum and maximum), wind speed and relative humidity. These data sets were fed into the WEAP model as monthly totals or averages for each of the study year. For illustrative purpose only, these values are presented below for

each of the three main catchments of Lesotho, plus a piece of land in the Mafeteng and Mohale's Hoek Districts (LO) that does not form any part of the catchment as each river leaves the borders of the country.

4.3.1 Rainfall

Monthly rainfall for the catchments was obtained from two sources: 1) Lesotho Meteorological services (LMS) (Figure 4-2) and 2) the NASA Goddard Earth Sciences (GES) Data and Information Services Center (DISC) (NASA, 2015) satellite rainfall at the spatial resolution of 0.1 Decimal Degree (Figure 4-3). The satellite rainfall was used as substitute in the cases where the LMS data was discontinuous / incomplete, especially from 2016 to 2017.

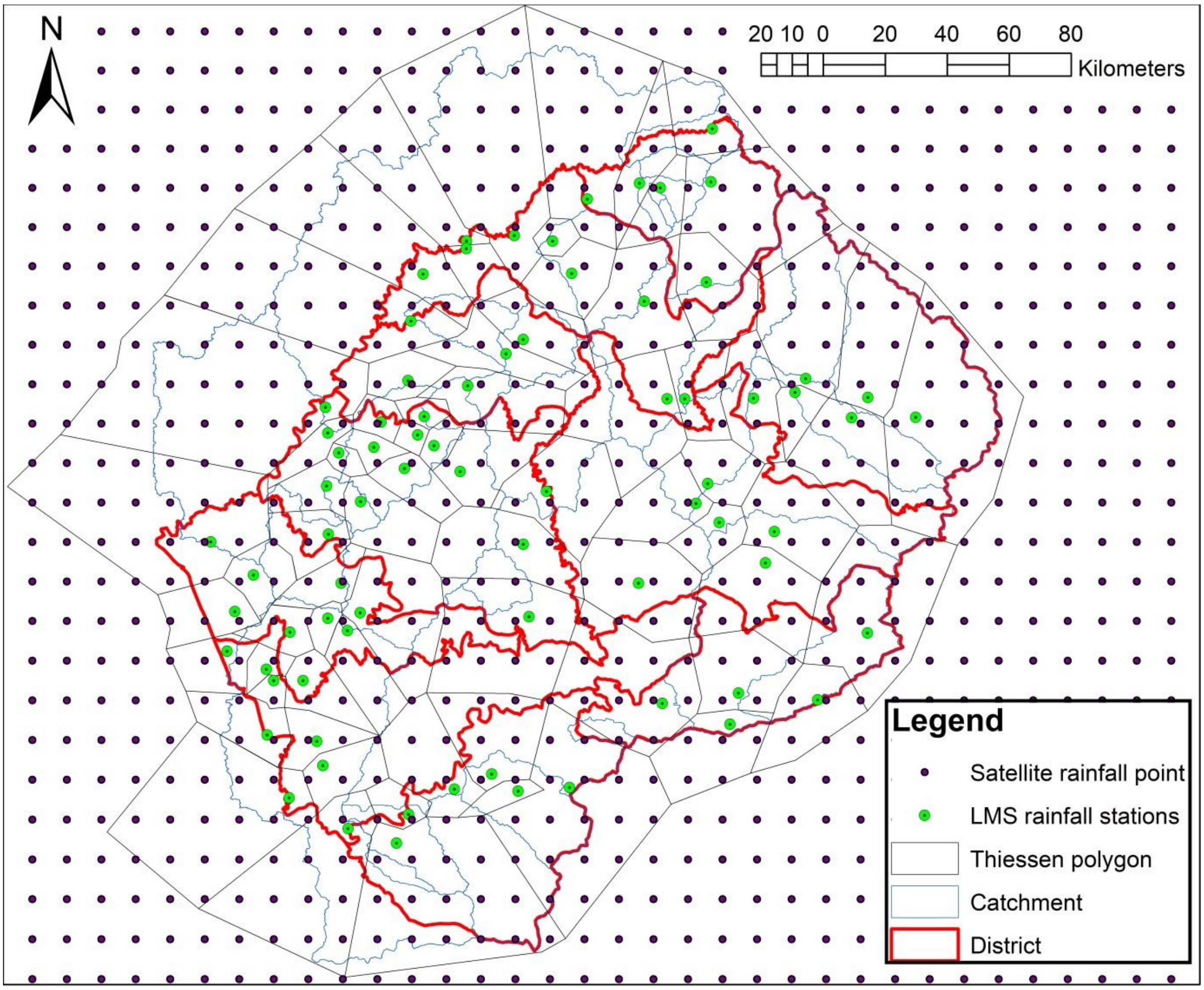


Figure 4-3: Rainfall observation points used in the study

Due to non-uniform distribution, the LMS stations rainfall was processed to obtain catchment rainfall using the Thiessen Polygon approach whereas for the satellite rainfall it was based on simple average after resampling (interpolating) to a finer resolution of 0.01 Decimal Degree. The monthly total rainfall (mm) for the major catchments of Lesotho for the year 2016/17 are presented in Figure 4-4.

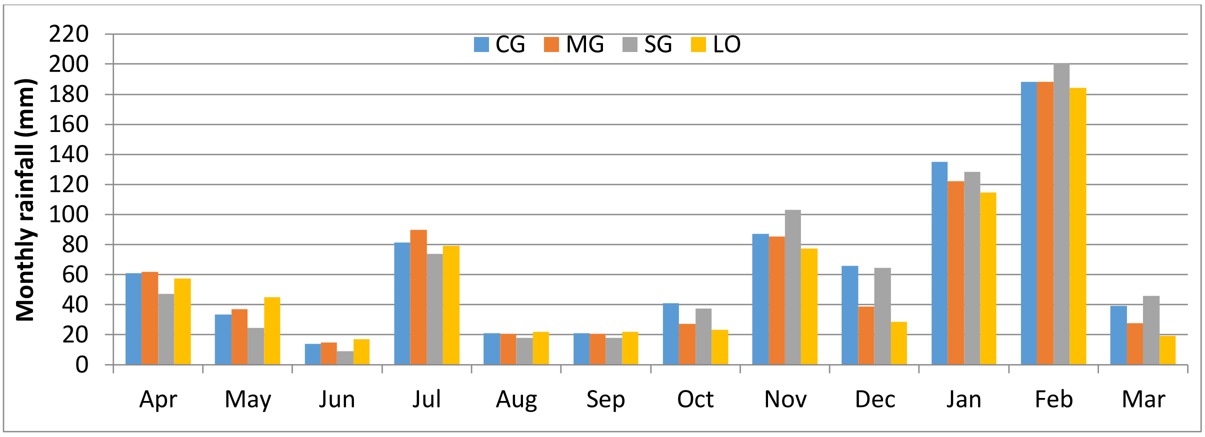
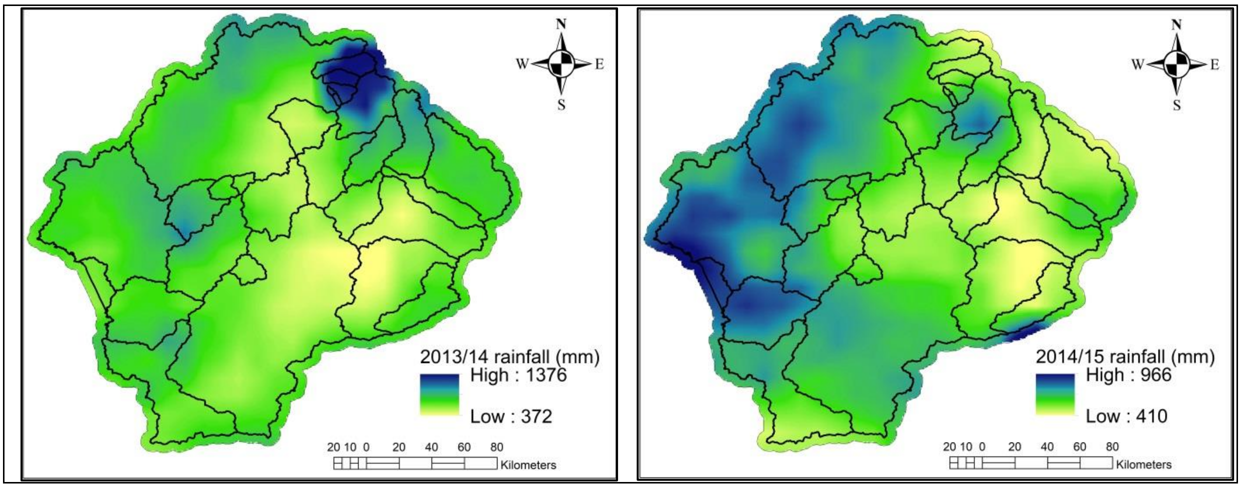


Figure 4-4: The 2016/17 areal monthly total rainfall (mm) for the Mohokare / Caledon (CG), Makhaleng (MG), Senqu River (SG) catchments, plus the land portion within Lesotho that does not belong to any of the catchments (LO).

In Figure 4-4 above, it is generally clear that June 2016 received the lowest rainfalls whereas February 2017 received the highest rainfall of the fiscal year 2016/17, and Senqu catchment receiving the highest rains.

At national level, the average annual rainfall distribution map of the year 2016/17, in relation to those of maps from 2013/14 to 2015/16 are presented in Figure 4-5 below, based on the rainfall data from the Lesotho Meteorological Stations along with the satellite rainfall observations from the NASA GES DISC.



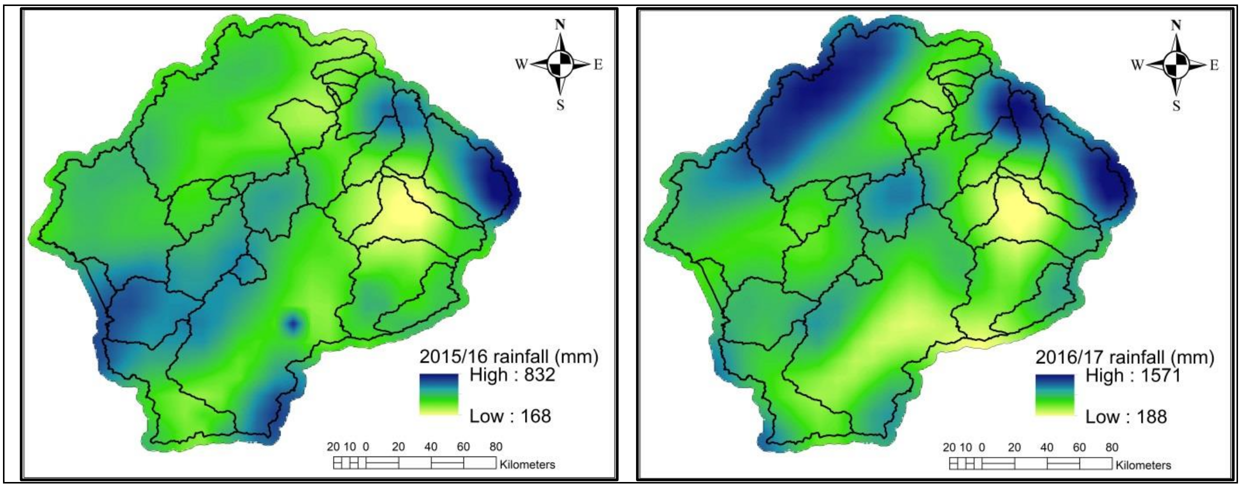


Figure 4-5: Annual rainfall distribution for the year 2016/17, in relation to those of the years 2013/14 to 2015/16.

In 2016/17, the highest rainfalls were also received in eastern side of the Mokhotlong District, and the lowest rainfalls were received in the western side of the Mokhotlong District (around the Polihali area) but in the eastern side of the Thaba-Tseka District. All these plots indicate that the Senqu and Malimatso valleys around the confluence of the two rivers (including the Polihali area) could be a rain shadow area of Lesotho.

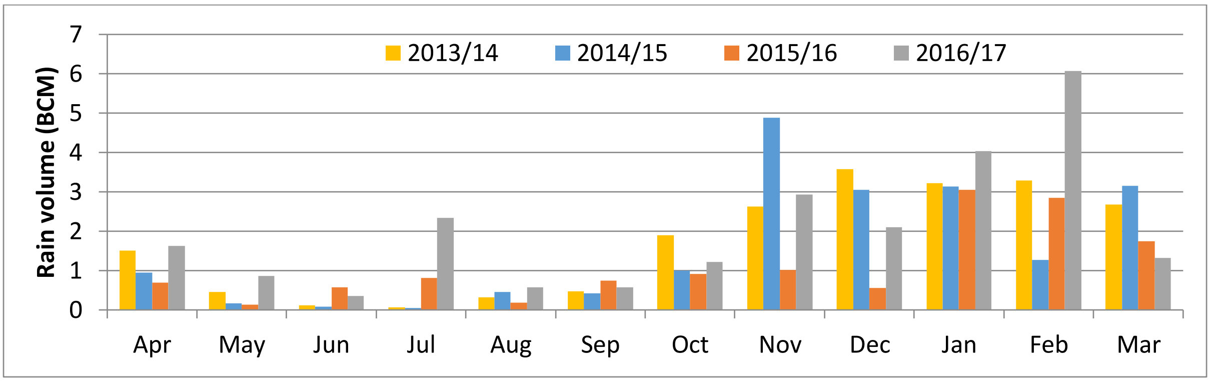
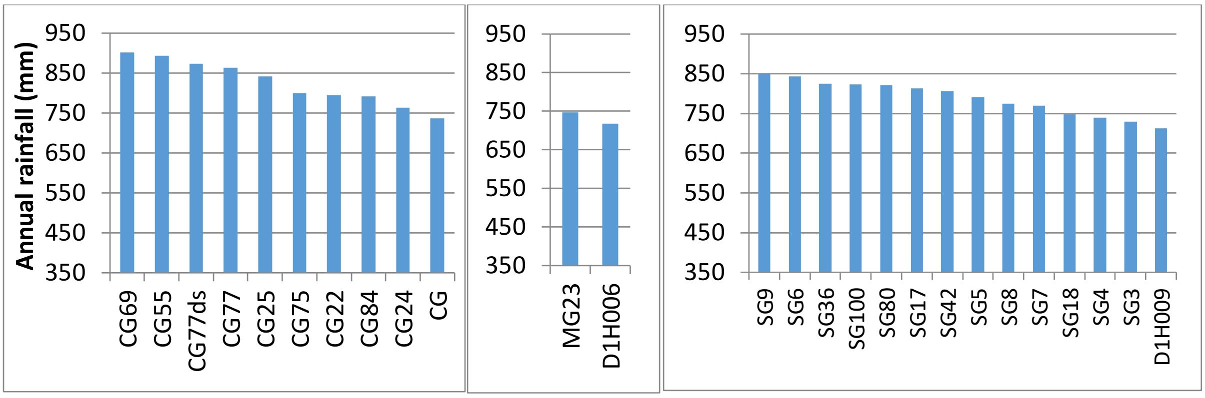


Figure 4-6: The country-wide monthly total rainfall volumes for the 2016/17, in relation to those of years 2013/14 to 2015/16.

The fiscal year 2016/17 was relatively wetter than the previous years since 2013/14. In this year 2016/17, the lowest rainfall was received in June 2016 whereas the highest was observed in this February 2017 (see Figure 4-6).

On an annual basis, in 2016/17, the amounts of rainfall received in each incremental catchment of the major catchments of Lesotho are presented in Figure 4-7 below.



a) Mohokare (CG) b) Makhaleng (MG) c) Senqu (SG) catchment

Figure 4-7: Ranked incremental catchments according to annual total rainfall for the fiscal year 2016/17.

Figure 4-7 above depicts the Senqu catchment to have received the lowest rainfalls of all the catchments in the year 2016/17, with the Orangedraai (D1H009) incremental catchment at the immediate downstream of Quthing Seaka Bridge (SG3) having received the lowest rainfall. In the same year, the Makhaleng catchment generally received the lowest rainfals whereas the Mohokare catchment generally received the highest rains followed by the Senqu catchment.

At the annual scale for the three major catchments, the received volumes of rainfall are depicted in Figure 4-8 below.

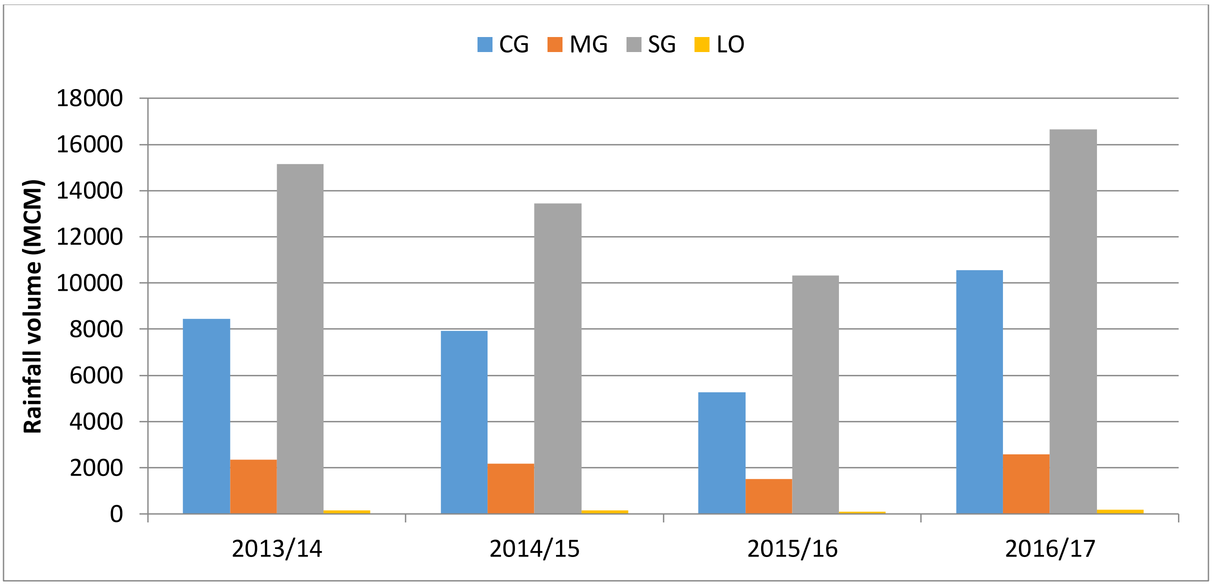


Figure 4-8: Catchment rainfall volume for the year 2016/17 in relation to those between the year 2013/14 and 2015/16.

Figure 4-8 above indicates that the Senqu (SG) catchment is receiving the highest volumes of annual rainfall, followed by the Mohokare (CG) catchment then the Makhaleng (MG) catchment. The area of land that does not belong to any of these catchments (LO) within Lesotho receives the lowest volumes of annual rainfall. All these volumes are in relation to the relative catchment areas. In all the catchments, rainfall volumes have been steadily decreasing over between 2013/14 and 2015/16, until they suddenly increased higher than ever

in 2016/17. These fluctuations are also reflected in the national plot of received rainfall volumes as depicted in Figure 4-9 below.

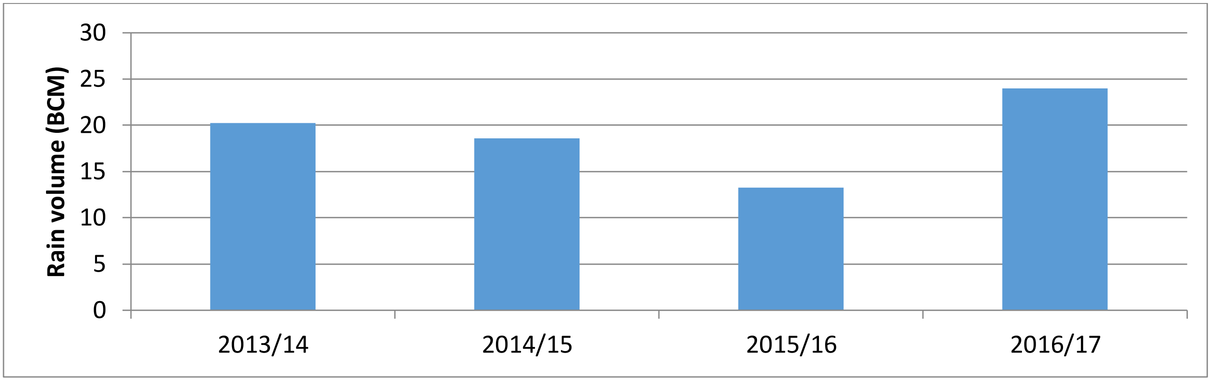


Figure 4-9: The country-wide annual total rainfall volume for the year 2016/17 in relation to the years between 2013/14 and 2015/16.

As depicted in Figure 4-9 above, the year 2016/17 was the wettest year since 2013/14.

The above discussed meteorological record was put in the WEAP with its output incremental catchment runoff compared with the observation and some drafts during the water balance model calibration.

4.3.2 Evapotranspiration

Catchment water loss due to evapotranspiration is estimated from data on some meteorological elements such as could-cover, temperature, wind speed and relative humidity.

a) Temperature

The temperature data (Table 4-3 and Figure 4-10) was obtained from the Lesotho Meteorological Services (LMS) and the NASA GES DISC for the period of study. The LMS record was for 34 stations (Figure 4-2) from which individual catchment temperature were calculated using the Thiessen Polygon approach. This record was fed into the WEAP model for use in calculating evapotranspiration.

Table 4-3: Minimum, average and maximum monthly temperature (Degree Celsius) per incremental catchment between 2013/14 and 2016/17

Catchment	April			May			June			July			August			September			October			November			December			January			February			March		
	Min	*Mean*	*Max*	*Min*	*Mean*	*Max*	*Min*	*Mean*	*Max*	*Min*	*Mean*	*Max*	*Min*	*Mean*	*Max*	*Min*	*Mean*	*Max*	*Min*	*Mean*	*Max*	*Min*	*Mean*	*Max*	*Min*	*Mean*	*Max*	*Min*	*Mean*	*Max*	*Min*	*Mean*	*Max*	*Min*	*Mean*	*Max*
LO	1.5	14.4	26.1	-0.1	11.7	26.1	-2.7	7.8	22.1	-2.8	8.4	24.9	-6.0	11.0	27.3	-2.1	14.8	30.4	-1.0	18.0	32.4	1.7	18.9	33.6	3.8	21.4	35.3	10.8	21.8	36.8	10.8	20.3	32.5	6.1	18.1	28.6
SG3	-5.3	10.9	25.1	-5.0	8.3	23.6	-8.1	4.5	19.6	-6.3	4.9	31.8	-6.7	8.0	24.9	-12.7	12.0	29.3	-3.6	14.4	31.8	-4.2	14.7	31.6	1.6	17.1	34.0	3.8	17.7	35.3	3.8	16.4	33.3	0.7	14.5	29.1
SG4	-3.9	9.9	25.6	-5.9	7.3	24.9	-7.9	4.0	20.3	-9.9	4.3	32.1	-6.8	7.3	24.6	-5.8	11.3	28.9	-3.9	13.1	31.9	-5.4	13.4	30.6	1.4	15.5	32.9	2.2	15.8	35.8	1.6	14.7	31.1	-0.1	13.2	27.4
SG5	-8.1	8.5	21.6	-6.7	6.0	23.4	-11.4	2.9	19.8	-10.8	3.0	29.9	-7.3	6.1	22.1	-6.6	10.3	27.4	-5.0	11.9	29.9	-4.0	12.4	27.6	0.9	14.1	29.9	0.8	14.4	34.3	0.9	13.5	30.3	-2.3	11.7	27.9
SG6	-7.5	7.3	21.6	-6.6	5.1	19.6	-8.9	2.3	16.8	-11.9	2.3	33.4	-8.4	5.1	26.1	-5.6	9.0	24.1	-5.9	10.3	33.4	-5.2	10.8	25.9	0.2	12.5	32.5	-0.3	12.6	34.5	0.1	11.8	25.9	-1.7	10.2	21.9
SG7	-4.7	8.3	24.6	-5.7	6.2	21.6	-7.1	3.4	19.8	-10.1	3.5	31.6	-7.0	6.3	24.4	-5.4	10.0	27.8	-3.5	11.3	31.6	-5.1	11.5	29.4	1.6	13.3	31.6	2.5	13.6	33.8	0.4	12.8	28.6	-0.4	11.4	26.9
SG8	-6.0	9.0	21.6	-5.6	6.3	22.6	-8.8	3.1	18.9	-10.2	3.2	31.3	-6.7	6.4	23.9	-5.7	10.5	26.6	-4.9	12.3	31.3	-3.5	12.9	26.8	2.3	14.5	29.4	2.4	14.9	34.1	1.6	13.9	28.9	-0.6	12.1	26.1
SG9	-5.1	7.1	21.9	-5.5	4.5	19.4	-7.6	1.5	15.9	-10.1	1.6	33.1	-8.9	4.4	25.4	-7.1	8.4	24.1	-6.0	10.2	33.1	-3.6	10.5	26.9	-0.8	12.3	30.9	1.6	12.6	33.0	0.6	11.7	25.9	-1.1	9.9	21.9
SG17	-4.9	8.0	22.1	-4.6	5.3	18.9	-9.3	1.8	16.9	-11.4	2.2	31.6	-7.6	5.2	23.4	-6.0	9.2	25.3	-3.9	11.4	31.6	-3.9	11.6	27.9	0.3	13.4	29.6	3.0	14.0	34.0	-0.7	12.9	27.4	0.2	11.0	23.4
SG18	-3.7	8.3	20.6	-4.0	5.7	20.4	-7.6	2.0	16.1	-9.8	2.3	31.6	-5.3	5.5	24.9	-4.0	9.5	24.4	-2.8	11.7	31.6	-2.8	12.0	26.8	3.8	14.1	31.9	5.0	14.5	32.0	1.4	13.3	27.4	1.4	11.4	22.6
CG22	-3.1	12.1	28.6	-3.5	9.3	23.9	-5.6	5.7	22.3	-6.6	6.1	33.8	-6.9	9.1	27.6	-5.9	13.2	30.3	-3.4	15.4	33.8	-1.2	15.7	34.0	1.2	17.9	35.5	2.8	18.5	36.8	2.9	17.2	31.8	0.5	15.2	28.1
MG23	-3.9	11.2	25.9	-4.0	8.5	24.6	-8.0	4.7	21.9	-9.6	5.2	31.9	-6.6	8.3	24.9	-4.1	12.4	29.1	-2.5	14.8	31.9	-1.7	15.1	31.1	2.9	17.4	33.0	3.7	17.9	34.6	1.4	16.7	32.1	1.1	14.7	28.3
CG24	-1.9	12.3	26.4	-2.5	9.4	22.6	-5.5	5.8	21.1	-6.8	6.3	31.9	-4.9	9.3	26.3	-3.9	13.5	29.3	-0.8	16.0	31.9	-0.8	16.3	33.0	6.1	18.6	34.8	6.2	19.1	35.8	3.0	17.7	31.4	1.9	15.7	28.1
CG25	-4.0	11.3	24.9	-3.9	8.2	23.1	-5.7	4.7	19.6	-6.4	5.2	33.4	-7.2	8.4	25.4	-6.6	12.6	28.1	-3.4	14.9	33.4	-1.2	15.1	30.9	1.2	17.2	32.5	2.9	17.8	34.1	3.2	16.6	32.0	0.7	14.4	27.1
SG36	-6.2	7.9	21.8	-5.7	5.3	22.3	-8.6	2.4	17.9	-10.1	2.5	32.4	-8.9	5.4	26.1	-7.3	9.4	25.8	-5.2	11.2	33.4	-3.4	11.5	26.6	-0.4	13.2	32.5	1.1	13.5	32.0	1.3	12.7	30.4	-2.0	11.0	25.6
SG42	-4.6	6.9	20.1	-5.2	4.4	18.1	-9.3	1.4	14.9	-11.8	1.5	33.0	-8.4	4.3	25.4	-6.8	8.3	22.4	-6.0	10.2	33.0	-4.2	10.5	25.1	-0.1	12.2	32.5	1.8	12.5	30.1	-0.1	11.7	25.3	-0.9	9.7	21.4
CG55	-4.5	10.0	23.8	-4.2	7.4	20.1	-8.8	4.3	17.1	-10.9	4.5	31.9	-7.2	7.2	24.3	-5.2	11.2	25.8	-3.5	13.2	31.9	-3.5	13.3	28.9	1.0	15.1	30.1	3.8	15.5	33.0	-0.2	14.5	27.4	1.1	12.7	24.3
CG69	-2.4	11.2	25.1	-2.6	8.7	21.1	-7.4	5.5	18.6	-9.2	5.7	31.6	-5.8	8.5	23.9	-5.1	12.4	26.9	-2.3	14.3	31.6	-0.4	14.3	30.1	1.7	16.2	31.6	4.8	16.5	33.4	2.7	15.6	28.6	2.1	13.9	25.6
CG75	-2.4	10.6	23.6	-2.1	7.9	22.3	-7.3	4.4	18.4	-9.2	4.8	27.6	-4.3	7.8	22.6	-4.0	11.9	26.4	-0.5	14.2	27.9	-0.1	14.4	29.3	3.4	16.4	31.1	3.3	16.9	32.9	3.2	15.8	29.6	1.7	13.8	25.1
CG77	-3.5	11.6	22.9	-2.9	8.7	21.3	-5.5	5.4	17.4	-7.1	5.8	32.6	-6.3	8.8	25.1	-5.5	12.9	25.4	-2.7	15.1	32.6	-0.6	15.2	28.1	1.7	17.2	30.6	3.7	17.7	32.9	3.6	16.5	28.8	1.4	14.6	23.9
SG80	-4.3	9.1	20.4	-4.6	6.4	17.8	-8.0	3.0	16.1	-9.1	3.3	33.0	-7.9	6.4	25.4	-6.9	10.5	24.1	-6.0	12.6	33.0	-3.3	12.8	25.6	0.7	14.5	32.5	2.1	14.9	34.0	2.2	13.9	27.6	-0.1	11.9	23.1
CG84	-4.6	10.7	24.9	-4.6	7.8	20.9	-8.4	4.2	19.4	-10.4	4.7	29.4	-6.4	7.7	23.9	-3.8	12.0	27.6	-3.1	14.4	29.4	-3.1	14.6	30.8	2.4	16.7	32.8	3.5	17.2	34.1	-0.4	15.9	29.9	1.0	13.8	26.1
SG100	-8.1	8.4	21.9	-7.0	5.6	22.1	-10.9	2.4	18.4	-7.1	2.7	32.6	-6.5	5.8	25.4	-6.0	10.1	26.6	-6.1	12.0	32.6	-5.7	12.2	27.6	0.6	14.0	31.1	-0.8	14.4	34.3	0.1	13.5	30.3	-2.2	11.6	25.4
CG77us	-4.8	8.9	22.1	-3.9	6.3	18.9	-7.7	3.2	15.4	-10.9	3.4	33.0	-7.5	6.2	25.3	-6.3	10.3	24.4	-4.2	12.2	33.0	-3.9	12.6	27.4	0.6	14.3	30.8	2.4	14.7	32.8	-0.2	13.7	26.3	-0.7	11.6	22.8
CG70	-4.2	12.9	26.9	-3.8	10.4	23.6	-8.4	6.5	21.8	-9.9	6.9	32.1	-6.5	9.8	27.6	-3.1	13.9	30.8	-2.3	16.5	32.8	-2.3	16.9	34.0	2.4	19.3	35.6	3.5	19.8	37.0	0.7	18.4	32.8	1.6	16.4	28.8
D1H006	-1.6	13.3	25.8	-1.8	10.8	23.9	-3.3	5.9	21.3	-4.6	7.2	29.9	-3.2	10.2	26.4	-3.2	14.3	30.1	-1.0	16.9	31.9	-0.3	17.4	33.1	4.8	20.0	35.0	7.2	20.8	36.8	6.9	19.3	33.5	4.0	17.2	29.6
D1H009	-3.3	12.3	25.8	-5.1	9.7	23.1	-6.7	5.7	21.3	-5.7	6.2	30.3	-6.2	9.1	26.6	-5.5	13.1	30.1	-2.4	15.8	31.9	0.7	16.3	33.4	2.2	18.9	35.4	5.0	19.7	36.8	5.0	18.4	32.5	1.5	16.2	28.1
National	-4.2	10.1	23.8	-4.3	7.4	21.9	-7.5	4.0	18.8	-8.8	4.4	31.5	-6.7	7.3	25.1	-5.5	11.4	27.1	-3.5	13.5	32.0	-2.6	13.8	29.5	1.7	15.8	32.4	3.2	16.3	34.2	2.0	15.2	29.7	0.5	13.3	25.8

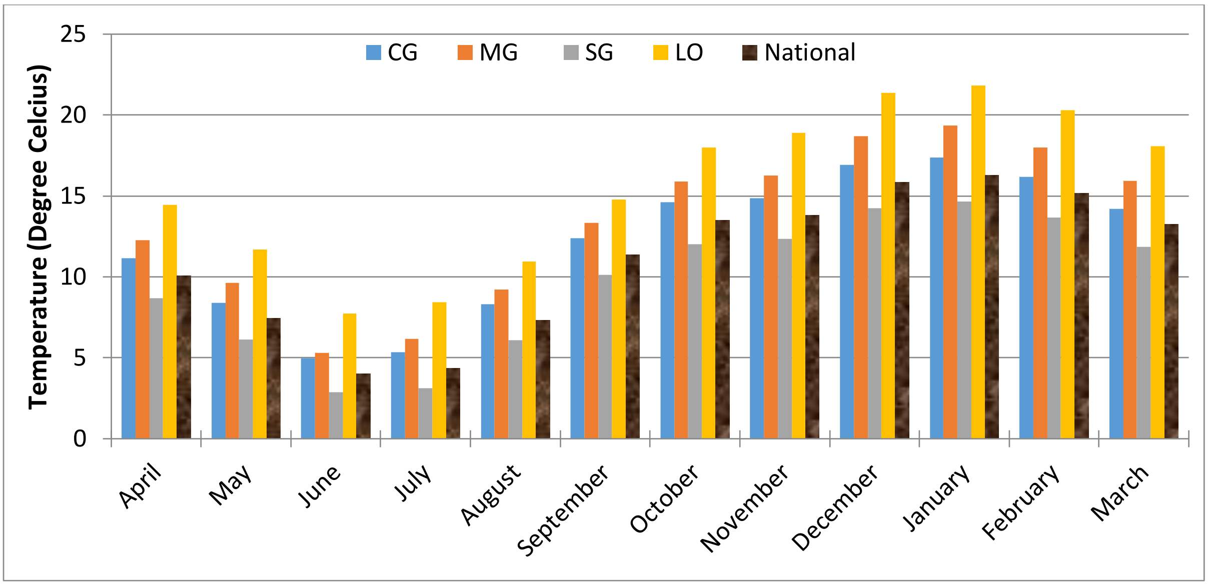


Figure 4-10: Long-term average monthly temperature over Lesotho since 2013/14

In Figure 4-10 above, the Mafeteng and Mohale's Hoek areas that contribute to the LO experience the highest temperature throughout the period under review. This is sequentially followed by the Makhaleng (MG23 and D1H006) catchment, Mohokare (CG) and then Senqu (SG) catchments.

b) Relative humidity

The relative humidity (RH) record was also provided by the LMS for the Automatic Weather Stations (AWS). This data was also supplemented by the RH calculations (Table 4-4) from the equation 1 below (Earth-Science, 2018) using the NASA GES DISC specific humidity, temperature and pressure.

$$RH = 0.263pq\left[exp\left(\frac{17.67(T-T_0)}{T-29.65}\right)\right]^{-1} \qquad \text{Eqn. 1}$$

Where RH is relative humidity (%), p is atmospheric pressure (Pa), q is specific humidity (-), T is temperature in Kelvin and T_0 is reference temperature of 273.16K.

Table 4-4: The calculated Relative Humidity (%) for 2016/17

Station Code	Apr 2016	May 2016	Jun 2016	Jul 2016	Aug 2016	Sep 2016	Oct 2016	Nov 2016	Dec 2016	Jan 2017	Feb 2017	Mar 2017
LO	50	56	52	48	36	34	33	48	43	52	63	46
SG3	56	60	55	53	38	41	40	56	54	61	71	57
SG4	50	54	47	47	32	37	38	53	53	61	71	59
SG5	52	54	48	48	32	37	36	51	52	60	69	59
SG6	57	60	50	50	37	44	44	61	63	73	82	70
SG7	55	59	48	50	35	42	45	62	62	71	80	68
SG8	54	56	52	51	35	40	39	55	55	61	70	59
SG9	62	65	55	55	41	46	46	67	69	76	85	72

SG17	60	63	59	56	40	45	43	63	63	70	79	66
SG18	60	63	58	57	39	45	42	61	59	67	77	62
CG22	50	56	52	50	36	37	39	58	56	60	71	58
MG23	56	60	57	53	38	40	38	56	54	61	71	57
CG24	52	56	53	50	35	37	35	53	50	56	66	52
CG25	53	57	53	51	37	38	37	55	54	60	70	58
SG36	58	60	51	51	38	44	42	61	63	71	80	67
SG42	59	61	54	53	38	43	41	60	61	69	78	66
CG55	53	57	50	50	37	39	39	58	58	64	73	61
CG69	52	57	49	50	37	40	41	61	60	66	75	63
CG75	54	57	53	51	36	39	38	57	56	61	70	57
CG77	52	56	50	49	36	38	37	55	54	61	69	58
SG80	58	60	56	53	38	42	41	61	61	68	77	65
CG84	55	59	55	52	37	39	38	57	55	61	71	57
SG100	55	56	49	50	34	39	36	52	54	63	73	62
CG77us	56	59	53	53	38	40	39	58	58	65	74	62
CG70	50	56	52	48	35	35	34	51	47	55	66	49
D1H006	54	59	54	50	37	36	36	52	48	55	66	49
D1H009	55	60	56	52	39	38	37	52	47	53	63	49

For ease of interpretation, the relative humidity data in Table 4-4 above is summarized according to the three major catchments of Lesotho as presented in Figure 4-11 below.

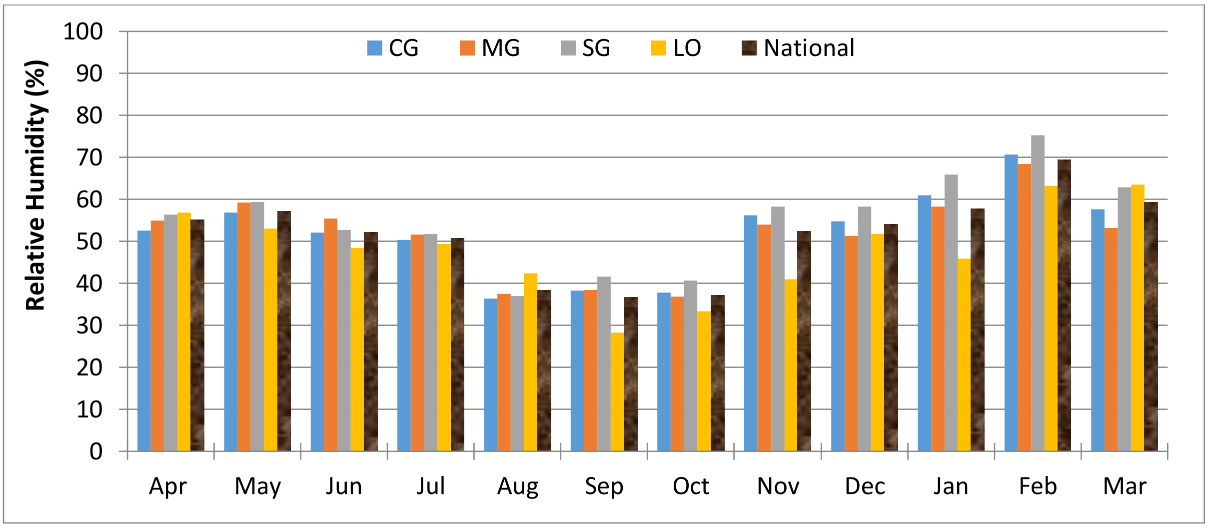


Figure 4-11: Average monthly relative humidity over Lesotho in 2016/17

As can be seen in Figure 4-11 above, the February 2017 was the most humid whereas October 2016 was the least humid. In general, the Senqu catchment was the most humid whereas the LO area was mostly least humid, generally below the national average humidity in most of the months of the fiscal year 2016/17.

c) Wind speed (m/s)

The wind-speed data were obtained from the Lesotho Meteorological Services (LMS) for the period of study. These records were from the 5 stations of Moshoeshoe I Airport, Oxbow, Mokhotlong, Semonkong and Qacha's Nek. These records were supplemented by the satellite monitored wind speed from the NASA GES DISC from which average individual catchment wind speeds were calculated (see Table 4-5). These records were used to calculate reference evapotranspiration (ETo) using the FAO ETo calculating tool.

Table 4-5: The wind speed (m/s) for 2016/17

Station Code	Apr 2016	May 2016	Jun 2016	Jul 2016	Aug 2016	Sep 2016	Oct 2016	Nov 2016	Dec 2016	Jan 2017	Feb 2017	Mar 2017
LO	2.133	1.754	1.959	2.241	2.180	3.382	3.112	3.539	3.280	2.237	1.905	1.951
SG3	2.631	1.677	2.207	2.425	2.306	3.615	3.407	3.150	3.071	2.143	1.886	2.077
SG4	2.923	1.843	2.510	2.624	2.679	4.022	3.813	3.335	3.050	2.163	1.863	2.172
SG5	2.507	1.521	1.994	2.065	2.319	4.022	3.710	3.268	2.940	1.877	1.647	1.873
SG6	2.675	1.707	2.188	2.328	2.443	3.376	3.338	2.793	2.550	1.818	1.594	1.861
SG7	2.938	1.919	2.601	2.724	2.683	3.777	3.483	3.012	2.869	2.069	1.768	2.236
SG8	2.378	1.457	1.968	2.015	2.226	3.625	3.638	3.165	2.921	1.801	1.593	1.713
SG9	2.615	1.593	1.989	2.200	2.248	3.371	3.400	2.714	2.533	1.715	1.577	1.717
SG17	2.408	1.459	1.688	1.887	2.078	3.451	3.457	3.130	2.899	1.913	1.728	1.801
SG18	2.574	1.607	2.121	2.282	2.254	3.679	3.485	3.225	3.086	2.012	1.722	1.925
CG22	2.073	1.612	1.631	1.937	1.865	2.480	2.490	2.319	2.456	1.809	1.654	1.638
MG23	2.219	1.507	1.693	1.972	1.976	3.174	3.122	3.084	2.907	1.959	1.739	1.896
CG24	1.911	1.531	1.521	1.739	1.861	2.704	2.649	2.693	2.646	1.867	1.695	1.798
CG25	1.906	1.404	1.401	1.596	1.690	2.470	2.593	2.310	2.395	1.694	1.562	1.641
SG36	2.471	1.560	1.989	2.253	2.261	3.361	3.393	2.694	2.505	1.665	1.466	1.730
SG42	2.410	1.463	1.987	2.128	2.268	3.763	3.752	3.092	2.782	1.670	1.451	1.695
CG55	2.461	1.710	1.958	2.257	2.020	2.568	2.685	2.368	2.382	1.739	1.727	1.793
CG69	2.730	1.863	2.174	2.481	2.233	2.796	2.839	2.505	2.472	1.861	1.839	1.908
CG75	2.037	1.434	1.431	1.681	1.827	2.727	2.818	2.651	2.609	1.828	1.679	1.744
CG77	2.170	1.564	1.716	2.019	1.790	2.286	2.469	2.189	2.303	1.666	1.640	1.697
SG80	2.468	1.485	1.957	2.017	2.282	3.830	3.775	3.236	2.880	1.821	1.605	1.727
CG84	1.947	1.479	1.469	1.686	1.821	2.627	2.660	2.564	2.580	1.816	1.662	1.757
SG100	2.436	1.517	1.883	1.972	2.255	3.629	3.809	3.343	2.920	1.812	1.605	1.801
CG77us	2.113	1.468	1.587	1.864	1.773	2.527	2.705	2.323	2.373	1.660	1.599	1.630
CG70	2.003	1.705	1.731	2.040	2.060	3.069	2.908	3.142	2.979	2.041	1.785	1.776
D1H006	2.199	1.613	1.925	2.224	2.088	3.317	3.074	3.248	2.981	2.089	1.783	1.988
D1H009	2.184	1.525	1.890	2.225	2.017	3.146	2.930	2.971	2.935	2.171	1.883	2.056

A summary plot of the above-tabulated catchments wind speed (m/s) is presented in Figure 4-12 below.

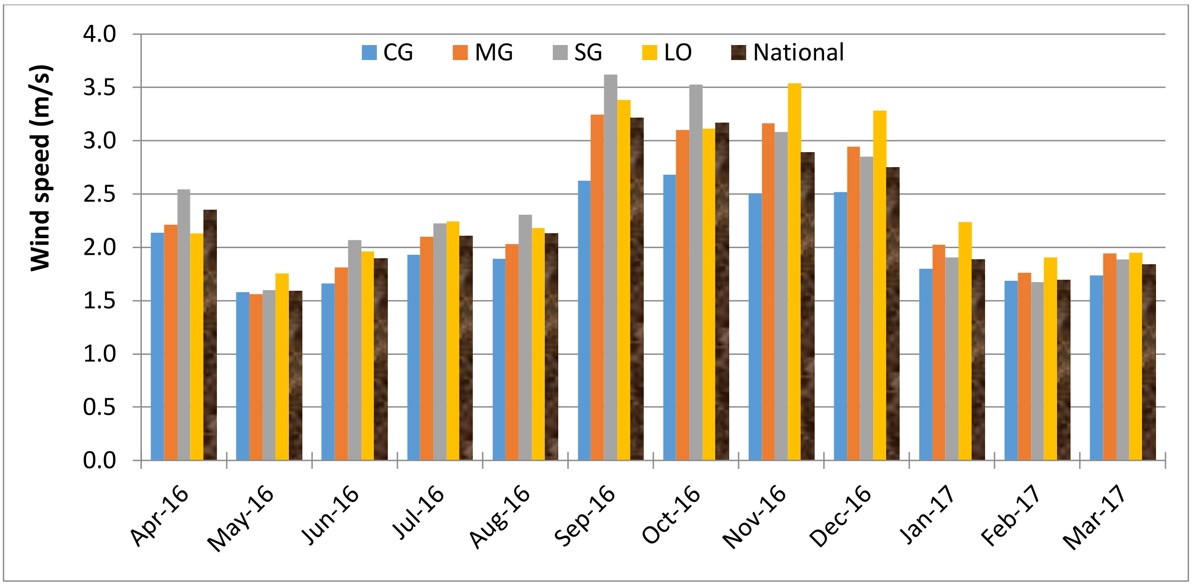


Figure 4-12: Average monthly wind speed (m/s) per major catchment and country-wide in 2016/17

Figure 4-12 indicates that wind speed is on average the highest in September and lowest in May and February. Senqu (SG) catchment generally experiences the highest wind speed, followed by the LO, Makhaleng (MG) and Mohokare (CG), respectively. The wind speed record along with relative humidity and temperature were used to calculate reference evapotranspiration as is subsequently described.

d) Reference evapotranspiration (ETo)

Monthly reference evapotranspiration (ETo) (mm/month) as calculated using the FAO ETo calculator tool (Figure 4-14) from wind-speed, relative humidity and temperature, is used in the estimation of catchment water losses through evapotranspiration. The output of the ETo Calculator is plotted in Figure 4-13 below.

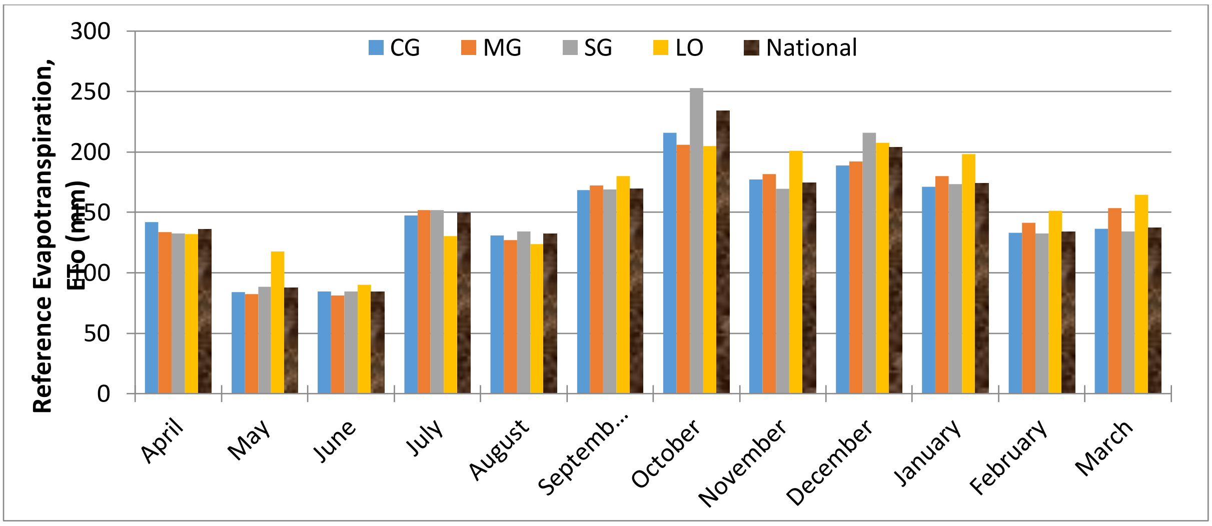


Figure 4-13: The calculated average monthly ETo for the fiscal year 2016/17

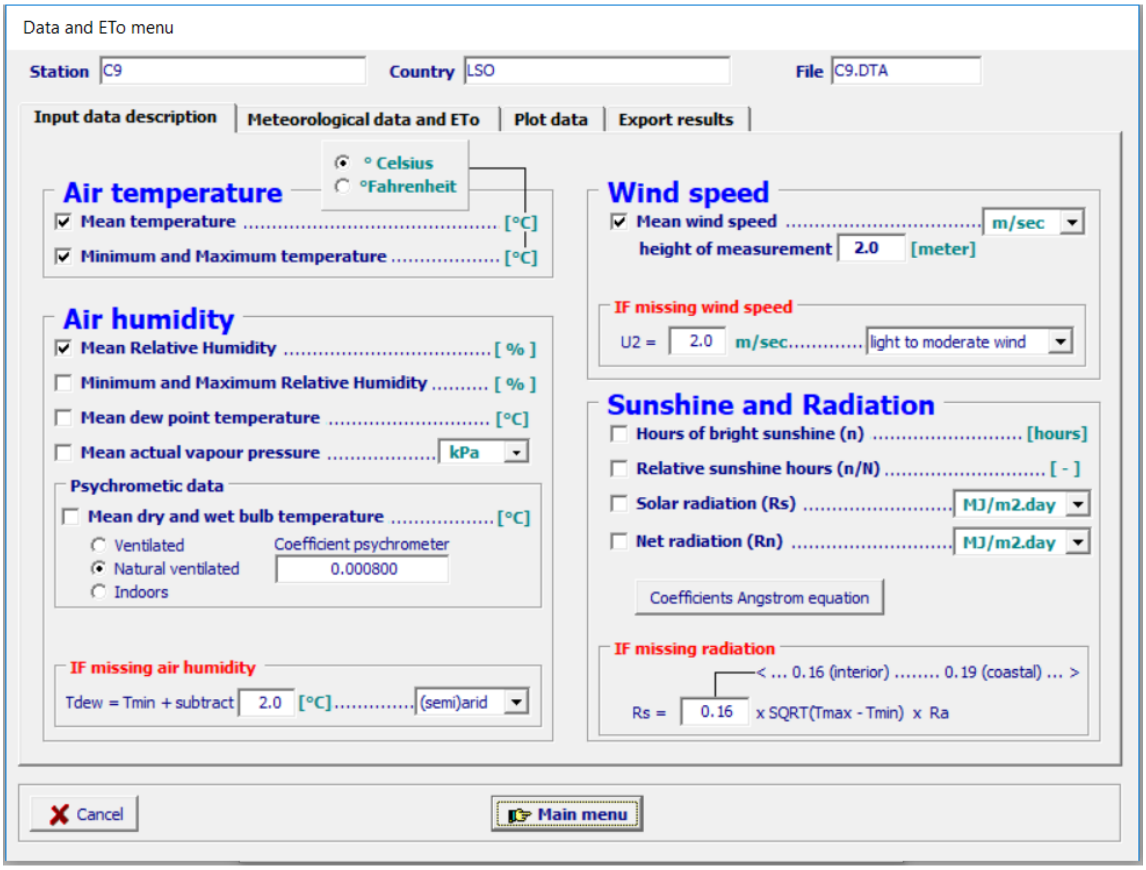


Figure 4-14: FAO ETo calculator tool

As Figure 4-13 depicts, the Senqu (SG) catchment experienced the highest ETo of all catchments in October 2016 and December 2017. This is sequentially followed by the LO area, Makhaleng (MG) and Mohokare (CG) catchments, respectively, for most of the months, ETo reached the lowest point in all catchments in June 2016. These catchments' ETo values were then used in the WEAP model to estimate catchments' actual evapotranspiration. Detailed ETo values for each incremental catchment are presented in Appendix 9.1-A.

e) The satellite observed versus the WEAP calculated actual evapotranspiration (ETa)

To estimate the actual water lost from the catchment through evapotranspiration, actual evapotranspiration (Eta) was calculated in the WEAP model from the FAO56 version of Penman-Monteith formulae. Due to absence of observed actual catchment-based evapotranspiration, the initial values of the effective evapotranspiration for use in the WEAP model to estimate the model's ETa were estimated based on the remotely sensed satellite's actual evapotranspiration from the NASA GES DISC. These effective evapotranspiration values were then modified during model calibration and the final values are presented in Appendix 9.1-B. The NASA GES DISC satellite actual evapotranspiration data is presented in Figure 4-15 for the fiscal year 2016/17.

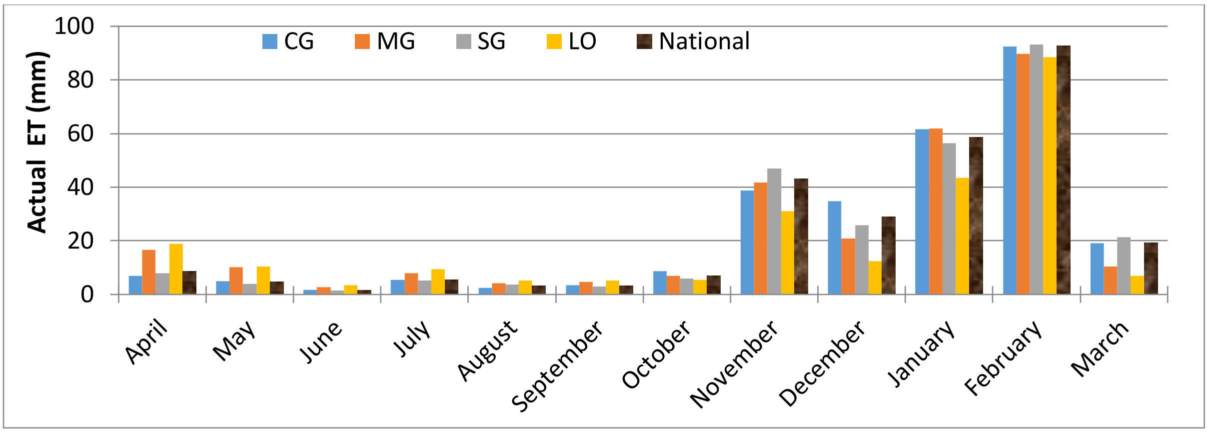
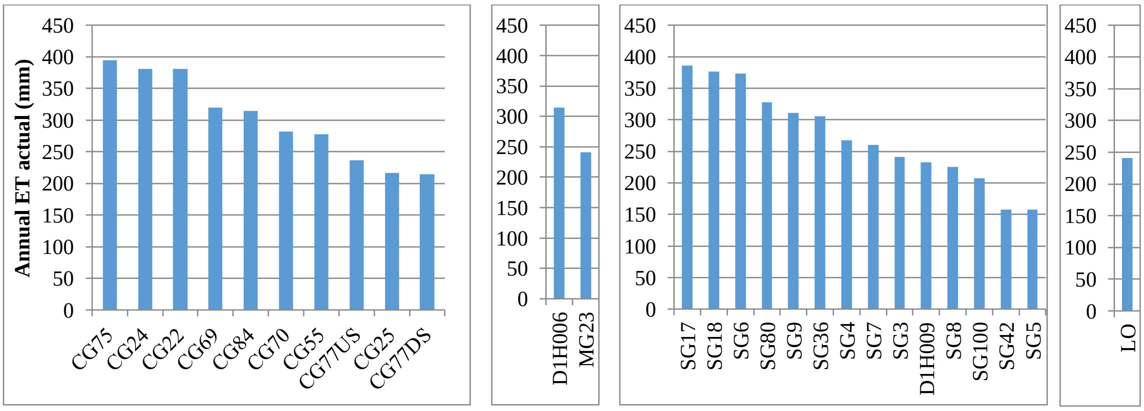


Figure 4-15: The 2016/17 actual total monthly evapotranspiration (ETa) for main catchments and country-wide as observed by NASA's satellites

As observed by the NASA's satellites, from April 2016 to October 2016, the NASA's satellites observed low evapotranspiration as compared to the relatively high values for the months between November 2016 and March 2017. The highest evapotranspiration was observed in February 2017 for all catchments.

Estimated actual evapotranspiration (ETa) values as estimated in the WEAP model for each incremental catchment are presented in Figure 4-16 below.



a) CG b) MG c) SG d) LO

Figure 4-16: The 2016/17 actual annual total evapotranspiration (ETa) at sub-catchment level

As can be seen in Figure 4-16 above, in 2016/17, the Mohokare (CG) catchment generally competes with the Senqu (SG) catchment for the highest ETa. Senqu also has the lowest ETa in the Matsoku (SG42) and the Senqu at Koma-koma (SG5) incremental catchments. The Makhaleng catchment experienced intermediate ETa. At national scale, summary monthly plot of ETa for each of the reporting years is depicted in Figure 4-17 below.

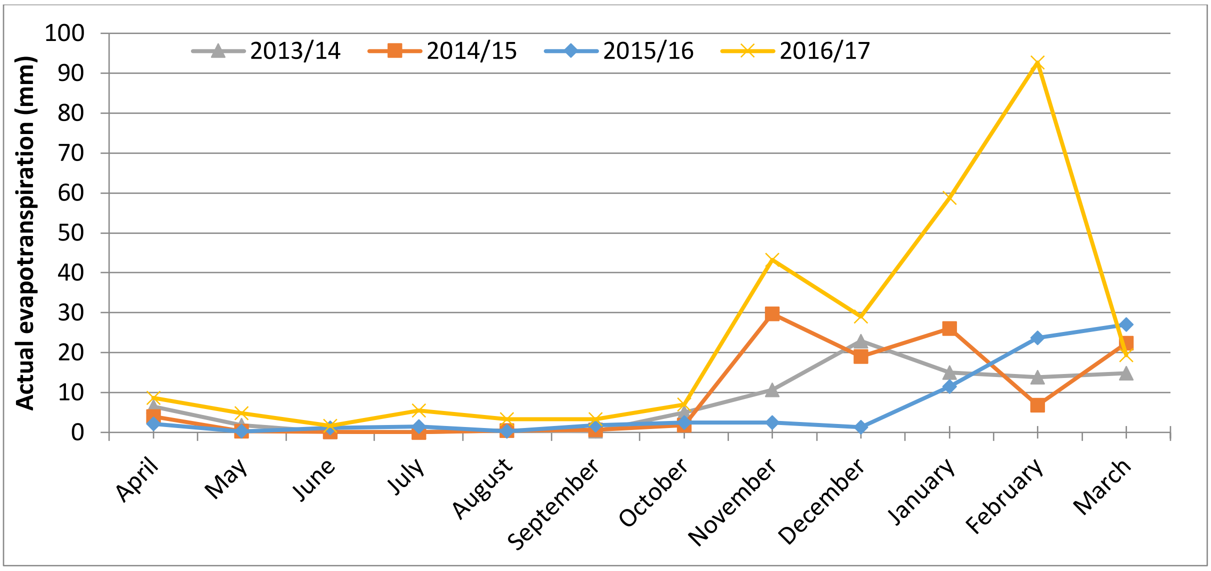


Figure 4-17: The 2016/17 actual total evapotranspiration (ETa) at national level in relation to the other years since 2013/14.

In general for the four years depicted, evapotranspiration is lowest during winter months of June and July, but highest in summer months of December and January, although extremely high in February 2017. This is generally in relation to temperatures that are lowest in winter and highest in summer.

4.4 Surface Water Resources

The monitoring of surface water resources is undertaken by the Department of Water Affairs. Limited monitoring, specific to the LHWP area, is also carried out by LHDA.

River and stream discharge is measured indirectly through the observation and subsequent conversion of water levels at gauging sites around the country. Analysis of the stream flow data reveals a total of 93 active stations country-wide, although only 53 stations are operational. In addition, water levels at the Katse, Mohale and ‘Muela Dams, as well as releases from these dams are monitored by LHDA. Of the 53 operational gauging stations, there are stations which are abandoned and vandalized. Some of these stations can still work but are not maintained, the hydrometric observers are no more on the ground while some stay very far from the stations thus deterring them from taking regular timely readings as expected and data is either not available or its integrity is affected as a result. The location and status of the surface water gauging stations are shown in Figure **4-18**.

Effectively monitored (hence calibrated) stations in the three catchments of the three main rivers, the Senqu (e.g. see Plate **4-1**), Mohokare and Makhaleng Rivers were selected for analysis in this report. There is a need to increase the number of effectively operational (monitored and calibrated) stations from the current six (6). The current low number of effectively operated stations is a result of lack of budgetary constraints and a shortage of qualified staff. There is a need to prioritise stations for rehabilitation and to programme and budget for this work.

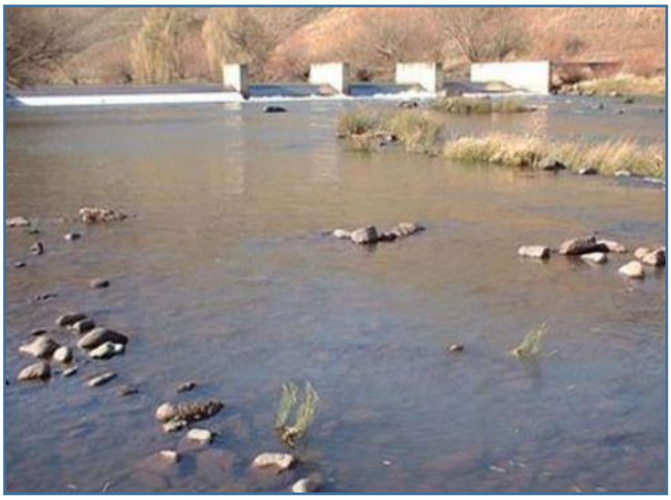


Plate 4-1: *Senqunyane River at Marakabei*

4.4.1 Water quantity

The average river daily flow values that were used to decide which incremental catchments were used in the study were obtained from the DWA, with the additional record from the LHDA. Additional information that was used to decide on the incremental catchments used in this study includes the consideration of the location of the approximate point where the water course leaves the border of Lesotho and the quality of the observed record. Quality of the observed hydrological record was decided based on the availability of the stage-discharge relationship at the hydrometric station (see Figure **4-18**) and its range of water levels for which it is applicable in relation to the height range of the cross-sectional profile, and the significance of the gaps in the observed water levels (as affected by the state of maintenance of the hydrometric station) (see Figure **4-19**). The stations that ware currently uncalibrated (with no established stage-discharge relationships) were excluded from the report regardless of how long the water level record is. The stations that are poorly observed (with significant gaps within their time series) were also excluded from the report regardless of how well calibrated the station was.

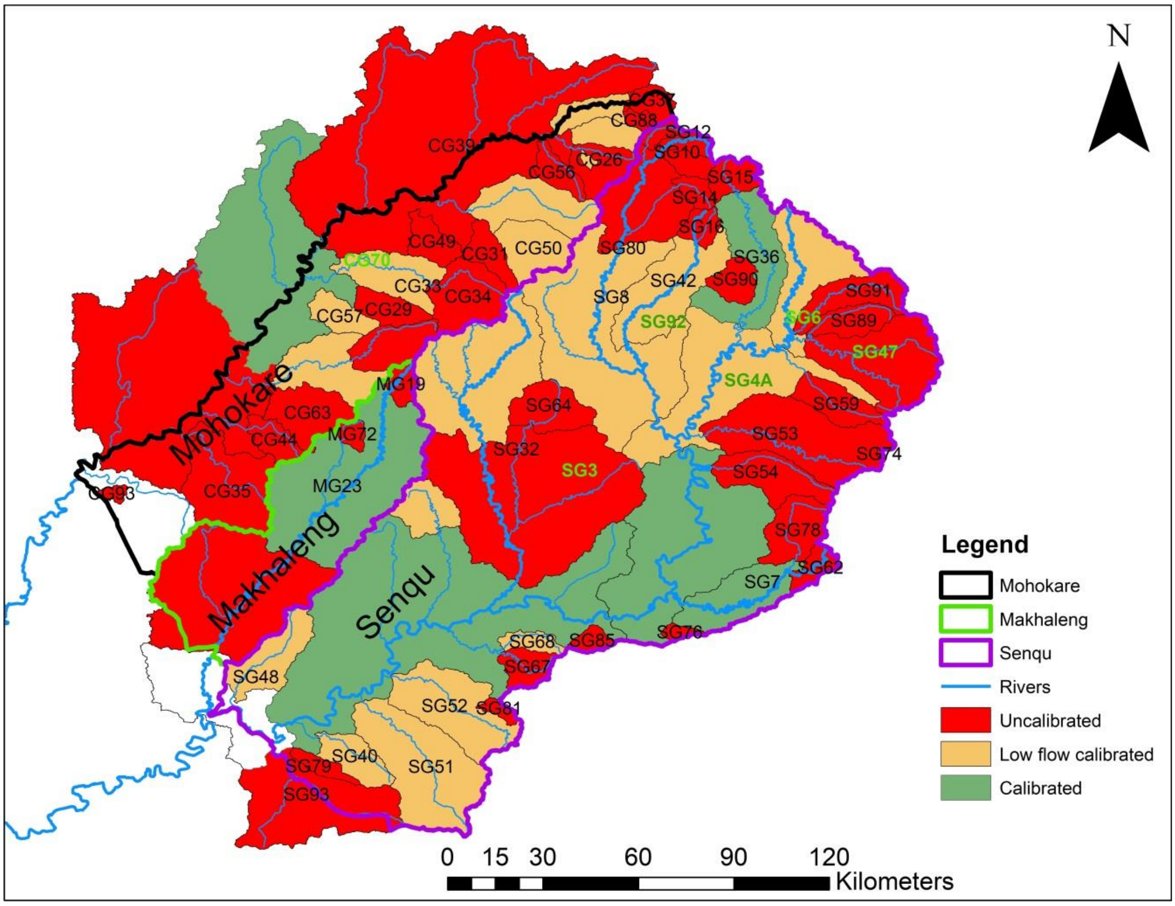


Figure 4-18: Calibration status of the national hydrometric stations

Due to unavailability of observed water levels and weir rating curve, the Senqu River weir at Ha ‘Mantilane (SG4A) was excluded from the analysis.

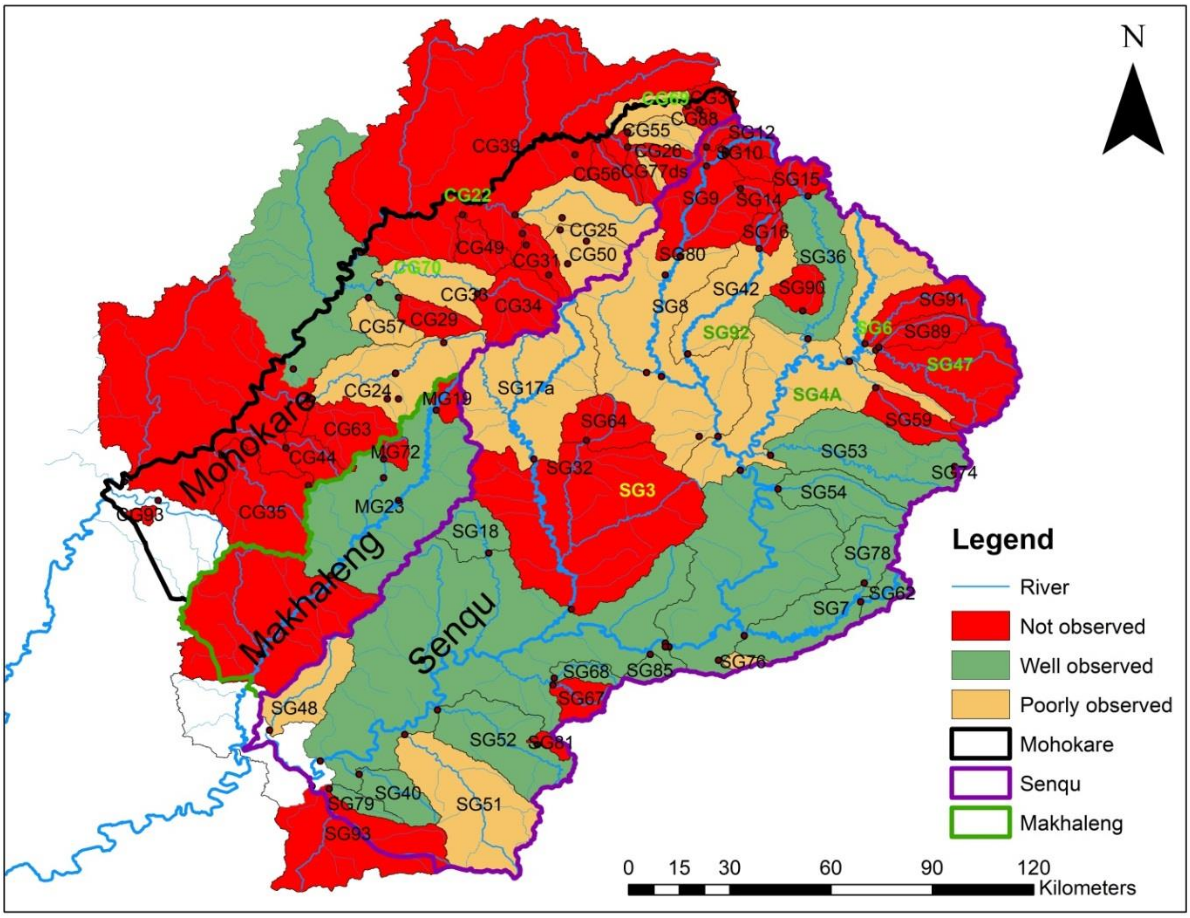


Figure 4-19: Observation status of the national hydrometric stations

Comparisons of simulated stream flows with observed flows, were made (see Table 4-6) at the following gauging sites that are representative to the three catchments: Mohokare River at Maseru (CG22), Makhaleng River at Ha Qaba (MG23) and Senqu River at Seaka Bridge (SG3). The observed (*obs.*) and simulated (*sim.*) monthly volumes together with their comparison ratios (*Sim./Obs.*) at these gauging stations are presented in the Appendix 9.2-A.

Table 4-6: Comparison of annual flow volumes per catchment at representative gauging stations per year from 2013/14 to 2016/17

Year	Volumes in Million Cubic Metres (MCM)								
	CG22			MG23			SG3		
	Obs.	*Sim.*	*Sim./Obs.*	*Obs.*	*Sim.*	*Sim./Obs.*	*Obs.*	*Sim.*	*Sim./Obs.*
2013/14	477	551	***1.2***	238	242	***1.0***	3384	3568	***1.1***
2014/15	412	462	***1.1***	75	84	***1.1***	2269	2264	***1.0***
2015/16	148	150	***1.0***	34	32	***1.0***	1102	1186	***1.1***
2016/17	533	543	***1.0***	94	92	***1.0***	3664	3591	***1.0***

Based on comparisons of the simulated and observed flow volumes in Table 4-6 above, it was considered that the WEAP model was sufficiently calibrated as the best fit ratio was 1.0 and the coarsest was 1.2. The model was then used to perform detailed water balance even for

ungauged locations for all the catchments of Makhaleng, Mohokare and Senqu Rivers at the point where they leave borders of Lesotho.

At the above selected gauging stations, the annual flow volumes have been decreasing consistently from the year 2013/14 through to 2017/17. The Senqu catchment consistently has the highest discharge volumes, followed by the Mohokare and the Makhaleng catchments, respectively.

4.4.2 Water quality

Surface water quality in rivers is monitored by the Department of Water Affairs. Measurements have been made for various purposes, sometimes as part of projects and as part of routine monitoring. According to the GIS database from the Department of Water Affairs, there are 80 operational water quality monitoring sites and these are shown on Figure **4-20**, 33 of which are in the Senqu catchment, 6 in the Makhaleng catchment and 41 in the Mohokare including the area in the Mafeteng District that does not belong to any of the three major catchments within Lesotho. However, measurements at most of these sites are rarely undertaken (see Table 4-9 and Table 4-10). Ten key sites have been chosen for regular monitoring. Three sites are located on the Senqu River, four on the Mohokare River and three on the Makhaleng River. Nonetheless, according to the monitoring records from the Department of Water Affairs, there is no apparent monitoring of the river water quality in the Senqu catchment. The parameters monitored include electrical conductivity (EC), pH, total dissolved solids (TDS), sulphates (SO_4); Phosphates (PO_4), Nitrates (NO_3), Suspended solids, Iron (Fe), Aluminium (Al), Manganese (Mn) and Fluoride (F). The water quality stations assessed are river stations.

The quality of surface water resources at catchment level and nationally as reported on in this study, at national and incremental catchment level, relied on the historical record of the physico-chemical analyses along with bio-indicator data for the recording period in relation to the established long-term average values (means and trends). These data were obtained from the DWA and LHDA as observed at the selected locations countrywide (see Figure **4-20**).

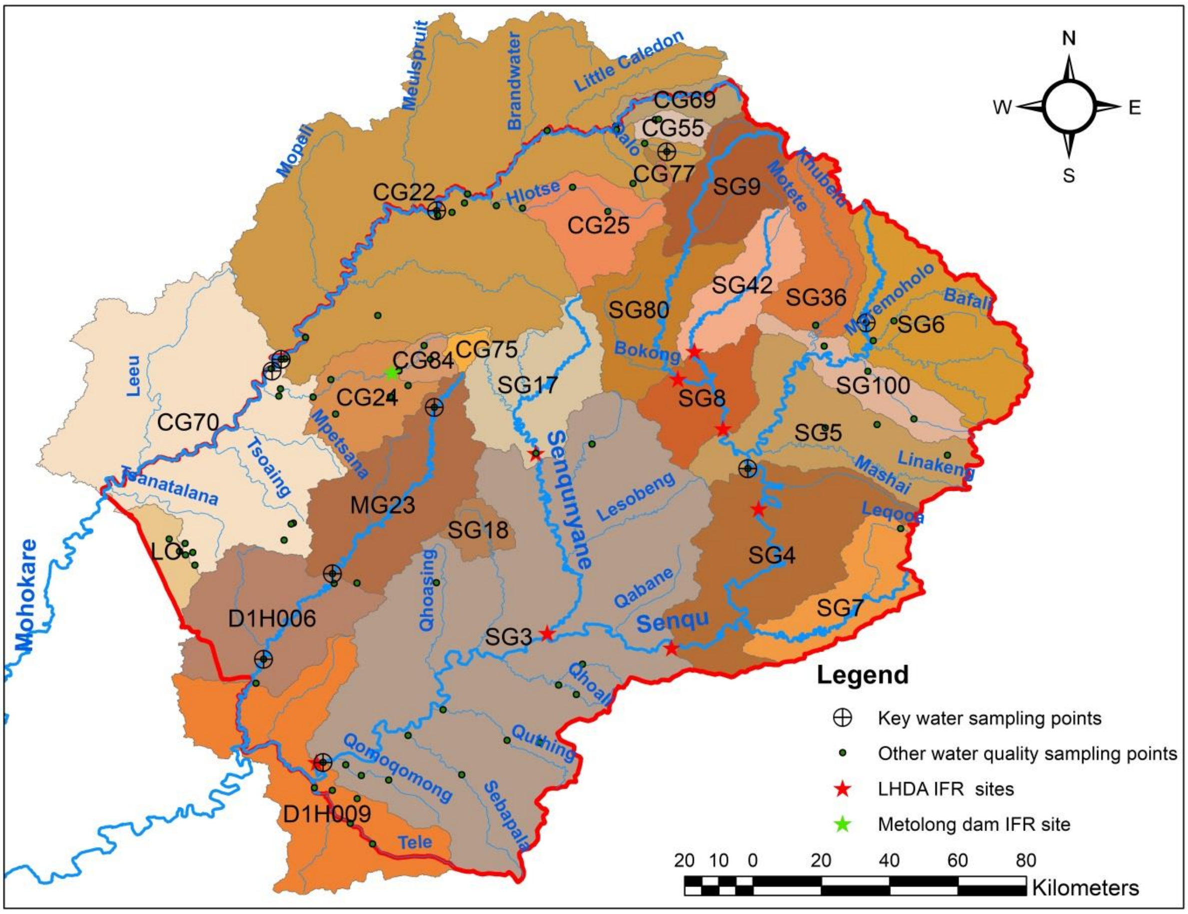


Figure 4-20: Surface water quality observation stations

The first State of Water Resources Report identified key sites for water quality monitoring and the parameters monitored were: conductivity, pH, Total dissolved solids, sulphates, phosphates, nitrates, total suspended solids, iron, aluminium, manganese and fluoride. The Department of Water Affairs do not monitor boreholes and springs on regular basis, that should normally be monthly. The proposition was suggested to be a quarterly measurement (CoW and WRP, 2012).

It is clear that water quality monitoring is still a huge problem and it remains a challenge. Recent water quality observations, especially from the LHWP and Metolong dam area, have quite a number of parameters and this would be good data for modelling if the parameters are monitored continually. The conclusion that was drawn from the results was that the nitrates concentrations showed sanitary problems of animal waste. Another possible cause could be fertilizers. Trends in water quality parameters were derived with respect to the same periods of the previous State of Water Resources reports, and then presented in this report of 2016/17. The same three main catchments of Lesotho and their key sub-catchments historically categorized according to key gauging stations (Figure 4-1) were used in the study.

The quality of river waters may vary with time and space. However, for an established water quality monitoring station along a river, only variation with time is recorded. These river water quality parameters, together with how they vary with time, their recommended

monitoring frequencies and monitoring instrumentation are presented in Table 4-7 below, as reported by the Department of Water Affairs.

Table 4-7: River water quality parameters variation and their measuring instrumentation

Parameter		**Temporal variation**	**Monitoring frequency**	**Instrumentation**
Catchment size (km^2)		-	Once-off	Planimeter
Sampling location (lat., long., alt.**)**		-	Once-off	GPS
Physico-chemical	Temperature	Time series	Continuous or monthly	Temperature sensor
	pH		Monthly	pH meter
	Dissolved oxygen			DO sensor
	BOD			Lab tests
	Total Dissolved Solids			TDS sensors, lab tests
	Electrical Conductivity		Continuous	EC sensors
	Turbidity		Continuous	Turbidity meter, turbidity tube
	Hardness		Monthly	Lab tests
	Alkalinity / acidity			
	Heavy metals	Time series		
	Nutrients			
	Other toxic metals			
	Organic chemicals			
Biological	Macro-invertebrates	Time series	Seasonal	SASS5 equipment
	Pathogens		Monthly	Lab tests
	Fish		Seasonal	Electro-shockers, nets
Sediment transport	Suspended sediment (g/m^3)	Time series	Monthly or event-based	Sampling bottle or pump-sampler
	Bed load (kg/day)	Time series		Runoff tubes, bed-load trench, bed-load traps, etc.

Information presented in Table 4-7 above is the desired one because some of the parameters such as BoD are not observed. Locations for collecting river water samples for laboratory analyses include the Senqu River at Phahameng in the Mokhotlong District (Plate 4-2).

Plate 4-2: River water quality sampling point at Senqu River at Phahameng Mokhotlong

River water physico-chemical parameters are observed In Situ on a monthly basis. These observations are performed by the DWA, although the LHDA also performs these observations at the established in-stream flow requirements (IRF) monitoring sites. There are no data loggers with appropriate water quality sensors such as pH, electrical conductivity and temperature installed at any sampling location for higher temporal resolution record. Biological parameters can only be recorded In Situ by technical personnel. These factors together render the monitoring of river water quality unsustainable especially in rampant shortage of transport in Government Ministries. It is therefore recommended that appropriate water quality data loggers be installed.

Water quality of three main catchments of Lesotho and nationally, as assessed for electrical conductivity as summarized in Table 4-8 below.

Table 4-9: Electrical conductivity (µS/m) of the river water of Lesotho

Catchment		2012/2013	2013/2014	2014/2015	2015/2016	2016/2017
Senqu (SG) *(Recommended annual sample size is 564)*	Sample size	-	-	-	-	-
	Minimum (µSm)	-	-	-	-	-
	Median (µSm)	-	-	-	-	-
	Mean (µSm)	-	-	-	-	-
	Maximum (µSm)	-	-	-	-	-
	Range (µSm)	-	-	-	-	-
Makhaleng (MG) *(Recommended annual sample size is 72)*	Sample size	1	6	0	7	6
	Minimum (µSm)	122.2	84.5	-	106.3	113
	Median (µSm)	122.2	150.2	-	184.5	156
	Mean (µSm)	122.2	177.8	-	211.1	146.1
	Maximum (µSm)	122.2	293.0	-	517.0	167.0
	Range (µSm)	0.0	208.5	-	410.7	54.0
Mohokare (CG) *(Recommended annual sample size is 948)*	Sample size	13	24	17	34	60
	Minimum (µSm)	55.4	37.4	18.2	0.79	0
	Median (µSm)	154.9	174.9	260.5	172.75	153.1
	Mean (µSm)	160.3	200.4	269.4	179.5	173.1
	Maximum (µSm)	364.0	444.0	463.0	463.0	375.0
	Range (µSm)	308.6	406.6	444.8	462.2	375.0
National (Recommended annual sample size is 1680)	Sample size	14	30	17	41	67
	Minimum (µSm)	55.4	37.4	18.2	0.79	0
	Median (µSm)	124.1	166	261	177	154.1
	Mean (µSm)	150.0	195.9	272.4	186.9	170.3
	Maximum (µSm)	364.0	444.0	454.0	517.0	375.0
	Range (µSm)	308.6	406.6	435.8	516.2	375.0

Source: Data from the Department of Water Affairs

As can be seen in Table 4-9, rivers in the Senqu catchment have not been sampled from 2012/13 through to 2016/17 even though it has sampling locations for river water quality. The Makhaleng catchment had 6 samples in the year 2016/17 whereas the recommended sampling rate is 72 samples per year based on monthly sampling schedules. In the Makhaleng Catchment, electrical conductivity (EC) ranges from 113 µSm to 167 µSm in the review year of 2016/17. The analysis of the mean values for the period since 2012/13 shows erratic pattern without any trend. Since 2012/13, the Mohokare catchment had between 13 (in 2012/13) and 60 (in 2016/17) samples per year out of the recommended annual rate of 492 samples. In this catchment from 2012/13 to 2016/17 the observed EC values range from 0.79 µSm to 463µSm, in the same year of 2015/16. However, for the year 2016/17, the observed values were 0 µSm and 375 µSm for the minimum and maximum, respectively. Of the two catchments that have observations Mohokare has the most extreme values of EC with both the lowest and highest in 2016/17.

In terms of the nitrates, water quality for surface water of Lesotho is presented in Table 4-10.

Table 4-10: Nitrates of the river surface water of Lesotho

Catchment		2012/2013	2013/2014	2014/2015	2015/2016	2016/2017
Senqu (SG) *(Recommended annual sample size is 396)*	Sample size	-	-	-	-	-
	Minimum (mg/L)	-	-	-	-	-
	Median (mg/L)	-	-	-	-	-
	Mean (mg/L)	-	-	-	-	-
	Maximum (mg/L)	-	-	-	-	-
	Range (mg/L)	-	-	-	-	-
Makhaleng (MG) *(Recommended annual sample size is 72)*	Sample size	1	6	0	7	6
	Minimum (mg/L)	1.3	1.3	-	0	0.5
	Median (mg/L)	1.3	2.05	-	0.9	1.6
	Mean (mg/L)	1.3	2.1	-	0.9	1.8
	Maximum (mg/L)	1.3	3.5	0.0	2.2	4.6
	Range (mg/L)	0.0	2.2	0.0	2.2	4.1
Mohokare (CG) *(Recommended annual sample size is 492)*	Sample size	13	24	17	34	60
	Minimum (mg/L)	0	0	0	0	0
	Median (mg/L)	1.7	1.2	3.1	0	0
	Mean (mg/L)	7.0	1.6	22.6	1.2	1.3
	Maximum (mg/L)	28.8	8.3	395.0	6.5	13.0
	Range (mg/L)	28.8	8.3	395.0	6.5	13.0
National (Recommended annual sample size is 960)	Sample size	14	30	17	41	66
	Minimum (mg/L)	0	0	0	0	0.5
	Median (mg/L)	1.5	1.4	3.7	0	0
	Mean (mg/L)	6.9	1.7	26.2	1.2	1.3
	Maximum (mg/L)	28.8	8.3	395.0	6.5	13.0
	Range (mg/L)	28.8	8.3	395.0	6.5	12.5

Source: Data from the Department of Water Affairs

In the Makhaleng catchment as indicated in table above, since 2012/13, the minimum nitrates concentration was once 0 mg/L in the year 2015/16 and the maximum reached was 4.6 mg/L in the year of 2016/17. The Mohokare catchment nitrates concentration ranges from 0 mg/L in all years to 395 mg/L in 2014/15, whereas the 2016/17 had the maximum of 13.0 mg/L.

The Total Dissolved Solids (TDS) (Appendix 9.2-B) ranged from 0 mg/L to 148 mg/L in the Makhaleng catchment whereas pH (Appendix 9.2-C) ranged from 6.9 to 8.3 in the years from 2013/14 to 2016/17, with the maximum value of 88 mg/L in 2016/17. The Mohokare catchment TDS ranged from 0 mg/L to 395 mg/L in the same years (i.e. 2013/14 to 2016/17), but with the maximum of 252 mg/L in the year 2016/17. There has been no peculiarity in the pH observations in the observed catchment with the ranges from 6.6 to 9.6, but with the observed maximum pH value of 8.8 in the Mohokare catchment against 8.2 of the Makhaleng catchment in 2016/17.

From the data presented, it is not possible to draw any conclusions whether in terms of picking trends or calculating meaningful statistics due to insignificant sample sizes.

4.5 Groundwater Resources

Groundwater resources are monitored by the Department of Water Affairs through observations of springs as well as in monitoring boreholes.

Figure 4-21 shows the locations of all operational key monitoring boreholes and springs distribution in Lesotho. The distribution of natural springs is all over the country while the monitoring boreholes are restricted to the lowlands of the Mohokare and Makhaleng catchments.

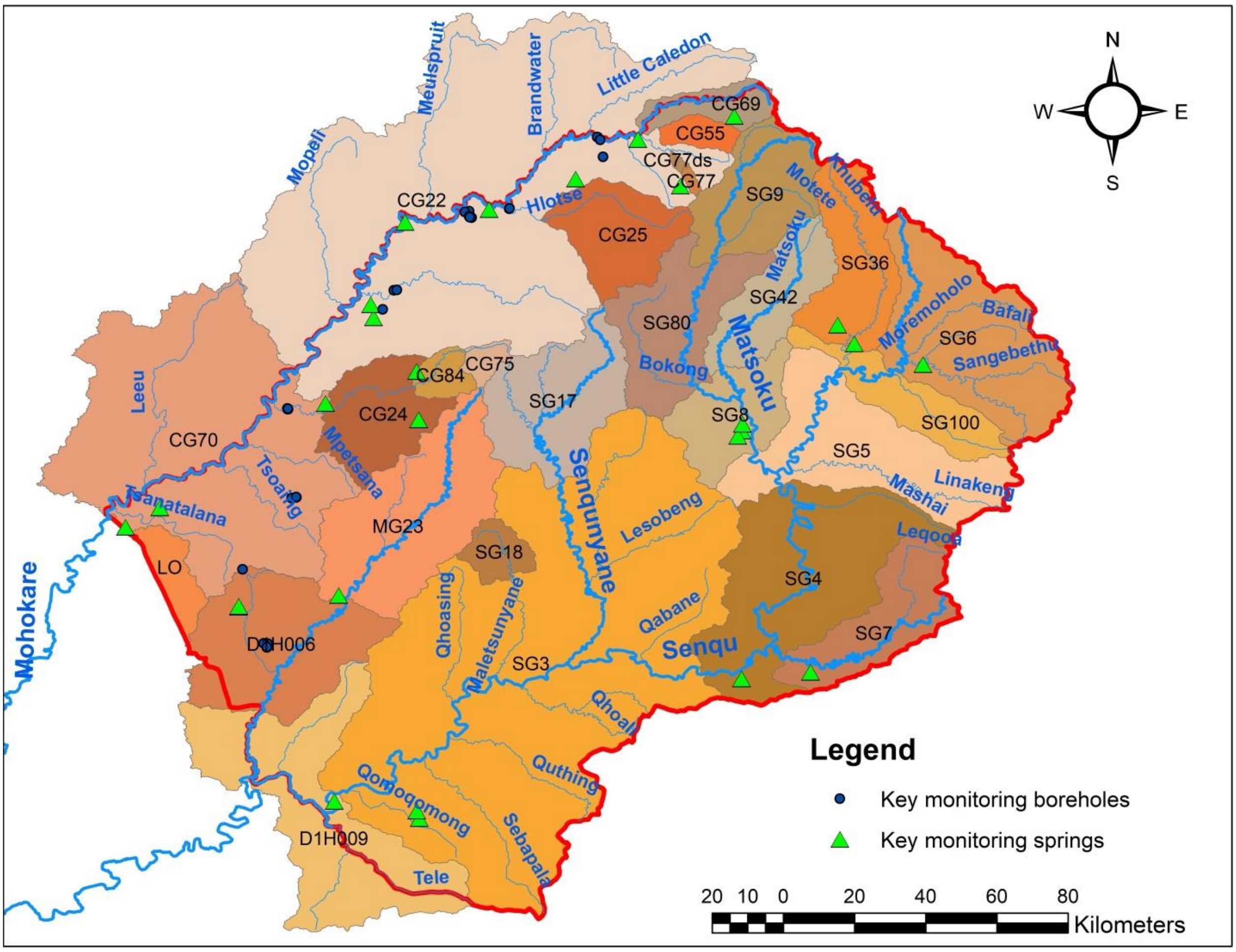


Figure 4-21: Groundwater quantity and quality observation stations

Groundwater quality for incremental catchments is observed from natural monitoring springs but not boreholes. It describes mineralogy of rocks through which it flows before erupting as natural spring.

4.5.1 Boreholes

A number of key observation boreholes for each of the 7 main well-fields, the Maputsoe, Matukeng, Morija, Berea, Botha-Bothe, Mafeteng and Likotsi Aquifers, have been selected. In future, at least quarterly readings should be carried out for these key observation boreholes. Groundwater resources at national and catchment levels were assessed and reported on in terms of water resources quantity and quality. The dynamic groundwater quantities per catchment (COW and WRP, 2012; COW, 2013), were also estimated using the WEAP model.

The distribution of monitoring boreholes is not adequate as the actively monitored (key boreholes) are all located in the lowlands, with none in the Senqu Valley and the highlands of

Lesotho. The frequency of monitoring is also low and irregular due to high operational costs. The irregular monitoring presents a challenge in drawing meaningful conclusions from the data. Therefore it is recommended that a regular monitoring programme is developed and strictly adhered to. Borehole water is not at all sampled for water quality determination, which should be done.

Although with low rates, borehole water parameters are expected to vary. It is necessary to observe how borehole water parameters vary with time, recommend observations frequencies in order to establish their rate of variation as well as the instrumentation used in monitoring as presented in Table 4-11.

Table 4-11: Borehole water monitoring parameters

Parameter		Temporal variation	Monitoring frequency	Instrumentation
Yield (l/s)		Time series	Once-off	Same as in springs
Location (lat., long., alt.)		-	Once-off	GPS
Vicinity land-use map		Time series	Seasonal	Remote sensing technology
Borehole's aquifer flow net		Time-varying pattern	Seasonal	Monitoring boreholes, borehole pumps, etc.
Borehole water levels (m)		Time-varying pattern	Daily or monthly	Water level sensors
Physico-chemical	Temperature	Time series	Same as in rivers (monthly)	Same as in rivers
	pH			
	Dissolved oxygen			
	BOD			
	Total Dissolved Solids			
	Electrical Conductivity			
	Turbidity			
	Hardness			
	Alkalinity / acidity			
	Heavy metals			
	Nutrients			
	Other toxic metals			
	Organic chemicals			
Biological	Pathogens	Time series	Monthly	Lab tests

Routine monitoring of boreholes is recommended to be performed on monthly basis to cover observation of depth to water, performance of In Situ water quality testing (temperature, pH, total dissolved solids and electrical conductivity) and grabbing of water samples for detailed laboratory analyses. To obtain daily water level in the boreholes, there is a need to install water level loggers for continuous level observation. However, where data gaps already exist, there is a need to develop groundwater models for use to infill data gaps. There is also a need to develop strategy to collect the rest of the borehole data that is not collected.

Where monitoring boreholes are available, groundwater level observations are summarized per catchment in Table 4-12and Figure 4-22 below.

Table 4-12: Annual borehole water level fluctuation range within catchments

Year / Range		Observed incremental catchment					
		LO	***CG22***	***CG24***	***CG70***	***D1H006***	***D1H009***
2009/10	*Sample size*	10	17	10	20	26	5
	Range(m)	0.52	4.76	0.49	9.54	20.24	0.48
2010/11	*Sample size*	0	0	1	6	0	0
	Range(m)	-	-	0	0	-	-
2011/12	*Sample size*	1	19	9	10	12	4
	Range(m)	0	7.73	2.11	17.92	0	0
2012/13	*Sample size*	14	16	10	19	26	7
	Range(m)	3.7	3.04	0.54	5.27	11.98	6.76
2013/14	*Sample size*	10	23	14	28	28	8
	Range(m)	0.28	2.52	2.63	17.09	7.22	6.85
2014/15	*Sample size*	23	52	24	46	48	9
	Range(m)	0.73	8.23	1.61	15.64	10	2.77
2015/16	*Sample size*	17	42	20	47	40	6
	Range(m)	0.46	4.68	0.81	7.66	11.72	0.95
2016/17	*Sample size*	6	11	0	3	13	4
	Range(m)	0	0	0	15.2	0	0

From the data presented in Table 4-12 above, it can be seen that borehole observation in the fiscal year 2016/17 indicate that borehole water level fluctuations occurred only in the CG70 which is mainly in the south-western districts of Mafeteng and part of Maseru. However, the numbers of observations were too few to draw any realistic situation. Therefore, it was not possible to draw any conclusions in terms of picking trends relative to previous years observations or calculating meaningful statistics due to the insignificant sample sizes.

4.5.2 Natural springs

The discharges of springs and water quality of groundwater through springs are not monitored on a regular basis. This is a major gap and it is now proposed to introduce a sampling programme at the springs which should be sampled on at least a quarterly basis. According to the GIS database of the Department of Water Affairs, a total of 139 springs are monitored although many of these are checked very infrequently. Three representative springs for each of the 10 districts have been selected as key monitoring springs. In future, at least quarterly readings should be carried out for these key observation springs.

Springs water parameters as expected to vary with time need to be regularly monitored using appropriate instrumentation for each parameter. The spring water parameters, how they vary with time, the recommended observation frequencies as well as the instrumentation used are presented in Table 4-13.

Table 4-13: Spring monitoring parameters

Parameter		Temporal variation	Monitoring frequency	Instrumentation
Yield (l/s)		Time series	Monthly	Stop-watch and known volume bucket
Location (lat., long., alt.)		-	Once off	GPS
Physico-chemical	Temperature	Time series	Same as in rivers (monthly)	Same as in rivers
	pH			
	Dissolved oxygen			
	BOD			
	Total Dissolved Solids			
	Electrical Conductivity			
	Turbidity			
	Hardness			
	Alkalinity / acidity			
	Heavy metals			
	Nutrients			
	Other toxic metals			
	Organic chemicals			
Biological	Macro-invertebrates	Time series	Seasonal	Same as in rivers
	Pathogens		Monthly	

Not all parameters presented in Table 4-13 above are monitored for each spring. Only In Situ parameters such as spring yield, temperature, pH, total dissolved solids and electrical conductivity and turbidity are measured on monthly basis at each monitored spring. Similarly, as the spring data are collected on monthly basis, it is recommended that a spring model for water quantity and quality be developed in order to obtain daily time series record. It is also recommended that for the parameters that are not observed In Situ, water samples be grabbed and transported for testing in the laboratory in Maseru. Macroinvertebrate assessment should also be introduced to springs to deduce the overall quality of spring water for drinking purpose.

The example springs that are used for monitoring groundwater include the one of Terateng Ha Mashapha, Mafeteng (Plate 4-3).

Plate 4-3: Natural spring of Ha Mashapha in Mafeteng District

A summary of the spring yields per major catchments are presented in Table 4-14 and Figure 4-22 below.

Table 4-14: Summary of spring yields (m^3/d) found in the major catchments of Lesotho

Catchment		2010/11	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17
Senqu (SG) *(Recommended annual sample size is 564)*	Sample size	3	34	24	97	126	94	3
	Minimum ((m3/d)	7.8	0.0	0.0	0.0	0.0	0.0	1.2
	Median (m3/d)	12	18	10	16	12	6	10.4
	Mean (m3/d)	13.5	36.5	15.5	33.2	26.0	17.1	7.6
	Maximum (m3/d)	20.7	186.6	54.4	191.8	172.8	163.3	11.2
	Range (m3/d)	13.0	186.6	54.4	191.8	172.8	163.3	10.1
Makhaleng (MG) *(Recommended annual sample size is 168)*	Sample size	6	9	19	15	0	30	0
	Minimum (m3/d)	15.6	5.2	7.8	2.6	-	0.0	-
	Median (m3/d)	26.8	51.8	24.2	16.4	-	8.2	-
	Mean (m3/d)	32.3	47.8	31.4	23.0	-	16.8	-
	Maximum (m3/d)	57.9	79.5	84.7	56.2	-	88.1	-
	Range (m3/d)	42.3	74.3	76.9	53.6	-	88.1	-
Mohokare (CG) *(Recommended annual sample size is 948)*	Sample size	9	33	80	139	187	161	0
	Minimum (m3/d)	4.3	1.7	0.0	0.0	0.0	0.0	-
	Median (m3/d)	21.6	11.2	10.8	5.2	8.4	5.2	-
	Mean (m3/d)	25.9	34.8	15.7	15.7	13.7	12.9	-
	Maximum (m3/d)	101.1	233.3	119.2	292.0	102.0	197.9	-
	Range (m3/d)	96.8	231.6	119.2	292.0	102.0	197.9	-
National (Recommended annual sample size is 1680)	Sample size	18	76	123	251	360	23	3
	Minimum (m3/d)	4.3	0.0	0.0	0.0	0.0	0.3	1.2
	Median (m3/d)	21.2	18.1	12.1	9.5	10.4	0.0	10.4
	Mean (m3/d)	26.0	37.1	18.1	22.9	19.4	6.0	7.6
	Maximum (m3/d)	101.1	233.3	119.2	292.0	172.8	197.9	11.2
	Range (m3/d)	96.8	233.3	119.2	292.0	172.8	197.9	10.1

In general, the spring yields for the fiscal year 2016/17 were by far lower than all other years in the Senqu catchment, and this may be due to the fact that a very small sample size was grabbed in this year. There were no samples grabbed and analysed in both the Makhaleng catchments in 2016/17. From the data presented in Table 4-14 above, it is not possible to draw any conclusions whether in terms of picking trends or calculating meaningful statistics due to insignificant and zero sample sizes.

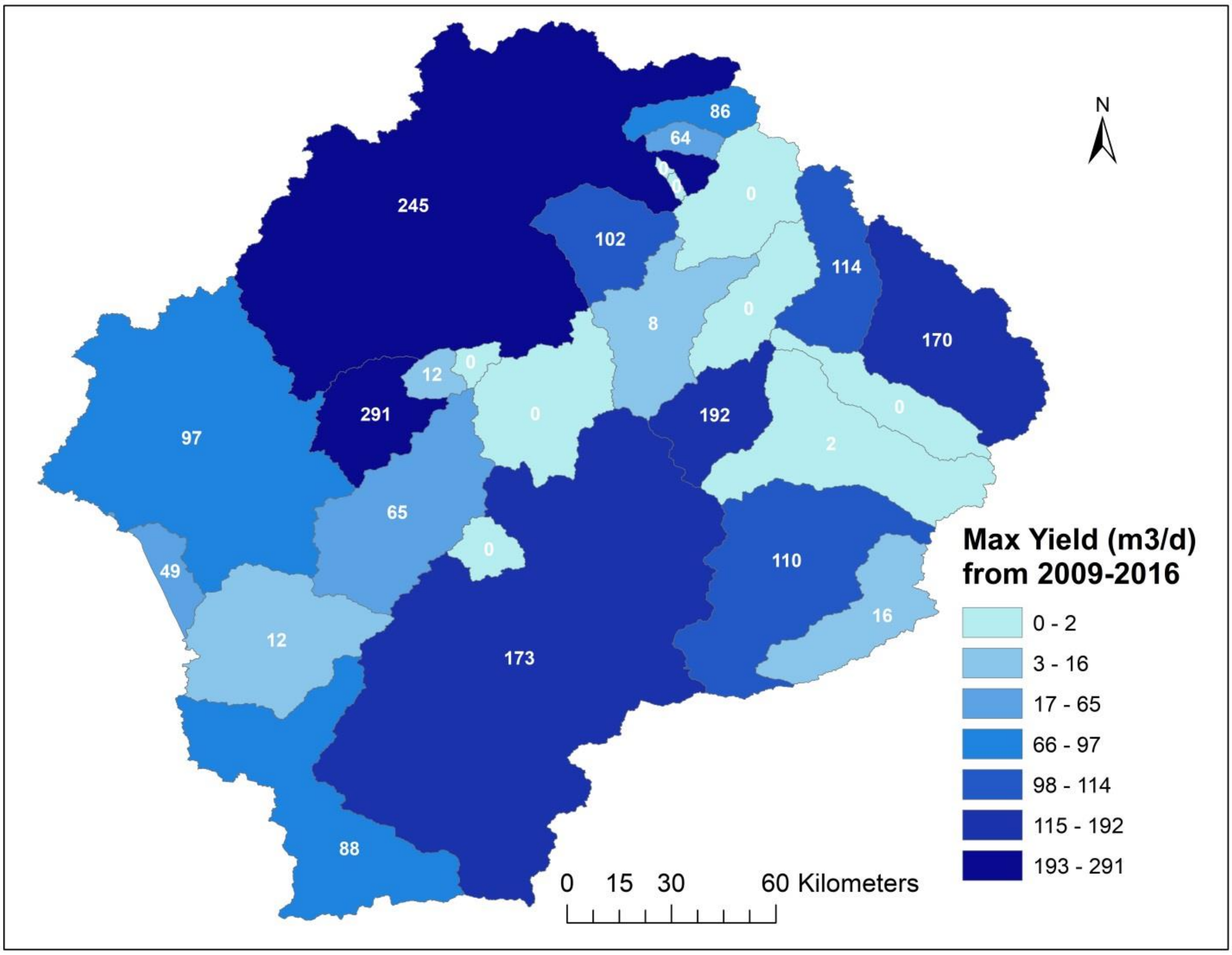


Figure 4-22: Spring maximum yield (m^3/day) per catchment

Available spring water data included the electrical conductivity (EC) (µSm), pH and salinity (ppt). The EC data is presented in Table 4-15 below while the pH and salinity are presented in Appendix 9.3-A and Appendix 9.3-B, respectively.

Table 4-15: Summary of spring water electrical conductivity (µS/m) in the three major catchments of Lesotho

Catchment		2010/11	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17
Senqu (SG) *(Recommended annual sample size is 564)*	Sample size	3	34	24	97	125	74	0
	Minimum (µS/m)	260	120	210	120	110	130	-
	Median (µS/m)	570	370	410	370	350	345	-
	Mean (µS/m)	513.33	445.71	500.63	416.60	403.44	378	-
	Maximum (µS/m)	710	1110	1160	1050	990	1020	-
	Range (µS/m)	450	990	950	930	880	890	-
Makhaleng (MG) *(Recommended annual sample size is 168)*	Sample size	6	9	19	15	0	4	0
	Minimum (µS/m)	130	130	130	140	-	250	-
	Median (µS/m)	275	250	250	250	-	251	-
	Mean (µS/m)	251.67	229.44	235.16	281.33	-	300.5	-
	Maximum (µS/m)	300	310	310	690	-	450	-
	Range (µS/m)	170	180	180	550	-	200	-
Mohokare (CG) *(Recommended*	Sample size	9	33	73	138	18	6	0
	Minimum (µS/m)	200	30	10	10	10	90	-

annual sample size is 948)	Median (µS/m)	300	200	200	240	300	270	-
	Mean (µS/m)	351.11	264	229.18	278	290.56	280	-
	Maximum (µS/m)	620	660	650	700	550	520	-
	Range (µS/m)	420	630	640	690	540	430	-
National (Recommended annual sample size is 1680)	Sample size	18	76	116	250	143	23	0
	Minimum (µS/m)	130	30	10	10	10	84	-
	Median (µS/m)	285	305	250	300	340	90	-
	Mean (µS/m)	345.00	341.04	286.32	331.94	389.23	340	-
	Maximum (µS/m)	710	1110	1160	1050	990	1020	-
	Range (µS/m)	580	1080	1150	1040	980	930	-

According to the record issued by the Department of Water Affairs for the fiscal year 2016/17, no spring-water quality analyses were performed. Therefore, it was not possible to relate the spring water quality of the year 2016/17 to that of previous years.

From the data presented in Table 4-15 above, it is not possible to draw any conclusions whether in terms of picking trends or calculating meaning statistics due to insignificant and zero sample sizes, especially due to the total lack of observations in the year 2016/17. Some suspiciously erroneous data has also been issued to contribute to this study, which the Department of Water Affairs have to check.

4.6 Wetlands

In spite of the presence of hydrological monitoring installations at Khalong-la-lithunya and Kotisephola (Figure 4-23) palustrine wetlands, for the 2016/17, there have been no hydrological observations made at the wetlands nor at their immediate downstream. Because of this, wetlands hydrology discussion is left out of this report. Based on the knowledge that the palustrine wetlands are not actively monitored for water quantity and quality, this study excluded the assessment of yields and quality of water from these wetlands.

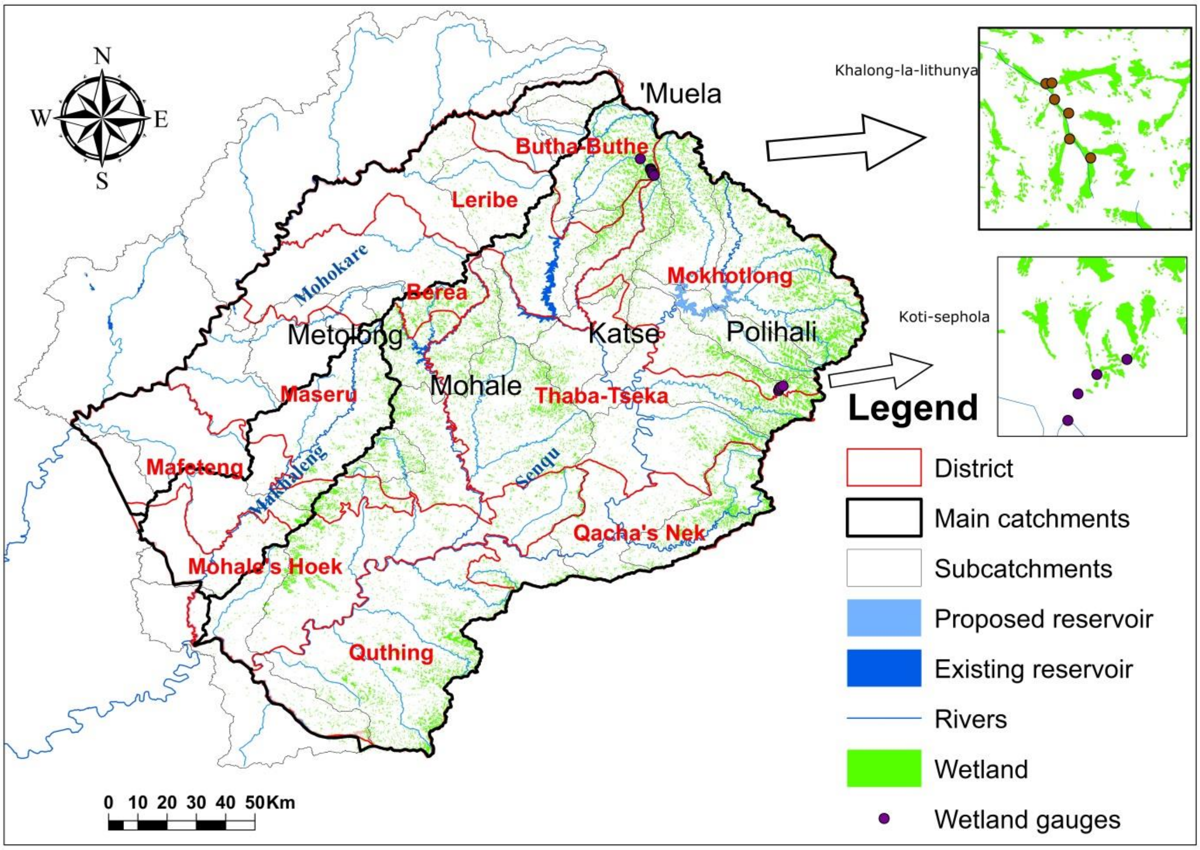


Figure 4-23: The palustrine wetlands of Lesotho

4.7 Reservoirs

Information on reservoir's (Figure **4-24**) water quantity as used in this report includes the stored water volumes. The reservoir water volumes are derived from the observed reservoirs water levels and the established storage-water levels relationships. Geometry information in relation to reservoir water volumes analyses were entered in the WEAP model for use in performing catchment water balance. Results on annual reservoir water storage are presented later in this report under the water balance chapter.

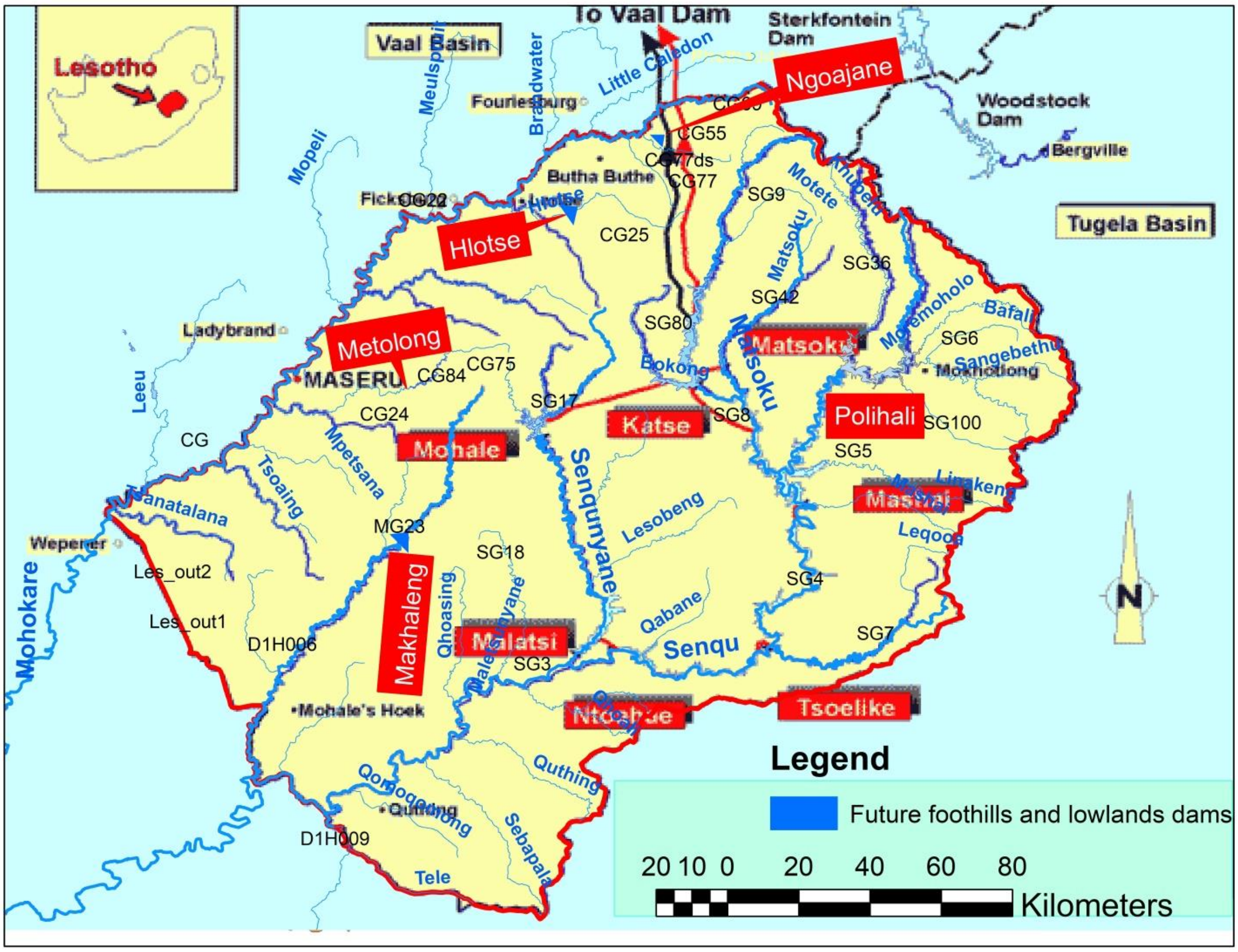


Figure 4-24: Lesotho current and proposed major dams' locations

Lesotho's Reservoirs as watercourses are also monitored for different parameters that also vary with time. These reservoir parameters, their variation with time, the instrumentation that is used for monitoring and the recommended monitoring frequencies are presented in Table 4-16.

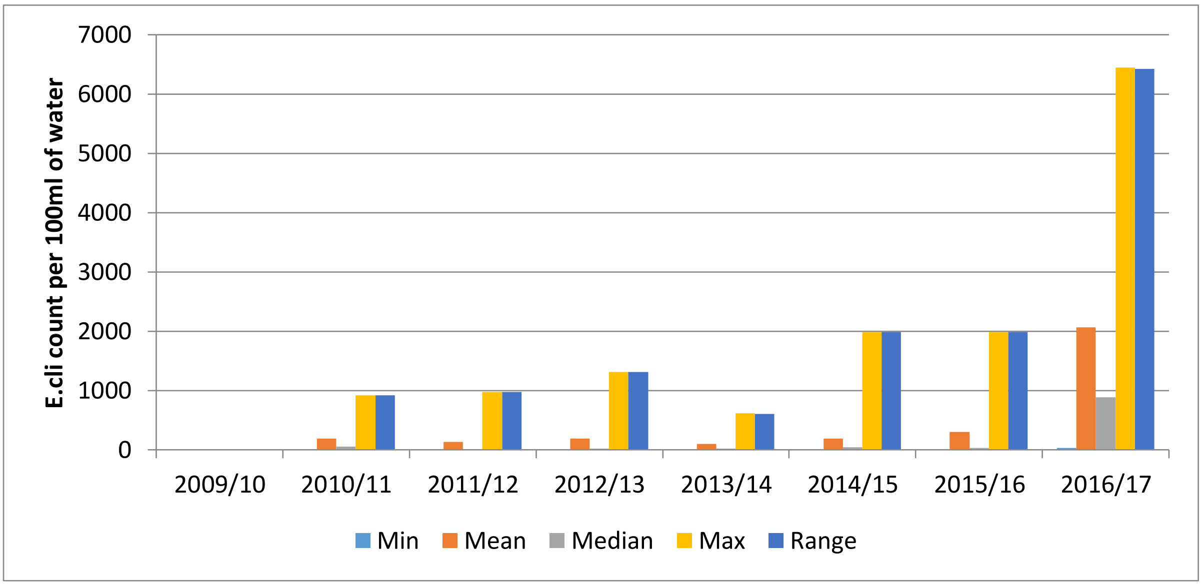
Table 4-16: Reservoir monitoring parameters

Parameter		**Temporal variation**	**Monitoring frequency**	**Instrumentation**
Catchment size (km^2)		-	Once-off	Planimeter
Physico-chemical	Temperature profile	Time series	Monthly	Same as in rivers
	pH		Same as in rivers (monthly)	
	Dissolved oxygen			
	BOD			
	Total Dissolved Solids			
	Electrical Conductivity			
	Turbidity			
	Hardness			
	Alkalinity / acidity			
	Heavy metals			
	Nutrients			
	Other toxic metals			
	Organic chemicals			

Biological	Pathogens	Time series	Monthly	Same as in rivers
	Fish		Seasonal	
Sediment load	Suspended sediment (g/m^3)	Time series	Monthly	Engine boat, life-jackets and GPS-integrated echo-sounders
	Sedimentation rate (mm/yr)		Seasonal	
Live storage	Bathymetry	Time-averaged time series	Annual	
	Volume-elevation relationship		Annual	
	Water levels	Time series	Continuous	Data loggers

Similar to river, reservoir water physico-chemical parameters are observed In Situ, normally on monthly basis. There are no instrumentation (data loggers) installed at any sampling location within reservoirs for high temporal resolution record of physico-chemical water parameters. Biological parameters can only be recorded *In Situ* by technical personnel even though in practice, these (macro-invertebrates) are not observed within major reservoirs as per SASS approach. Not all of the above-tabulated physico-chemical parameters are monitored for reservoirs. For instance, the BOD testing machine at DWA Lab is currently not working. Therefore, Table 4-16 presents the recommended list of parameters. Frequency of observations of these parameters is normally once a month. Therefore, for continuous time series record of these, there is a need to develop a water quality model of each catchment to produce results at daily resolution. Transport availability to the DWA still remains a major hindrance to routine monitoring of reservoirs.

Probably due to increasing population and economic activities along the reservoir, the water of the reservoirs, especially the Katse Reservoir is deteriorating in terms of microbial loads. As depicted in Figure 4-25 below, the trend of microbial load (e.g. E. coli) as observed in selected spots around and within the reservoir has been gradually increasing since 2009/10. However, there was a sudden increase in the E. Coli count in the fiscal year 2016/17, the courses of which should be investigated.



Source: LHDA (2017)

Figure 4-25: E. coli concentrations as sampled in the Katse reservoir.

4.8 Conclusions and Recommendations

As compared to the previous years of 2013/14 to 2015/16, the review year of 2016/17 saw the reversal of the downward trend in received rainfall volumes in which the rains of the 2016/17 were the highest in those picked years. Concerning evapotranspiration, there was no peculiar difference in experienced evapotraspiration in the three major catchments for the fiscal year 2016/17.

In general, the country has ample water resources for potential exploitation and these are detailed in Chapter 6.

It is generally recommended that a regular and systematic monitoring programme is developed and strictly adhered to for all water resources ranging from hydro-meteorological element (e.g. rainfall, relative humidity, wind speed, etc.) through surface water to groundwater to ensure that there is enough observed data for analyses and therefore reduce heavy reliance on insufficiently calibrated models.

5. Water Demands for different uses

This chapter provides an overview of water use by each of the main user sectors.

5.1 Introduction

The demand of water in Lesotho and globally is met through construction of water abstraction infrastructure. In Lesotho, major water infrastructure is on the surface water currently comprising three dams constructed under the LHWP programme namely Katse, Mohale and 'Muela Dams, with Polihali dam in the procurement stage. There is also the recently completed Metolong Dam that has been constructed under the Lowlands Water Supply Programme. The smaller reservoirs found predominantly in urban areas include the Sebaboleng and Maqalika dams in Maseru city, and the Skanska, Raleting, Tšalitlama, Tšanatalana and Tšakholo dams in Mafeteng town.

Groundwater abstraction infrastructure in the form of boreholes is clustered in the lowlands agro-ecological zone of the country. Urban areas that rely heavily on groundwater through boreholes include Mafeteng, Maputsoe and Botha-Bothe. Hlotse and Tejatejaneng towns have been supplied from well-points that are sunk along sandy river beds of Hlotse River, North Phuthiatsana River and Tejatejaneng River. Numerous sporadic water supply boreholes are drilled in rural areas by individual households while village gravity-fed water supply is addressed by the protected springs.

TAMS (1996) identified a number of water use sectors and this included;

- Domestic use
    - urban water supply and sanitation,
    - rural water supply and sanitation,
- agriculture,
- industry and commerce,
- hydroelectricity and
- environmental flows.

After the renewal of the 1986 LHWP treaty in 1998, LHDA was obliged to perform the Environmental Flow Assessment as part of the treaty and this is done for all the dams. As the LHWP system was designed to maximise water transfers to South Africa only 5% of MAR would be released downstream without any flush floods (IUCN, 2003). Environmental Flow release is also implemented in the Metolong Dam which is part of Lesotho Lowlands Water Supply Scheme.

In this study, water demands of Lesotho were built from categories of the domestic (non-WASCO serviced areas), WASCO serviced uses (domestic, institutional and industrial), mining, commercial water bottling, institutional (non-WASCO serviced rural schools, hospitals and LHWP villages) and agriculture (irrigation) (see Figure 5-1 below).

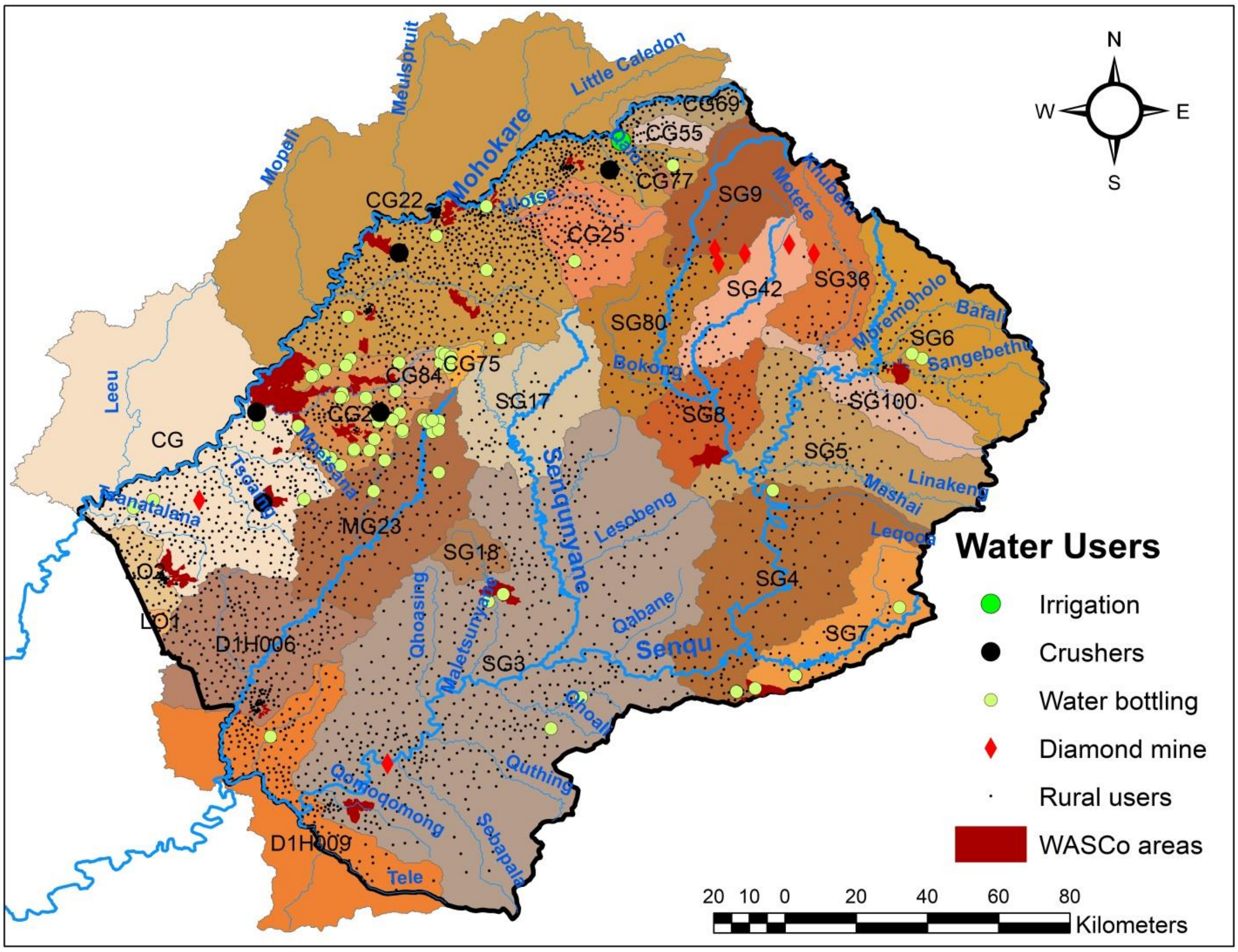


Figure 5-1: Water services and users distributions in Lesotho

Water supply is the amount of water that is distributed to users per day. The Water Act of 2008 requires that all abstracted raw water be metered at source. Purchase of meters for metering of abstracted raw water is the responsibility of the licensee. However, the responsibility to confirm compliance to license terms lies with the DWA. Lack of enforcement of raw water abstraction metering as well as meter reading by the DWA results in loss of data for use in water balance studies.

Water uses are categorized into consumptive and non-consumptive uses. The consumptive water uses consist of domestic, industrial and agricultural uses, whereas non-consumptive uses include hydropower generation, recreation and navigation. Industrial water use can be non-consumptive if water is used for machinery cooling, even though a consumptive use may include washing or mineral processing for mining industry. Agricultural uses include irrigation and animal husbandry.

The demand for water is the amount of water that is required to satisfy specified needs per day. These needs include consumptive and non-consumptive as classified by sectoral uses as indicated above.

Potable water demand for human consumption is a function of policy and human population. In this report, human population for two census year were available, with the 2006 census

having detailed population at village level whereas the 2016 census currently has the preliminary results with the overall population at national, district and enumeration areas levels while village names are still being verified by the BoS. This information was used to derive population for other years assuming linear population growth within the two census years and later. The following formula was therefore established to estimate population of each year for use in estimating potable water demand.

$$\boldsymbol{P_{Y_{Cur}}} = \boldsymbol{P_{Y_{Cen}}} \times \left[\mathbf{1} + \frac{N_G}{P_{Y_{Cen}}}\right]^{(Y_{Cur}-Y_{Cen})} \qquad \text{Eqn. 5-1}$$

where $P_{Y_{Cur}}$= population of the current year, $P_{Y_{Cen}} = 1{,}876{,}633$= population of the previous census year (or of any base year), $N_G = 12{,}691$ = net annual population growth (i.e. number of births less number of deaths), Y_{Cur} = current year for which population is being estimated, and $Y_{Cen} = 2006$ = year of previous census (or base year).

5.2 Domestic use

Water

1. Basic water use policy statement, i.e. every Mosotho is entitled to basic daily water amount of 30 litres/day (Government of Lesotho, 2007).
2. Population and its projection to date (Eqn. 5-1)
3. Daily Demand = Population x 30l/day

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Table 5-1. Population estimates for incremental catchments since the 2013/14 fiscal year

Catchment		Year			
Name	Area (sq. km)	2013/14	2014/15	2015/16	2016/17
CG24	715	99,613	100,244	100,879	102,161
SG6	1677	40,513	40,770	41,028	41,550
SG36	848	14,268	14,359	14,449	14,633
SG100	598	20,445	20,575	20,705	20,968
SG42	675	13,192	13,275	13,359	13,529
SG9	849	4,967	4,998	5,030	5,094
SG80	1017	30,107	30,298	30,490	30,877
SG8	692	33,393	33,605	33,818	34,248
SG5	1553	46,589	46,884	47/,181	47,781
SG7	796	15,920	16,020	16,122	16,327
SG4	2023	63,489	63,891	64,296	65,113
SG18	219	1,003	1,009	1,016	1,028
SG17	1107	14,943	15,038	15,133	15,325
SG3	7643	235,227	236,717	238,216	241,243
D1H006	1420	105,379	106,046	106,718	108,074

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MG23	1567	49,814	50,130	50,447	51,089
CG77	21	1,262	1,270	1,278	1,294
CG77ds	14	2,256	2,270	2,285	2,314
CG55	143	8,787	8,843	8,899	9,012
CG69	306	15,443	15,541	15,639	15,838
CG25	721	64,673	65,083	65,495	66,327
CG22	7181	672,991	677,254	681,544	690,205
CG75	97	4,400	4,428	4,456	4,512
CG84	162	13,431	13,516	13,602	13,775
CGd/s	4023	323,273	325,321	327,381	331,542
D1H009	1991	39,818	40,070	40,324	40,836
LO	259	30,747	30,942	31,138	31,533

5.2.1 Urban Water Supply and Sanitation

Urban water supply and sanitation is the responsibility of WASCO. WASCO provides potable water to 16 urban centres. Water is sourced from rivers via treatment plants, boreholes and springs and/or well points. Although the operational state has not been verified, Table **5-2** summarises the design capacities of the treatment plants and the recommended yield of boreholes and well points under the control of WASCO.

Table 5-2: Water Supply capacities at urban centres

Urban centre	**Production capacity (ML/day)**			
	Treatment plant	***Borehole / spring***	***Well points***	***Total***
Maseru	110.283			110.283
Maputsoe		4.50		4.50
Peka			0.25	0.25
Teyateyaneng	1.2	2.65		3.85
Hlotse	2.5	0.10	0.20	2.80
Botha-Bothe	0.6	0.46		0.60
Mokhotlong	0.7			0.70
Thaba-Tseka	0.4	0.30		0.70
Roma	0.44	0.44	2.50	2.94
Morija	0.1	0.22		0.32
Mafeteng	2.6	0.20		2.80
Mohale's Hoek	0.8	0.33		2.13
Moyeni	0.3	1.50		2.80
Qacha's Nek	0.2	0.60		0.80
Mapoteng	0.2			0.20
Total				**135.673**

Since the completion of the Metolong Dam project, Maseru, Tejatejaneng, Roma, Mazenod and Morija are supplied by the Metolong Water Treatment Plant (herein referred to as Maseru) thereby rendering their respective treatment plants in Table **5-2** above non-operational. However, due to unavailability of record on water extraction by WASCO, the catchment's water balance exercise relied on the actual water produced from the treatment plants, as presented in Table **5-3** below.

Table 5-3: WASCO Water production

	Megaliters Produced				**Source**
Operating Centre	**2013/14**	**2014/15**	**2015/16**	**2016/17**	R= River, D=Dam, S=Spring, A=Aquifer
Hlotse	442	469	467	472	Hlotse (R 100%)
Maputsoe	573	427	1,034	943	Mohokare (R 10%, A 90%)
Mafeteng	712	434	604	759	Likhoele (D) (90%; Duma 5%; Tsalitlama 5%)
Mohale's Hoek	471	137	503	526	Makhaleng (R 90%, A 10%)
Maseru	13,253	13,897	17,973	16,639	Metolong (D 90%); Mohokare (R 10%)
Quthing	229	145	248	275	Qomo-qomong (R 100%)
Qacha's Nek	218	190	244	223	Lijabatho (R 60%); Hill side springs (S 25%); Mosaqane (S 15%)
Thaba-Tseka	176	733	185	181	-
Mokhotlong	215	248	218	267	Mokhotlong (R 80%)
Butha-Buthe	376	243	365	388	Moroeroe (R 50%); Mohokare (R 5%); A 45%
Peka	94	861	168	144	Mohokare (R 100%)
T.Y.	452	419	502	483	Metolong (D 100%)
Roma	-	-	-	-	Metolong (D 100%)
Morija	-	-	-	-	Metolong (D 100%)
Mapoteng	-	-	-	-	'Makaliso (S 100%)

" - " No information available in the literature.

The unavailability of production record at Mapoteng compelled us to use the production capacity of the treatment plant for catchment water balance. The Semonkong urban centre (also due to data unavailability) was considered to be totally rural (refer to the next subsection) for the purpose of water balance in this study. The amount of water that was accounted for in the distribution network through metering is presented in Table **5-4** below.

Table 5-4: WASCO Water consumed

Urban center		*Megaliters Consumed*			
		2013/14	2014/15	2015/16	2016/17
Hlotse	Households	200	179	179	170
	Industrial	-	-	-	-
	Other	152	122	123	105
Maputsoe	Households	405	396	396	380
	Industrial	121	102	102	163
	Other	122	88	89	103
Mafeteng	Households	309	265	264	322
	Industrial	14	2	2	5
	Other	114	81	83	141
Mohale's Hoek	Households	159	175	173	175
	Industrial	-	-	-	-
	Other	60	56	57	66
Maseru	Households	3,492	5,356	4,164	3,735
	Industrial	3,142	3,144	3,389	3,778
	Other	3,041	2,866	2,372	2,369
Quthing	Household	92	89	87	90

	Industrial	-	-	-	-
	Other	54	47	48	50
Qacha's Nek	Households	70	76	76	76
	Industrial	-	-	-	-
	Other	59	59	59	63
Thaba-Tseka	Households	61	67	66	70
	Industrial	-	-	-	-
	Other	108	89	89	74
Butha-Buthe	Households	143	131	129	141
	Industrial	-	-	-	-
	Other	73	73	75	84
Peka	Households	45	78	50	46
	Industrial	-	-	-	-
	Other	5	15	75	9
T.Y	Households	229	1,702	271	259
	Industrial	-	-	-	-
	Other	62	64	75	77

The information presented in Table **5-3** and Table **5-4** above could be used to derive the non-revenue water (NRW) as the difference of produced and consumed water. In so doing, it could be realized that the NRW could range between 13% in 2014/15 at Qacha’s Nek and as high as 62% at Peka in 2016/17. There was no data available on water consumed in five WASCO serviced areas of Mokhotlong, Roma, Morija, Semonkong and Mapoteng. For these five urban centres, consumed water was estimated from the population figures and the 30l/day/person policy in the similar manner as applied to rural areas.

WASCO as the urban area water supply company is expected to collect water demand and supply data through population survey in urban areas (Table 5-6). The demand for water is expected to fluctuate on diurnal basis around a certain quantity in response to immigration and emigration (tourism activities). Based on information from the Department of Rural Water Supply District Information System (DIS) for 2013 to 2017, as depicted in Figure 5-4, and the GIS data issued by WASCO, the following Table **5-5** presents the urban population that is supplied with potable water by WASCO in each catchment

Table 5-5. Estimates of urban population supplied with potable water since 2013/14 per catchment

Name	2013/14	2014/15	2015/16	2016/17
CG24	0	0	0	0
SG6	6747	6790	6833	6876
SG36	0	0	0	0
SG100	0	0	0	0
SG42	0	0	0	0
SG9	0	0	0	0
SG80	0	0	0	0
SG8	3226	3247	3267	3288
SG5	2555	2571	2588	2604
SG7	0	0	0	0

SG4	0	0	0	0
SG18	0	0	0	0
SG17	0	0	0	0
SG3	10625	10692	10760	10828
D1H006	20,816	20,948	21,080	21,214
MG23	0	0	0	0
CG77	0	0	0	0
CG77ds	0	0	0	0
CG55	0	0	0	0
CG69	0	0	0	0
CG25	0	0	0	0
CG22	267,550	269,244	270,950	272,666
CG75	0	0	0	0
CG84	0	0	0	0
CGd/s	156,627	157,619	158,617	159,622
D1H009	1,985	1,998	2,010	2,023
LO	11,658	11,732	11,806	11,881

To enable compilation of figures on the amount of water that was supplied by WASCO in its service area, it is therefore recommended that the requisite information is regularly obtained from WASCO on the volumes of raw water abstracted as well as treated water that has been supplied to different types of consumers. This information would help to estimate non-revenue water. Collection of this information is hoped to be guided by the application of the format presented in Table 5-6.

Table 5-6: WASCO Water demand data collection system

Supply type		**Description**	**Type of meters**				**Observation frequency**
			None	***Conventional***	***Smart***	***GPS coordinates***	
Abstraction		The permitted direct metered water abstraction quantities and sources for all gazetted urban areas.	?	?	?	?	Daily
Domestic	***Potable***	Households and public prepaid supplies	?	?	?		
	Sewage		?	?	?	?	
Demand type		**Description**					
Domestic	***Location***	GPS coordinates of the centroid of the spring water demand					Once off
	Potable	Population per river catchment					Annual updates / projections
	Sanitation						

Currently, there are no GPS coordinates for WASCO's raw water abstraction points and also no meters. There are also no records for GPS locations for public standpipe and household supply meter locations as these would indicate water demand points. There are no meters installed to measure sanitary wastewater flowing out of households, and this implies there is no record to indicate household wastewater that needs to be treated. There is only one wastewater treatment plant in the country (i.e. the one at Agric. College in Maseru) in which inflowing wastewater is metered. These factors imply that Table 5-6 above is the recommended format for compilation of State of Water Resources Reports in the future.

WASCO either install conventional post-paid or prepaid meters which should be replaced with smart meters to ease collection of the actual spent amount of water per household and detect water losses through leakages at real-time.

It is not only important to meter potable water and sewage discharge but also critical as to what choice of meter type is used. With conventional meters, it is difficult and exorbitant to monitor water losses due to both leakages and human reading errors and meters by-passing both of which are detectable with use of smart metering. Inclusion of meter locations by recording meters coordinates would be a good indicator of spatial distribution of water supply services.

Sanitation services for all liquid household wastes from the old residential areas as well as the Central Business Districts (CBD) of all urban areas are provided by WASCO. The household solid wastes for these areas are handled by municipality or town-clerk offices in the Ministry of Local Government (MoLG). Sanitation services in the peri-urban areas where WASCO systems and municipality services are not provided remain the responsibility of households as they have to arrange private septic tanker services which are in the business to empty individual households septic tanks and pit-latrines.

5.2.2 Rural Water Supply and Sanitation

The Department of Rural Water Supply (DRWS), households and individual institutions are responsible for provision of water supply and sanitation services in the rural areas, even though sanitation mostly remain individual household's responsibilities. The Department has offices in each of the ten Districts. It maintains a District Information System which is used for monitoring, planning and generation of data for reporting purposes.

The domestic water accounts at catchment level in rural areas were constructed based on the policy statement that every citizen is entitled to the basic water of 30 litres per day. The population data sets of the 2006 census and 2016 census were used to linearly interpolate population nationally and catchment-wide for other years as depicted in Figure 5-2 below.

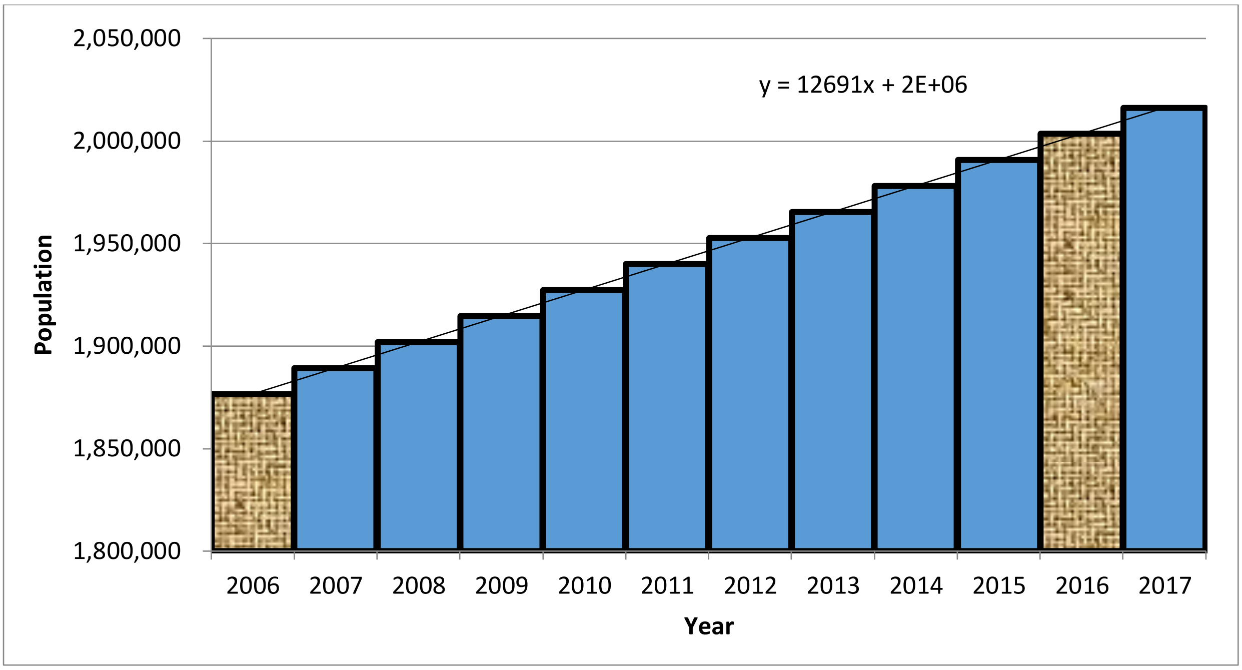

Figure 5-2: Observed and interpolated / extrapolated national population figures between 2006 and 2016, and beyond (i.e. 2017)

From the fitted trend line equation in Figure 5-2 above, it can be observed that the population increases at the rate of approximately 13,000 people per year. This rate was therefore assumed uniform for every incremental catchment when used to estimate the domestic water demand at catchment level. In the case where a catchment has WASCO serviced areas, such WASCO served population figure was removed from the respective catchment population in order to avoid double catching.

Additionally, the District Information Systems of the Department of Rural Water Supply provided information on the state and coverage of rural water supplies and sanitation. Areas at catchment level, which are still not supplied with water and sanitation, are therefore estimated per year from 2013/14 to 2016/17.

Improvement of the coverage of water supply in rural areas is a priority of the Government of Lesotho and significant resources are committed to this goal. **Error! Reference source not found.** provides a summary of the status of rural water supply by district for the years

Demand for potable water demand for human consumption in rural areas of Lesotho is met by the service from the Department of Rural Water Supply, mainly as gravity fed systems from sources of natural springs. The Department of Rural Water Supply provides basic data sources for calculating domestic water demand as follows:

1. Captured springs for rural water supplies: Location and yield
2. Population data sources:
    a) Statistical census of 2006 and population growth model or
    b) MoLG➔District Council ➔Urban & Community Councils ➔Village Councillors & Chiefs (Figure 5-3) (Births and Deaths registrations and village immigration & emigration registrations)

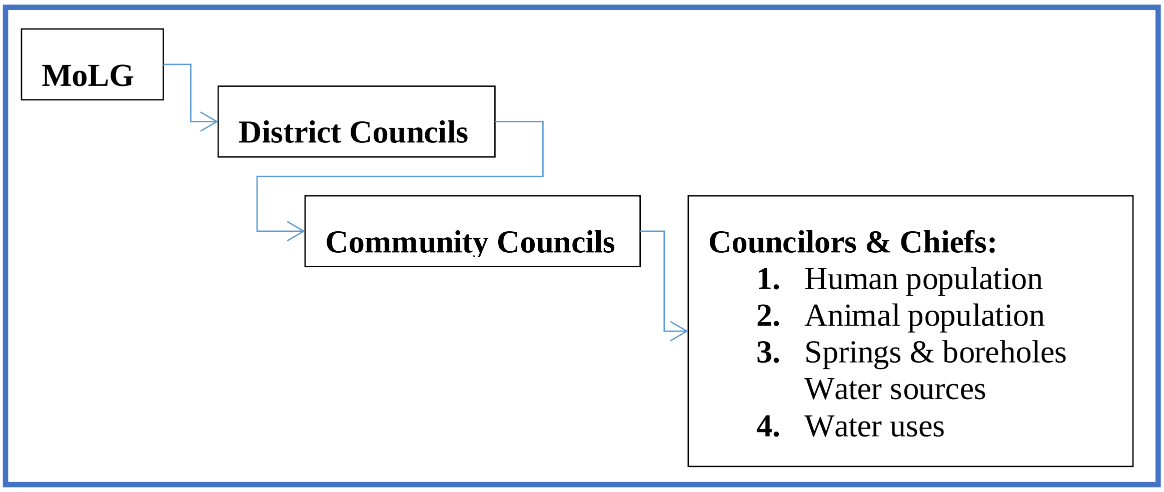

Figure 5-3: Ministry of Local Government population and water demand data

However, this study opted for option a) of population figures and growth rates from the BoS. The amount of supplied water against its demand for household domestic purpose is expected to be fairly constant in each year as long as there is no significant intra-annual population growth. The approach that has been adopted in this report is based on population by catchment.

Analysis of the availed District Information System data from the Department of Rural Water Supply, (DRWS) it has been established that the coverage of potable water in the country since 2013/14 has been fairly constant. This spatial coverage is depicted in Figure 5-4 below.

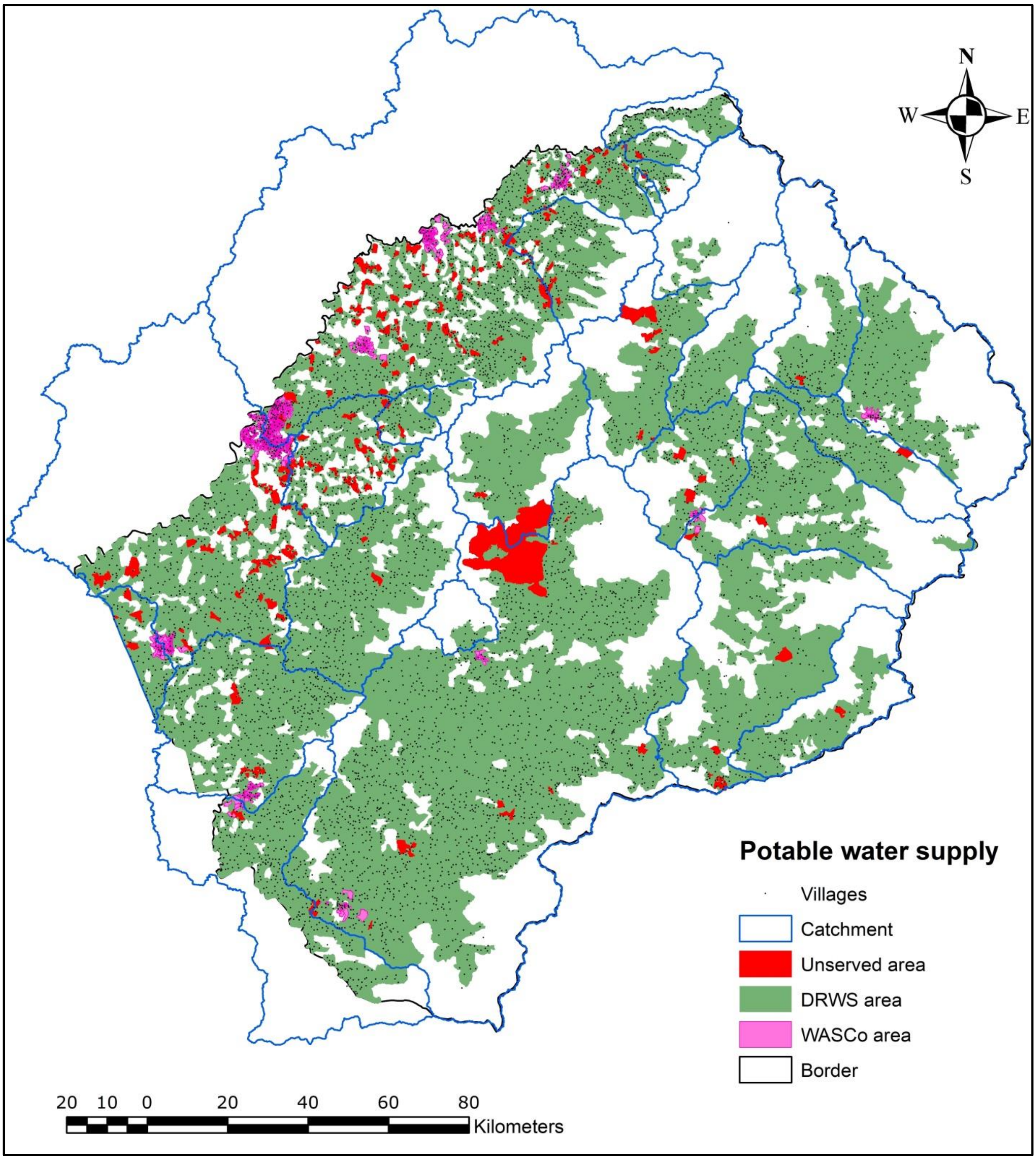

Figure 5-4: Area coverage of portable water and sanitation in Lesotho since 2013/14

The spatial extent of area covered by portable water supplies depicted in Figure 5-4 was assumed to be constant because not been any increase in area covered by the water supply and sanitation in the country since 2013/14. However, some other supply aspects such % population served per catchment could have varied. Further GIS-based analyses of this information since 2013/14 per catchment yielded the details presented in Table **5-7**.

Table 5-7. Estimates of rural population supplied with potable water between 2014/15 and 2016/17 per catchment

	2014/15			2015/16			2016/17		
Name	**Served**	**Not served**	**%**	**Served**	**Not served**	**%**	**Served**	**Not served**	**%**
CG24	70,582	29,117	59	71,029	29,301	59	71,479	29,487	59
SG6	33,980	0	100	34,195	0	100	34,412	0	100
SG36	13,097	1,262	90	13,180	1,270	90	13,263	1,278	90
SG100	20,482	93	100	20,611	93	100	20,742	94	100
SG42	13,275	0	100	13,359	0	100	13,444	0	100
SG9	4,998	0	100	5,030	0	100	5,062	0	100
SG80	28,045	2,253	92	28,222	2,268	92	28,401	2,282	92
SG8	28,843	1,515	95	29,026	1,524	95	29,210	1,534	95
SG5	44,045	268	99	44,324	269	99	44,605	271	99
SG7	15,738	282	98	15,838	284	98	15,938	286	98
SG4	55,419	8,472	85	55,770	8,526	85	56,123	8,580	85
SG18	1,009	0	100	1,016	0	100	1,022	0	100
SG17	10,919	4,119	62	10,988	4,145	62	11,058	4,171	62
SG3	214,181	11,843	94	215,538	11,919	94	216,903	11,994	94
D1H006	80,519	4,888	94	81,029	4,919	94	81,542	4,950	94
MG23	49,080	1,050	98	49,391	1,056	98	49,704	1,063	98
CG77	519	0	100	1,278	0	100	1,286	0	100
CG77ds	1,940	330	83	1,953	332	83	1,965	334	83
CG55	8,181	662	92	8,233	666	92	8,285	670	92
CG69	15,541	0	100	15,639	0	100	15,738	0	100
CG25	61,430	3,653	94	61,819	3,676	94	62,211	3,699	94
CG22	349,825	58,184	83	352,041	58,553	83	354,271	58,924	83
CG75	4,428	0	100	4,456	0	100	4,484	0	100
CG84	12,307	1,210	90	12,385	1,217	90	12,463	1,225	90
CGd/s	135,391	32,310	76	136,249	32,515	76	137,112	32,721	76
D1H009	36,931	1,141	97	37,165	1,149	97	37,400	1,156	97
LO	18,006	1,204	93	18,120	1,211	93	18,235	1,219	93

As can be seen in Table **5-7** some catchments have all their settlements fully supplied with potable water while some are not. As Figure 5-5 depicts, percentage of water supply coverage on rural settlements per incremental catchment ranges from 59 % in the South Phuthiatsana River catchment (CG24) at Masianokeng to 100% coverage in the highlands of Lesotho, e.g. Senqu River at Mokhotlong catchment (SG6), Matsoku catchment (SG42) and the Mohokare catchments of Malibamatšo at Kao catchment (SG9), Maletsunyane River at Semonkong (SG18), and the Mohokare catchments of Nqoe River at ‘Muela (CG77) and Mohokare River at Ha Mabine (CG69).

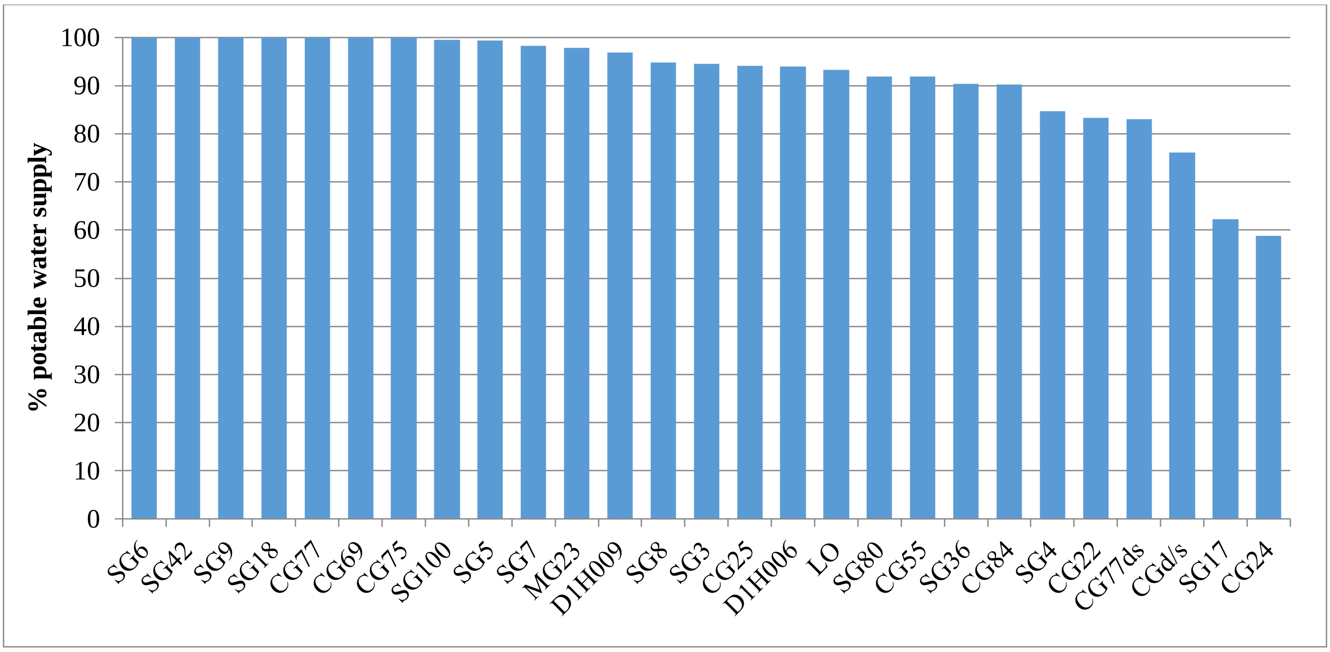

Figure 5-5. Potable water supply coverage (%) per catchment since 2013

Despite the % supply coverage being so high in some catchments, the demand is still growing as it is a function of population growth even if the basic water policy does not change. It is therefore expected that the demand for water would outgrow the systems supply capacity. Investigation into these conditions can be further enhanced with the modifications in the data collection methods and formats.

To better capture the accurate and more easily analysable data in space, it is recommended that geographic coordinates be collected to describe the physical location of the water supply infrastructure. Therefore, the recommended data collection formats for these demands and supply for potable water are presented in Table 5-8 below.

Table 5-8: Rural Water supply and demand data collection system

Supply type		**Description**	**Temporal variation**	**Observation frequency**	**Equipment used**
Springs	***Location***	Spring GPS coordinates (lat., long., & alt.)	-	Once-off	GPS
	Yield	Yield per spring per season	seasonal	Seasonal	Stopwatch, 2 or 5 litre bucket, 75mm x 1m hose pipe
Boreholes	***Location***	Borehole GPS coordinates (lat., long., & alt.)	-	Once-off	GPS
	Yield	Yield per borehole	-	Once-off	Pumping test equipment
Demand type		**Description**			
Springs	***Location***	GPS coordinates of the centroid of the spring water demand	-	Once-off	GPS
	Demand	Population per village	-	Annual	-
Boreholes	***Location***	GPS coordinates of the centroid of the borehole water demand	-	Once-off	GPS
	Demand	Population per village	-	Annual	GPS

For water supply from springs (see Table 5-8 above), there is duplication of efforts such that the Department of Rural Water Supply (DRWS) monitors spring yield every season for two consecutive years before deducing its supply capacity without involving DWA. The population size to be supplied by the same spring is also determined from local authorities (chiefs and councillors) to determine water demand on the basis of 30 l/day per person. In this way, the amount of available spring water against water demand is established. A similar approach is followed for water supply from boreholes. However, for boreholes, the DRWS engages the DWA to perform borehole pumping tests in order to establish the safe yield (available water) of the borehole against the required amount. The GPS locations for both springs and boreholes are never located, which they should. It is also noted that the targeted village for a spring may be very far from the potential supply spring and without recording the centroid coordinates for a village, it is not accurate in terms of planning to accurately estimate the material that is needed to transfer water from that spring to demand locations. The recorded data is not shared with the Water and Sanitation Sector Planning Unit within the Office of Water Commission.

The Department of Rural Water Supply also provides sanitation services through construction of ventilated improved pit (VIP) latrines in the rural areas. The responsibility of availability of sanitary facilities remains with households even though district offices maintain annual budget provision for contributing towards the cost of construction materials and supervision whereas labour and locally available materials such as sand and stones are contributed by the beneficiary villages. Sanitation services are not communal and as a result it is not easy to determine sanitary coverage at household level as there is no clear information within the Districts Information Systems (DIS) on the household numbers per village relating to target provision of the sanitary facilities.

The sanitation in urban and rural areas faces challenges concerning handling of synthetic (non-biodegradable) materials such as disposable sanitary towels. Utility companies and municipalities should consider developing sustainable sanitary solid waste management strategy.

5.3 Institutional use

In Lesotho, there are governmental and non-governmental institutions based in urban areas whose water needs are met by Water and Sewerage Company (WASCO) while those outside urban areas have to construct their own water supply and waste-water handling (septic tanks or biodigesters) systems.

a) Supply and demand for WASCO serviced institutions

As of now, due to lack of data, institutional water uses in the non-WASCO serviced areas are accounted for under the domestic category. Future attempts are therefore recommended to account for water uses for non-WASCO areas as water consumption patterns could differ from the domestic category. Similar to domestic water supplies and uses in urban areas, WASCO is expected to install meters for both treated supplied water and effluents against their demands. Some of the identified types of institutions whose water demands are met by WASCO are presented in Table 5-9 below.

Table 5-9: Institutional water supply and demand serviced by WASCO

Supply type		**Description**	**Type of meters**				**Frequency of observation**
			None	***Conventional***	***Smart***	***GPS coordinates***	
Institutional	***Potable***	Institutional bulk supply meters and tariffs data	?	?	?	?	Daily
	Sewage		?	?	?	?	
Demand type							
Institution type		**Demand**					
Missions / Parish centres		Number of residents					Annual
Schools	***Day scholars***	Annual student rolls					
	Boarding	Annual boarding registers					
	Warden /matron	Population					
Health Centres	***Outpatients***	Monthly numbers					Daily
	Admissions	Monthly # of days per admission					
Hotels, guesthouses and B&Bs	***Locals***	Monthly # of nights per guest					Daily
	Foreigners	Monthly # of nights per guest					Daily

Record of the actual amount of water that is supplied to the above intuitions is available at WASCO. However, there is a problem of reading the conventional meters to establish the actual amount of water used. This results in unreliable estimates of record of the amount of water that is supplied by WASCO to these institutions. There are also no water meters installed at water treatment plants to record the amount of water that is distributed to users. Therefore, it is impossible to account for abstracted water against revenue and non-revenue water. This implies that water balance figures from WASCO are unreliable. It is therefore recommended that bulk meters be installed from water treatment plants. It is also recommended that smart meters be installed at each institution to enable detection of leakages and unregulated pressure reduction, hence contribute to reduction of non-revenue water.

There is no data-collection format for water demand from institutions. Therefore, Table 5-9 above presents recommended data collection format for the WASCO serviced institutions on actual amount of water supplied against water demand.

b) Other institutional water supply and demand

Other institutions that independently abstract water for their own usage include rural based clinics, missions, hospitals and schools (Table 5-10).

Table 5-10: Other institutional water supply and demand

Demand type		**Description**		**Observation frequency**
		Supply	**Demand**	
LHDA villages / LHWP camps		Permitted metered abstractions and / or quantities (Water Use Permits from DWA)	Number of residents	Annual
Missions / Parish centres			Number of residents	
Schools			Annual student rolls	
Health Centres	**Outpatients**		Monthly numbers	Daily
	Admissions		Monthly # of days per	

			admission	
Remote hotels, guesthouses and B&Bs	**Locals**		Monthly # of nights per guest	
	Foreigners		Monthly # of nights per guest	

Institutions that are not supplied water by WASCO generally do not have water meters. This implies that the DWA should enforce installation of water meters from abstraction points to improve accounting for water use across the country. Therefore, the above Table 5-10 presents recommended data collection format and parameters on the amount of water supplied against its demand. Data from the Ministry of Home Affairs (MoHA) at ports of entry is also critical to pick transit visitors as this may indicate potential demand should they decide to put up overnight in future.

5.4 Hydropower

The hydropower generation is not a consumptive user but rather depends on the discharge of the flow on a daily basis and it has a direct relationship. There are three operational hydropower schemes in the country and these are: ‘Muela (72 MW), Semonkong (0.18 MW) and Mantsonyane (2 MW) although the Mantsonyane is currently supplied from the national grid as it was uneconomic to run it as a stand-alone (IUCN, 2003).

5.5 Industrial demands

WASCO also supplies treated water to meet water industrial demands that could also be expected to fluctuate around certain magnitude on daily basis. The demand for water is expected to fluctuate on diurnal basis around a certain quantity in response to regular factories or industries activities (linen washing).

Data for industrial water supply and demand along with monitoring frequency should be obtained by the office of the Commissioner of Water from WASCO, or from water bottling companies using the proposed format presented in Table 5-11. This format is expected to provide the essential data for compilation of the national economic water accounts.

Table 5-11: Industrial water supply and demands data

Supply type		**Description**	**Type of meter**				**Observation frequency**
			None	***Conventional***	***Smart***	***GPS coordinates***	
Water Bottling	***Potable***	Permitted metered abstractions and / or quantities	?	?	?	?	Daily
	Sewage						
Mining consumptive uses	***Potable***	Permitted metered abstractions and / or quantities	?	?	?	?	
	Sewage						
Mining non-consumptive	***Raw***	Permitted metered hot-	?	?	?	?	

use (cooling and return flows)	***Sewage***	water disposal and treated waste disposal					
Industrial (WASCO supplied)	***Potable***	WASCO's metered supplies (Application form & bulk metered supplies)	?	?	?	?	
	Sewage		?	?	?	?	
Recreation & rituals	***Raw***	Number of recreational reservoirs					
	Potable	Number of fountains	?	?	?	?	
	Ponds	Numbers of river / artificial ponds / pools					
Navigation	***Rivers***	Number of navigation ports					
	Reservoir	Number of reservoirs					
Demand type		**Description**					
Water Bottling	***Potable***	Design plant production capacity in litres per day					Daily
	Sewage	Plant workers population (from which to assume sanitary demand)					
Mining consumptive uses	***Potable***	Mineworkers population					
		Daily volume of water required to process / wash rocks					
	Sewage	Mineworkers population (from which to assume sanitary demand)					
		Daily volume discharged after process / wash rocks					
Mining non-consumptive use (cooling and return flows)	***Raw***	Daily volume of water required to cool machinery					Daily
	Discharge	Daily volume of heated water required to discharge into environment					
Industrial (WASCO supplied)	***Potable***	Factory workers population					
		Daily volume of water required to wash & iron linen					
	Sewage	Daily volume of linen washed water to dispose					
		Daily volume of wastewater required to discharge into sewer					
Recreation & rituals	***Raw***	Number of tourists per month					
	Potable	Volume of water required per fountain per day					
	Ponds	Numbers of traditional hears and Baptists					
Navigation	***Rivers***	Number of visitors per port per day					
	Reservoir	Number of visitors per port per day					

At a glance, none of the tabulated water supply and demand data is recorded. This is despite the requirements of the water use permits issued by the DWA. Therefore, Table 5-11 above represents the desired record required to enable compilation of the State of Water Resources reports as there is currently no format used to collect and report on this kind of data. For industrial water supply, it is recommended that WASCO install smart meters to ease collection of the actual spent amount of water per factory and detect water losses through leakages at real-time. Also for industrial waste water discharge, it is recommended that factories install smart waste water meters to ease collection of the actual discharged amount of pre-treated waste water per factory.

a) Mining

Mining industry is considered to be another major water user in Lesotho. The major mining areas include the Letšeng Diamond mine, Kao mine, Liqhobong mine, Mothae mine and Kolo mine. Other small mines in Lesotho include the Mount Moorosi alluvial diamond mine, the Moradi Stone Crushers (at Morija, Peka and Botha-Bothe), Kou Stone Crusher at Ha Ntsi, Chinese Dolerite Crusher at Ha Tšiame and a cluster of Sandstone Quarry miners at Lekokoaneng. All these mining and quarrying companies as depicted in Figure 5-1 are responsible to supply water for their own use.

b) Commercial water bottling

Figure 5-1 (in Section 5.1) indicates that most of the catchments in the country have commercial water bottling locations. Therefore, this category of economic water uses was accounted for in every catchment.

5.6 Agriculture

The agricultural area estimated for irrigation was 1 100 ha in 2011 and 1 200 ha in 2013, (CoW, 2013) and it is estimated that for irrigation schemes with 75% efficiency, the gross annual irrigation requirements are 5 500 m^3/ha and 10 500 m^3/ha for schemes with 40% efficiency. That area is assumed to be unchanged between 2013 and 2017. Agricultural sector demands also include livestock water demands. In Lesotho livestock is watered mainly in catch dams and rivers and form part of water users. The Bureau of Statistics keeps a record of livestock per district and the four ecological regions. The 2010 livestock census was used to estimate the average number of livestock of each kind per household in each study catchment (see Table 5-13). These figures were used to estimate the total demand for water by livestock per study catchment.

All catchments have provisions to account for water use for irrigation. However, Figure 5-1 depicts only one irrigation scheme that is active near Khukhune in Botha-Bothe.

In agricultural activities, water is supplied as is required for use in animal husbandry and irrigation purpose. As agricultural water demand is normally for raw water from rivers, reservoirs and ponds, there is tendency for water users not to be regulated on the amount of water they require to use or reporting the amount of water they have used for agricultural purpose. However, water demand can be estimated from assumed non-policy stipulated water demand of animal categories (higher or lower) and irrigated crops and fruit trees. An agricultural demand for water is categorized into livestock and irrigation Table 5-14.

Livestock water demand per catchment was estimated for each type of animal that is reared in the catchment. Table 5-12 and Table 5-13 below provide the basis that was used to estimate livestock water demand.

Table 5-12: Basis for livestock water demand estimate per each type of animal

Demand	Cow	Sheep	Goat	Pig	Horse	Donkey	Dog	Cat	Mule	Poultry
Daily (L)	30	5	5	15	30	30	2	0.5	30	0.5
Annual Unity (L)	10956	1826	1826	5479	10958	10958	731	183	10958	183
Annual Unity (m^3)	11	2	1.8	5.5	11.0	11.0	0.7	0.2	11.0	0.2

Table 5-13: Livestock numbers estimates per incremental catchment

Catchment	Goats	Sheep	Donkeys	Horses	Cattle	Pigs	Dogs	Cats	Mules	Poultry
CG24	28250	11681	4973	1611	28410	6208	9256	2855	96	16092
SG6	42410	59201	6002	5456	22916	1160	12604	2934	0	14942
SG36	15064	21020	2123	1942	8142	409	4482	1047	0	5311
SG100	21448	29938	3036	2758	11596	580	6382	1489	0	7556
SG42	4684	12304	1137	438	3038	178	1708	672	0	1811
SG9	8749	25067	852	636	3865	43	1061	126	0	1868
SG80	21868	58494	4683	1941	13301	668	6927	2589	0	7660
SG8	28144	67670	3269	2512	14528	481	5284	1463	6	4955
SG5	45521	90883	5206	4734	23397	867	9768	2304	3	10241
SG7	26163	49522	1542	2354	18306	955	3351	1001	46	6919
SG4	58935	84520	5720	4172	30074	2168	9964	2244	126	13036
SG18	3075	4908	171	204	738	81	213	69	0	381
SG17	27386	45326	1618	1849	7088	704	2076	633	0	3413
SG3	245511	322122	22308	16324	85133	9273	31616	11721	81	66950
D1H006	49290	86777	16077	3913	56733	9405	16123	6078	85	48763
MG23	63596	16921	5059	2579	29467	3637	7522	3010	0	12875
CG77	202	569	53	13	290	3	69	44	0	760
CG77ds	622	1595	158	37	849	13	202	126	0	2137
CG55	2998	5814	726	182	3577	117	851	477	0	79130
CG69	5329	9594	1247	316	6042	232	1426	784	0	12703
CG25	14449	14038	3724	1750	26612	3911	7619	3581	423	21682
CG22	77037	100575	28050	9358	143738	25717	37110	14017	1246	139236
CG75	1677	1246	435	164	2055	454	737	283	8	1657
CG84	5846	3711	1313	505	6515	1303	2123	781	21	4873
CG	50689	78957	14637	2722	65106	12303	20354	6111	117	70939
D1H009	19288	11769	2363	1029	6859	1948	2750	917	17	7703
LO	6679	13655	1903	290	7643	1136	2141	686	12	9296

Table 5-14: Agricultural water supply and demands data sources

Water supply	**Water supply per source**			**Observation / estimation frequency**
	Surface water		***Groundwater (boreholes)***	
Animal husbandry	Population x litres / day		Permitted metered abstraction	Daily
Irrigation	Permitted metered abstraction			Daily
Demand type				
Institution			**Demand**	
Animal husbandry	***Livestock***	***Higher***	Populations of cattle, horses, and donkeys (assuming 30L/day/ animal)	Annual
		Lower	Populations of goats, sheep and pigs (assuming 3L/day/ animal)	
	Poultry	***Higher***	Populations of turkeys, duck, geese (assuming 3L/day/ bird)	
		Lower	Populations of chicken (assuming 50ml/day/ bird)	
	Fishery		Annual populations of fish (assuming 50L/day/ animal)	
Irrigation	***Cash crops***		Annual heads of crops (assuming 1L/day/ head)	
	Orchards		Annual fruit tree populations (assuming 50L/day/ tree)	
	Lawns		Daily evapotranspiration demand per square meter (assuming 10L/sq.m/non-rainy day in growing season)	

Due to communal land tenure system of Lesotho, i.e. communal grazing and watering of livestock, most livestock owners do not have water use permits. So, the amount of water they use is not known. However, every household that owns livestock has official record of livestock type and numbers. From this information, the amount of drinking water for livestock can be estimated per village. There is no record on the free-range and caged type of poultry in households and poultry farms in Lesotho. This condition renders it impossible to estimate the water demand for poultry. It is therefore recommended that poultry records should be maintained and documented by all community council offices. In this study, the 2010 livestock census estimates per enumeration area from the Bureau of Statistics (BoS) were used to derive the required livestock per incremental catchment (Table 5-13) as required to estimate water demand.

5.7 Water transfers

Major water transfers in Lesotho include the Lesotho to South Africa and the abstraction from the Metolong dam (inter-catchment water transfer from the downstream incremental catchment of CG84 to the upstream catchment of CG22). According to the 1988 treaty of the LHWP, the Kingdom of Lesotho is bound to transfer 780 million cubic meters per year to the Republic of South Africa (Table 5-15). The actual amount of water transferred closely undulates around this figure. Therefore, this amount was entered in the WEAP model as a constant number to signify constant transfer rate from the LHWP to South Africa. Information on the hydropower water demand, LHWP water transfer and Environmental Flow Requirement magnitude information was obtained from the LHWP study documents for

the flow requirements to generate electricity while water is in transit to The Republic of South Africa. It was considered that hydropower generation is only a by-product of water transfer through the LHWP tunnels, therefore is dependent on the water transfer quantities as stipulated in the LHWP treaty (currently only on the fully implemented Phase 1). Information on the Environmental Flow Requirements or Instream Flow Requirements (IFRs) from the Metolong Reservoir was obtained from Table 1 in the report on the Environmental Flow Operating Rules (Rossouw & Walker, 2015), even though this policy would have been implemented from December 2013 (Brown, 2013).

The Metolong dam project avails 75 Mℓ/day for abstraction in the central lowlands of Lesotho. Also the Maseru Water Supply System has the capacity to deliver 45 Mℓ /day (MCA-Lesotho, 2010). All these water transfers datasets were used in the WEAP model to perform water balance.

Table 5-15: LHWP Water Deliveries to South Africa

Year	**Water transfer (MCM)**		**Deviation %**
	Target	***Delivered***	
2010/11	780	723	-7.4
2011/12	780	876	12.3
2012/13	780	730	-6.4
2013/14	780	783	0.38
2014/15	780	780	0.01
2015/16	780	773	-
2016/17	780	794	-

Source: LHDA Annual Reports

6. Annual Water Balance

This chapter presents the value of water to the economy of Lesotho, during the period under review.

6.1 Introduction

In this chapter an attempt was made, with the use of the WEAP model, to provide a physical account of water available, water used, and water available for further use in the main three catchments of Makhaleng, Mohokare and Senqu, for the period of 2013/14 to 2016/17, including the reporting year of 2016/17. In each catchment, a number of aspects were considered where applicable, namely:

i) Water used in urban areas
ii) Water used in rural areas
iii) Water used for irrigation
iv) Transfer of water to the Republic of South Africa under the Lesotho Highlands Water Project, including gains or losses in stored water in the system.
v) Observed flow
vi) Natural flow

All these water accounts were made at incremental catchment level though reported at national level as well as at the level of the three national major catchments of Mohokare, Makhaleng and Senqu.

In compiling the water accounts, it was considered that watercourses in Lesotho are composed of the surface water and groundwater bodies. Input into the watercourses comes as precipitation in the form of rainfall, hail snow for surface water, and infiltration and percolation for groundwater. Losses from the watercourses systems are mainly in the form of evaporation. Precipitation and evaporation are observed by the Lesotho Meteorological Services (LMS) whereas the surface and groundwater resources are the mandate of the Commissioner of Water through the Department of Water Affairs. Compilation of the State of Water Resources Report therefore entails the administration and use of the meteorological / climate data as well as the water resources data (Figure 6-1).

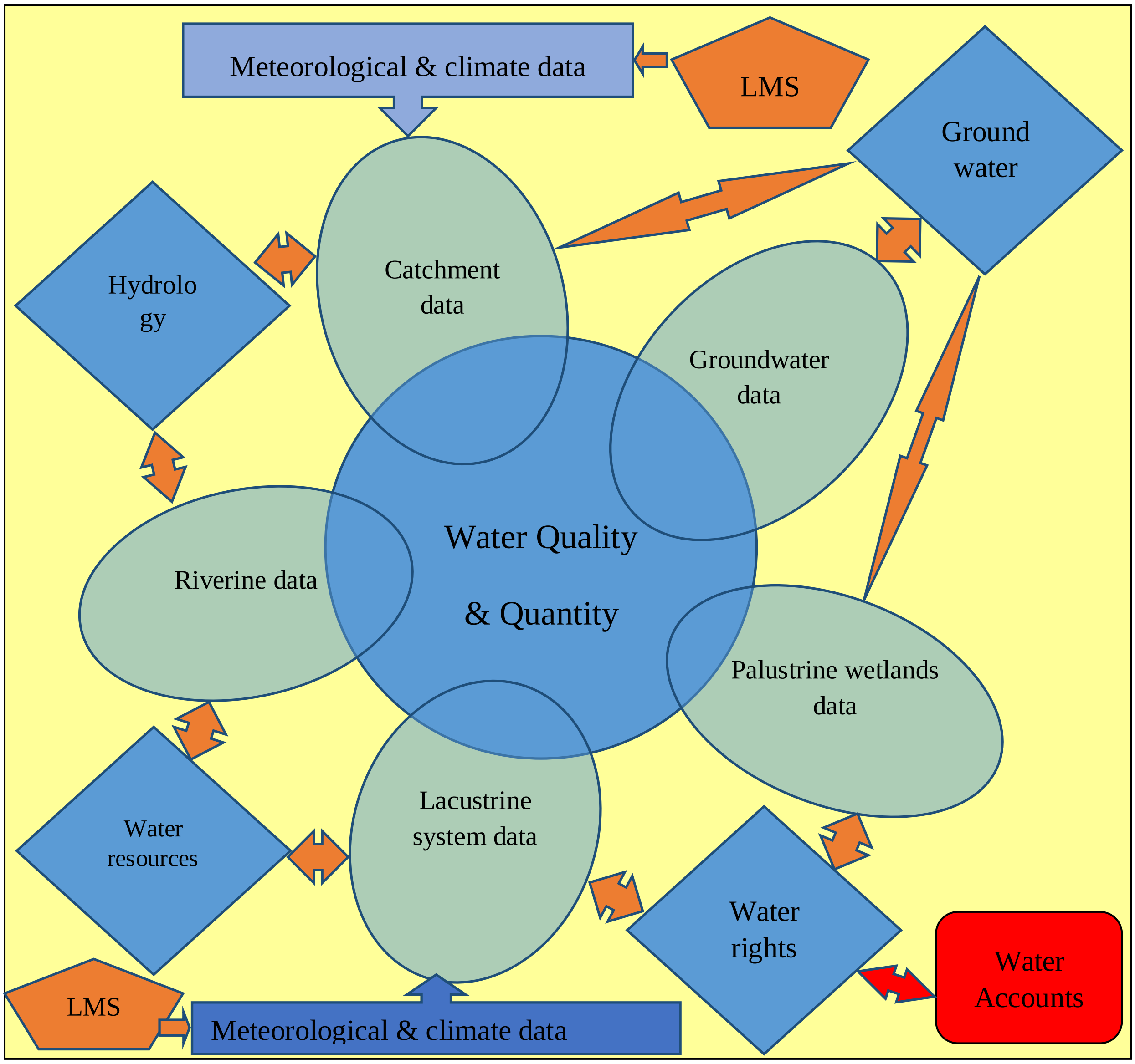

Figure 6-1: Watercourses management and administration

As Figure 6-1 above indicates, water resources inventorization is carried out mainly by the Department of Water Affairs. In the Department, there is also a Water Rights Division that is in charge of directly issuing water rights to different users. The role of Water Rights Division is also to monitor and enforce compliance of different users to licensed water uses. However, technical operations of the Water Rights Division in licensing, monitoring and enforcing water use compliance is impeded by lack of qualified staff, lack of staff duty orientation and hands-on training, and severe shortage of transport.

In this study, water balance was compiled through using WEAP model to perform analyses based on the schematic in Figure 6-2 below.

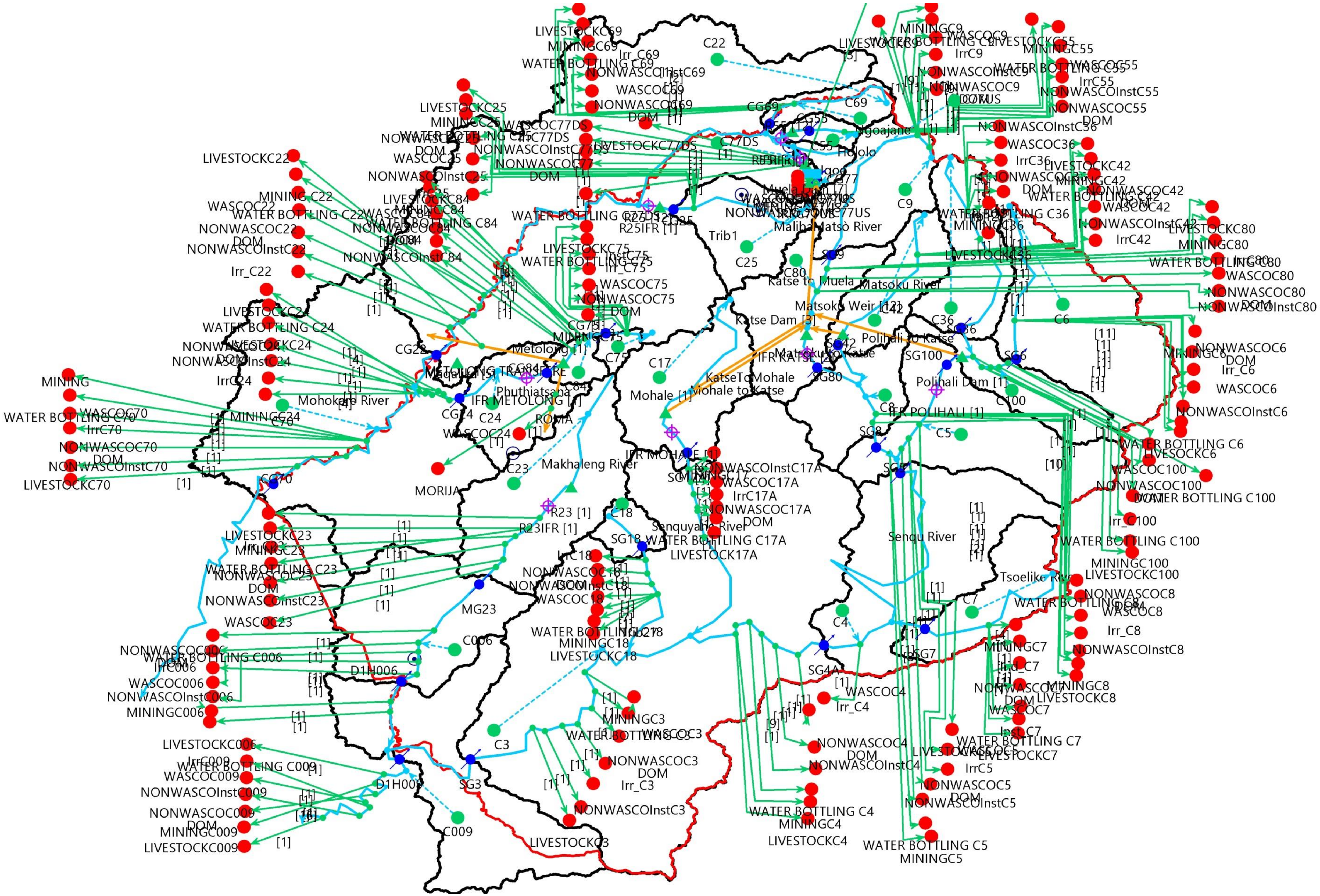

Figure 6-2: The WEAP model schematic setup as applied in the study

6.2 Water use - Existing Water Licences

According to Water Act 2008, section (20) subsection (1), for any water abstractions, an application for a water-use permit should be made to the Department of Water Affairs and the quantity is determined by the director (section 20 subsection 10). It is perceived that all water users in the country are registered and permitted. Using this perception, all the known different categories of water users were displayed in Figure 5-1 of water services and users and existing licences based on major water abstraction infrastructure capacities as presented in Table **5-2**.

6.3 Water transfers

The amount of water transferred (in previous Table 5-15) to South Africa since 2010 to date undulates around the target delivery of 780MCM per year. However, in the last three years, i.e. since 2013, delivered water has been very close to the target delivery.

6.4 Summary of System Demands

To be able to determine a realistic and reliable water balance for Lesotho it is of utmost importance to obtain reliable information on the water demands as well as the water resource capability. Currently most of the demand centres in Lesotho that are supplied from surface water, obtain their water from direct river runoff abstractions. Of late, the role played by reservoirs is growing with the developments in the Lesotho Lowlands Water Supply Scheme (LLWSS) through construction of the Metolong dam and plans to construct the other dams that include the Hlotse dam and Makhaleng dams. These developments were incorporated in the water balance system (the WEAP model). Other demands were incorporated per catchment according to population size in each catchment and the 30 l/day per person national policy for basic water. Livestock water demand based on types and numbers of livestock per catchment as estimated from the 2010 livestock census were also fed into the water balance (WEAP) model. Other types of water demand per catchment that were incorporated into the WEAP model are the environmental release requirements based on policies and the urban, industrial (mining and water bottling), rural, irrigation and institutional demands..

These system demands are not always fully supplied due to the variance in the rainfall runoff and the current lack of storage dams. To be able to determine the complex interaction between the actual demands, actual supply, the large transfers from Lesotho to South Africa, environmental release requirements, the varying runoff from rainfall and the available storage in the storage dams within the system, the water resource model called WEAP was used.

6.5 Priority Classification

The priority classification is used to define the required assurance of supply to the different water use sectors and is used as a basis to assist in the decision making process regarding restrictions during drought periods. The WEAP model is flexibly developed to use the criteria of inter-reservoir transfer, but it is not immediately explicit as to how to configure the required restriction during a drought period to ensure that the users are in fact receiving their required water supply.

The priorities for supplies to different demand types as were set in the model are presented in Table 6-1 below.

Table 6-1: Water supply priorities set for different uses in the WEAP model system

#	Water use (licenced)	Supply priority	Justification of priority
1.	Mining	2	-
2.	WASCO abstractions	1	Human domestic
3.	LHWP transfer to RSA	1	LHWP Treaty obligation
4.	Water bottling	2	-
5.	Irrigation	3	Non-conserving water use
6.	Livestock	1	Life-saving
7.	Non-WASCO (Rural) drinking	1	Human domestic
8.	Non-WASCO Institutional (rural)	1	Human domestic

6.6 Starting Storage Levels of Reservoirs

At the start of each operating year it is of utmost importance to check the storage levels in each of the storage dams, and to include this data into the WEAP model for the annual storage analysis. These levels are essential as they relate directly to the short-term yield that is available from the particular storage dam. When a dam is full or close to full, the dam would be able to supply a much higher yield over the next three or five years, than a dam that is for example only at 20% of its live storage at the start of the operational year.

6.7 Water Balance

The water balance was built using the WEAP model in the fiscal year of 2016/17. The water resources quantities in both mm/year and MCM/year per catchment are presented in Table **6-2** and Table **6-3** below. The values presented in millimetres are equivalent of catchment's annual surface runoff to enable easy comparison of annual yield of small catchment to large catchment. Runoff values for downstream incremental catchments include even the input runoff from upstream incremental catchments. In the event where actual evapotranspiration is greater than rainfall, and yet there is catchment runoff, such runoff is contributed by upstream catchments.

Table 6-2. Estimated water resources use partitioning (mm) for the 2016/17 per catchment

Catchment	Rainfall (mm)	Actual Evapotranspiration Eta (mm)	Domestic (mm)	Industrial (mm)	Irrigation (mm)	Livestock (mm)	Institutional (mm)	Reservoir (mm)	Streamflow (mm)
CG70	736	686	0.9043	0.0082	0.0000	0.4026	0.0029	0	205
CG22	795	729	1.0549	0.0016	0.0000	0.4255	0.2276	0	74

CG24	764	644	1.5589	0.0010	0.0000	2.0671	0.0000	0	128
CG25	842	760	0.7318	0.0040	0.0000	0.5540	0.0037	0	81
CG55	894	782	0.2478	0.0000	0.0605	0.2541	0.0000	0	111
CG69	902	1033	0.5672	0.0587	0.0000	0.4965	0.0587	0	1664
CG75	801	705	0.4672	0.0117	0.0000	0.4794	0.0000	0	95
CG77	864	756	0.1935	0.0000	0.0000	0.2638	0.0000	0	108
CG77ds	873	765	1.5673	0.0000	0.0000	1.2482	0.0000	0	108
CG84	791	714	0.8537	0.0000	0.0000	0.9287	0.0102	112189531	40
D1H006	718	668	0.8537	0.0019	0.0000	1.0538	0.0045	0	114
D1H009	713	552	0.2251	0.0000	0.0000	1.7224	0.0000	0	2045
MG23	747	988	0.3578	0.0184	0.0002	0.7161	0.0048	0	59
SG100	824	587	0.3849	0.0060	0.0062	0.7528	0.0000	0	1303
SG17	813	589	0.1520	0.0000	0.0000	0.4369	0.0000	331085520	78
SG18	748	562	0.0515	0.0000	0.0000	0.2432	0.0000	0	186
SG3	730	532	2.0027	0.0025	0.0000	0.5864	0.0007	0	479
SG36	825	591	0.1895	0.0000	0.0000	0.3729	0.0000	0	251
SG4	739	582	0.3533	0.0002	0.0000	0.5923	0.0000	0	972
SG42	806	594	0.2201	0.0021	0.0000	0.1708	0.0000	0	32
SG5	792	253	0.3191	0.0000	0.0000	0.6281	0.0035	0	962
SG6	843	275	0.2266	0.0000	0.0000	0.5306	0.0000	0	254
SG7	769	575	0.2250	0.0367	0.0000	0.7637	0.0000	0	193
SG8	774	568	0.4908	0.0000	0.0000	0.8979	0.0010	0	585
SG80	822	592	0.0550	0.0395	0.0000	0.1875	0.0000	557346939	259
SG9	850	196	0.0658	0.0473	0.0000	0.2245	0.0000	0	223
LO	690	644	0.4584	0.0000	0.0000	0.5402	0.7506	0	43

Table 6-3. Estimated water resources use partitioning (MCM) for the 2016/17 per catchment

Catchment	**Rainfall**	**Actual Evapo-transpiration Eta**	**Domestic**	**Industrial**	**Irrigation**	**Livestock**	**Institutional**	**Reservoir**	**Stream flow**
CG70	2960.59	2758.28	833.78	0.03	0.00	1.62	0.01	0.00	906
CG22	5710.27	5232.20	7.58	0.01	0.00	3.06	1.63	0.00	576
CG24	546.60	460.69	1.12	0.00	0.00	1.48	0.00	0.00	113
CG25	606.93	547.86	0.53	0.00	0.00	0.40	0.00	0.00	60
CG55	127.71	111.78	0.04	0.00	0.01	0.04	0.00	0.00	16
CG69	276.47	316.54	0.17	0.02	0.00	0.15	0.02	0.00	549
CG75	77.66	68.38	0.05	0.00	0.00	0.05	0.00	0.00	10

CG77	18.18	15.91	0.00	0.00	0.00	0.01	0.00	0.00	2
CG77ds	12.62	11.06	0.02	0.00	0.00	0.02	0.00	0.00	2
CG84	128.25	115.64	0.14	0.00	0.00	0.15	0.00	18.18	7
D1H006	1019.48	948.71	1.21	0.00	0.00	1.50	0.01	0.00	166
D1H009	1420.25	1099.32	0.45	0.00	0.00	3.43	0.00	0.00	4341
MG23	1170.83	1549.01	0.56	0.03	0.00	1.12	0.01	0.00	97
SG100	492.49	351.24	0.23	0.00	0.00	0.45	0.00	0.00	829
SG17	899.73	651.74	0.17	0.00	0.00	0.48	0.00	366.44	90
SG18	163.93	123.11	0.01	0.02	0.00	0.05	0.00	0.00	44
SG3	5577.27	4069.11	15.31	0.02	0.00	4.48	0.01	0.00	3823
SG36	699.61	501.24	0.16	0.00	0.00	0.32	0.00	0.00	227
SG4	1495.44	1177.97	0.71	0.00	0.00	1.20	0.00	0.00	2093
SG42	543.65	400.85	0.15	0.00	0.00	0.12	0.00	0.00	27
SG5	1229.86	393.24	0.50	0.00	0.00	0.98	0.01	0.00	1584
SG6	1414.09	460.69	0.38	0.00	0.00	0.89	0.00	0.00	906
SG7	612.53	457.78	0.18	0.03	0.00	0.61	0.00	0.00	166
SG8	535.74	393.24	0.34	0.00	0.00	0.62	0.00	0.00	424
SG80	835.67	602.12	0.06	0.04	0.00	0.19	0.00	566.74	274
SG9	721.96	166.88	0.06	0.04	0.00	0.19	0.00	0.00	200
LO	178.63	527.39	0.12	0.00	0.00	0.14	0.19	0.00	12

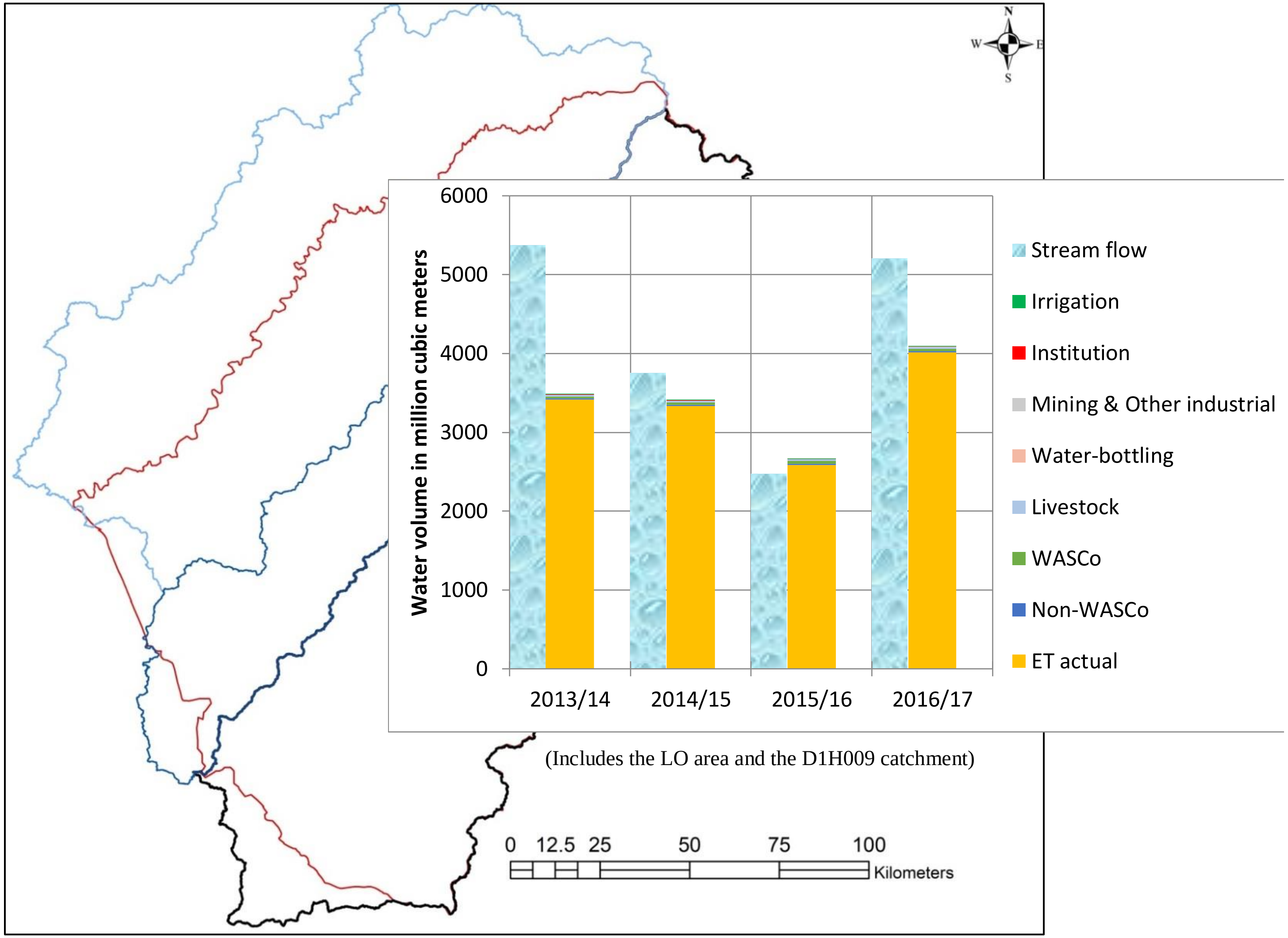

Figure 6-3: National available water (stream flow) and consumption estimates in million cubic meters (MCM) between the fiscal years 2016/17

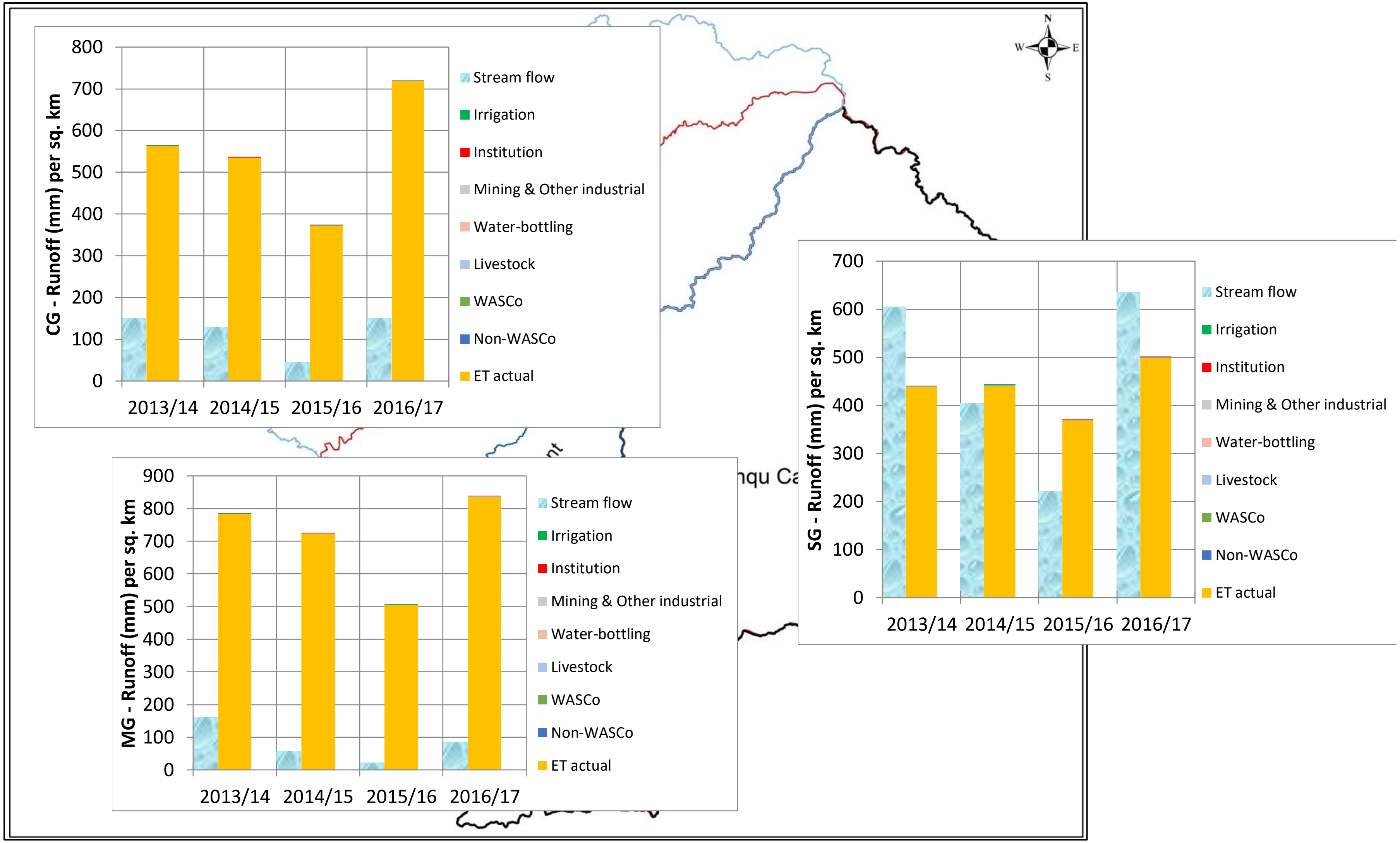

Figure 6-4: Available water (stream flow) and consumption estimates in mm/s.q. km and uses in the three major catchments of Lesotho

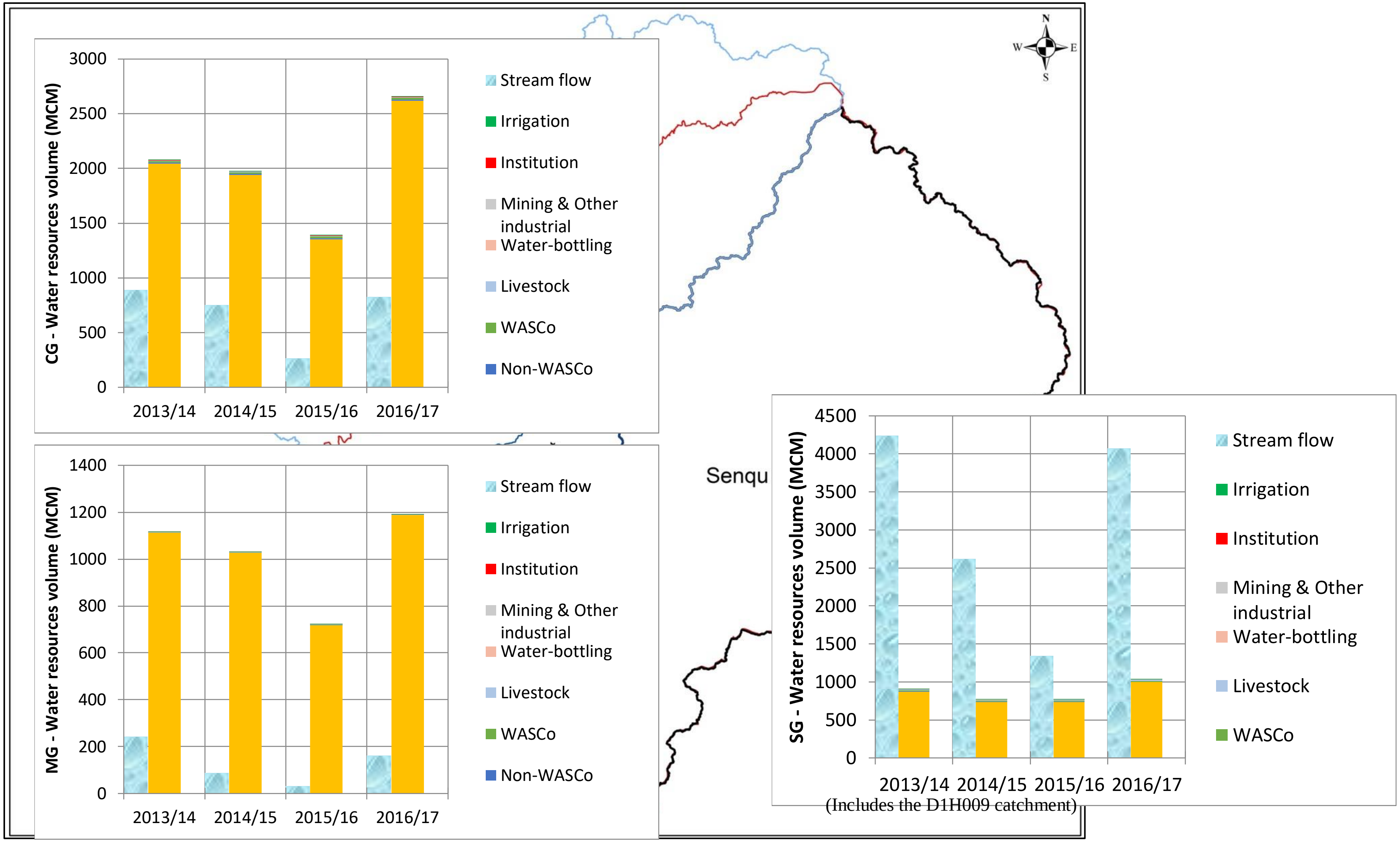

Figure 6-5: Available water resources (stream flow) and consumption estimates in million cubic meters (MCM) in each major river catchment

At the national scale (Figure 6-3), all the years depicted, including the 2016/17 under review, indicate that significant amount of catchment waters are lost through evapotranspiration. Nonetheless, there are still large amounts of water resources available for exploitation. However, the Senqu catchment depicts the relative lowest losses to evapotranspiration as compared to the higher relative losses in the Mohokare and Makhaleng catchments (Figure 6-4 and Figure 6-5). The amount of available water by far surpasses human and animal consumption.

6.8 Availability of water for use

In the above tables of water balance, the last two columns of stream outflow from the catchment along with water in reservoir storage represent the amount of water that is available for allocation to other users including the environment.

6.9 Natural Flow

Naturalized flows per major catchments in Lesotho are presented in Figure 6-6 and Table 6-4 below.

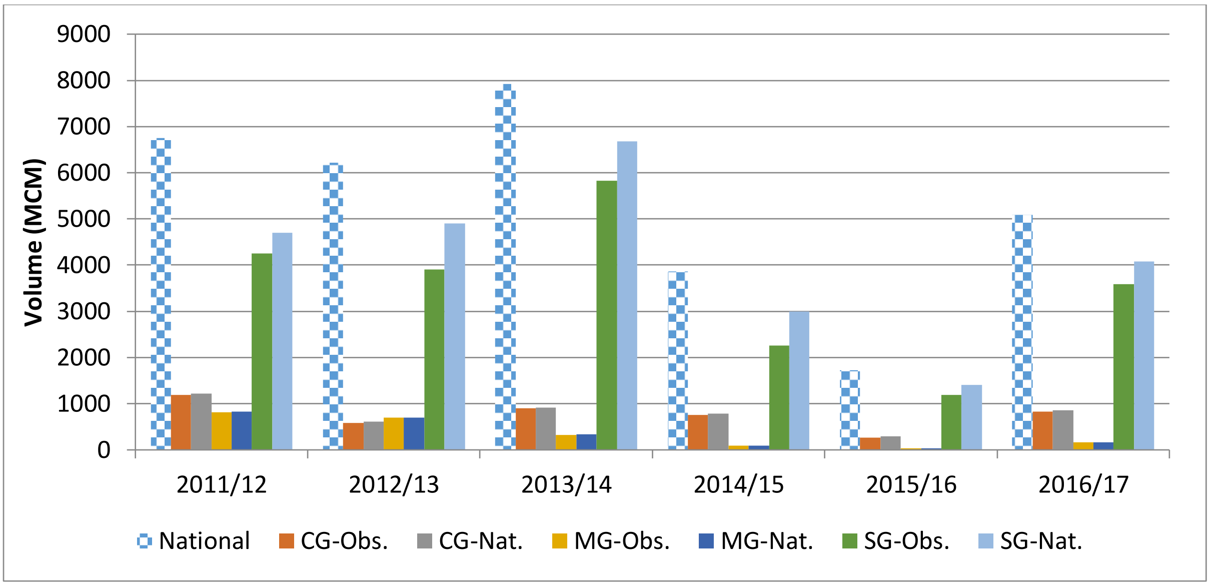

Figure 6-6: Water Resources Yield in Lesotho (in Million Cubic Meters)

Table 6-4: Naturalized catchment flows (Mm^3/year) in Lesotho

Catchment	Category	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17	Remarks
Senqu catchment (SG3 Senqu @ Seaka)	**Observed (or simulated) flow**	**4259.15**	**3904.72**	**5832.96**	**2264.46**	**1186.17**	**3591.39**	
	+ Urban water use	0.89	0.93	1.06	0.55	0.56	0.58	Simulated
	+ Rural water use	2.43	2.7	10.45	4.99	5.35	5.57	Simulated
	+ Irrigation water use	7.66	8.78	0.01	0.01	0.01	0.01	Simulated
	+ Mining water use	-	-	0.10	0.04	0.05	0.06	Simulated
	+ Water bottling amount	-	-	0.0080	0.0034	0.0040	0.0046	Simulated
	+ Rural institutional water use	-	-	0.0352	0.0156	0.0182	0.0195	Simulated
	+ Livestock water use	-	-	10.30	9.30	9.92	10.30	Simulated
	+ Water transfers to RSA	876.27	729.97	783	780	773	794	From LHDA
	+ Change in storage in Katse & Mohale dams	-450.8	248.67	12.14	-97.54	-601.791	-362.297	From LHDA
	+ Evaporation from Katse and Mohale dams	8.67	8.67	26.156	32.441	32.282	32.538	Simulated (not observed)
	= Natural flow from Senqu Catchment	**4704.27**	**4904.44**	**6676.22**	**2994.27**	**1405.57**	**4072.17**	
Makhaleng Catchment (D1H006 Makhaleng @ Kornerspruit)	**Observed (or simulated) flow**	**819.5**	**692.38**	**330.27**	**87.91**	**31.66**	**161.76**	
	+ Urban water use	0.45	0.43	0.461	0.231	0.233	0.234	Simulated
	+ Rural water use	0.8	0.69	2.982	1.496	1.506	1.516	Simulated
	+ Irrigation water use	1.19	1.19	0.00	0.00	0.00	0.00	Simulated
	+ Water bottling amount	-	-	0.0412	0.0206	0.0206	0.0234	Simulated
	+ Rural institutional water use	-	-	0.0279	0.0140	0.0140	0.0139	Simulated
	+ Livestock water use	-	-	2.62	2.62	2.62	2.62	Simulated
	= Natural flow from Makhaleng Catchment	**821.94**	**694.69**	**336.41**	**92.29**	**36.05**	**166.16**	
Mohokare Catchment (Mohokare at Bolikela, also known as Caledon at Wilgerdraai)	**Simulated flow**	**1196.28**	**587.28**	**894.88**	**758.07**	**265.58**	**833.65**	
	+ Urban water use	16.65	17.31	2.21	4.71	4.74	4.77	Simulated
	+ Rural water use	3.13	3.07	7.62	8.04	8.14	8.33	Simulated
	+ Irrigation water use	4.3	4.3	0.01	0.01	0.01	0.01	Simulated
	+ Mining water use	-	-	2.12	1.00	1.09	1.14	Simulated
	+ Water bottling amount	-	-	0.0161	0.0173	0.0173	0.0172	Simulated
	+ Rural institutional water use	-	-	1.68	1.68	1.68	1.68	Simulated
	+ Livestock water use	-	-	6.44	6.83	6.86	6.96	Simulated
	= Natural flow from Mohokare Catchment	**1220.36**	**611.96**	**914.98**	**780.37**	**288.12**	**856.56**	
National	**Total Natural flow from the complete system** (Senqu + Mohokare + Makhaleng)	**6,746.57**	**6,211.09**	**7,927.61**	**3,866.93**	**1,729.74**	**5,094.89**	

Source: This study (previous data extracted from the 1st, 2nd & 3rd State of Water Resources Reports)

Figure 6-6 and Table 6-4 illustrates that there is a general decreasing trend in the national water resources quantity, most probably due to increasing evapotranspiration and decreasing rainfall.

For accurate catchment natural flows determination for a riverine system, it should be known what size of catchment it drains at every gauging station. Location of the gauging station and all stream flow parameters (station profiles, discharge measurements and water level) time series should be recorded. It should also be noted as to how each parameter varies with time in order to establish the frequency of observation of these parameters along with the instrumentation that are used to carry out these observations (see Table 6-5 below).

Table 6-5: River water quantity parameters variation and their measuring instrumentation

<table>
<tr><th colspan="2">Parameter</th><th>Temporal variation</th><th>Monitoring frequency</th><th>Instrumentation</th></tr>
<tr><td colspan="2">Catchment size / area (km^2)</td><td>-</td><td>Once-off</td><td>Planimeter</td></tr>
<tr><td colspan="2">Gauging station location (lat., long., alt.)</td><td>-</td><td>Once-off</td><td>GPS</td></tr>
<tr><td rowspan="6">Flow</td><td>Discharge measurements (m^3/s)</td><td>Time series</td><td>Monthly or event-based</td><td>Current meters</td></tr>
<tr><td>Cross-sectional profile</td><td rowspan="2">Time series</td><td>Seasonal</td><td rowspan="2">Survey equipment (GPS, theodolite, etc.)</td></tr>
<tr><td>Longitudinal profile</td><td>Seasonal</td></tr>
<tr><td>Water levels (m)</td><td>Time series</td><td>Continuous</td><td>Staff gauges, pressure probes</td></tr>
<tr><td>Stage-Discharge relationship</td><td>Time-averaged</td><td>Monthly</td><td>-</td></tr>
<tr><td>Stream flow time series (m^3/s)</td><td>Time series</td><td>Continuous</td><td>-</td></tr>
</table>

In most river gauging stations in Lesotho, all the above presented stream flow parameters are observed though gaps exist as indicated in Figure **4-19** above. The existing gaps within the stream flow time series was infilled by using rainfall-runoff model in the WEAP model. However, data gaps infilling by using physically based distributed catchment rainfall-runoff models would be highly recommended for patching daily or higher temporal resolution stream flow record and are generally easy to calibrate as they employ physically-based laws.

6.10 Conclusions and Recommendations

An important observation in the national trends of water resources is that they are in general gradually decreasing. The WEAP's Soil Moisture Method of rainfall runoff is not impressive in its simulations as it hardly responds to calibration of its parameter. This study eventually relied on the WEAP's Simplified Coefficient method (i.e. the simplest method in WEAP with very few parameters) which was responsive to adjustments of the effective transpiration during calibration. The reliance of this method on calibration with effective transpiration implies that the WEAP runoff simulations should be verified by using another runoff model, most probably the physically-based catchment models, as the effective transpiration adjustment could be too crude and get to 100% in some cases. Apart from that, more resources should be directed to water resources monitoring and therefore reduce unnecessary reliance on inaccurate output of runoff models.

The amount of water resources that was available for further exploitation in 2016/17 was 3591.39 MCM; 161.76 MCM; and 833.65 MCM, for the Senqu, Makhaleng and Mohokare catchments, respectively. Nationally, the total amount of water resources that was available for further exploitation in 2016/17 was 4586.8 MCM

7. Economic Value of Water in Lesotho

This chapter presents the value of water to the economy of Lesotho, during the period under review.

7.1 Introduction

According to the National Strategic Development Plan (NSDP) 2012/13-2016/17, water is the important natural resource that needs to be carefully managed. It is a key determinant of economic growth which can lead to the sustainable development in the country. Water in Lesotho has the potential to contribute to the developments of huge and numerous investments which could lead to high job creation as well as to propel economic growth in the country. It is also regarded as an enabler for other sectors to grow. This chapter therefore reveals the value of water in Lesotho in terms of its contribution to the GDP, the revenues collected from its sales and royalties, its existing investments and their financing to push growth during the period under review. This chapter again portrays some of water's potential value chains that could be exploited to maximize its value added to the economic growth of the country. All these have been analysed to show the role water plays in accelerating growth in the country as well as the challenges the sector faces for its optimization.

7.2 Contributions of water to the GDP

According to 2011/12-2016/17 Macro-Economic Framework shown below, water contributed 0.5% and 1.9% to the GDP in 2011/12 and 2012/13 respectively. This indicates a good picture as there is an increase between the years under review. This is attributed to the increase in water usage both domestically and transfers to South Africa. With regards to the projections; even though the projections start at a lower base in 2013/14 (which could be a result of a drought), there are some increases projected up to 2016/17 which could be a result of more water from the Metolong dam coupled with the increased usage expected during the implementation of the NSDP in supporting productive sectors.

Table 7-1: The 2011/12 to 2016/17 Macro-Economic Framework baseline year and projections of contribution of water to NSDP in percentage (%)

2011/12-2016/17 Macro-Economic Framework Baseline	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17	2015/16 - 2016/17 NSDP Scenario
Agriculture	-2.1	0.9	3.1	3.1	3.4	3.2	7.8 to 7.2
Mining & Quarrying	19.2	20	-14.2	3.9	0.1	3.6	20.4 to 30.6
Electricity and Water	2.2	3.8	2.7	4.8	6.2	6.2	6.2 to 6.2
Electricity		5.9			7.5		
Water	0.5	1.9	0.4	4.8	5.5	5.7	5.5 to 5.7
GDP at purchasers' price	3.8	6.8	3.8	2.4	3.4	5.1	5.7 to 6.8

7.3 LHWP Royalties and Electricity sales revenue

Lesotho generates revenue from the Lesotho Highlands Water Project in the form of royalties and electricity sales. The hydropower generated from the Project at 'Muela Dam is sold to

Lesotho Electricity Company and ESKOM South Africa. The royalties are based on savings on capital costs, operation and maintenance costs, as well as pumping electricity costs of an alternative scheme, Orange-Vaal Transfer Scheme (OVTS) that RSA would have otherwise relied on had it not opted for the less costly LWHP scheme. The OVTS was intended to pump water from Senqu River downstream of Lesotho up into the Vaal Dam. The savings are described below:

- **Cost savings on capital costs:** A fixed amount in real terms paid over fifty years on monthly basis. The amount is adjusted for inflation using Producer Price Index (PPI) on monthly basis.
- **Cost savings on O&M costs:** A variable amount which depends on the amount of water delivered. The unit charge is adjusted for inflation using PPI on monthly basis.
- **Cost savings on pumping electricity costs:** A variable amount which depends on the amount of water delivered. The unit charge is adjusted for inflation using Eskom electricity price on annual basis.

Revenue from both electricity sales and royalties is presented in Table **7-2**.

Table 7-2: LHWP Royalties and Electricity sales revenue, in Million Maloti

	2010/11	**2011/12**	**2012/13**	**2013/14**	**2014/15**	**2015/16**	**2016/17**
Water transferred (Mm3)	730	876	730	783	780	773	794
Royalties							
Fixed royalty	166.8	182.7	191	-	219	232	-
Operation and maintenance royalty	15.5	20.8	18.2	-	-	-	-
Electricity royalty	254.9	411.3	421.6	-	-	-	-
Total Royalties	437.2	614.8	630.7	733.9	735.9	775	-
Electricity sales							
Local Sales - Lesotho Electricity Company	55.6	54.9	50.1	56.7	54.86	-	-
Export Sales - South Africa ESKOM	0.1	7.7	2.7	0.4	0.66	-	-
Total Electricity sales	55.7	62.7	52.8	57.1	55.52	-	-
Total Revenue (Royalties + Electricity sales)	**492.9**	**677.4**	**683.5**	**791.0**	**791.42**	-	-

Despite the lack of published information (in annual reports) in the years 2015/16 and 2016/17, Table **7-2** indicates slight increase in total revenue collected from royalties and electricity sales between 2013/14 and 2014/15.

7.4 Budget allocation and utilization

In spite of the significant contribution that water makes to the national economy, water resources monitoring and management is allocated a limiting budget to effective monitoring for accurate accounting of this useful natural resource. The apparently continuing absence of a proper database and commonly agreed data collection and sharing formats throughout the years under review has hindered the comparative analysis that was adopted as the approach in

compiling this report. Thus the quantitative information pertaining to budget allocation and utilization is therefore lacking in this.

7.5 Conclusions and Recommendations

Over the period under review, there has been a general increase in royalties, from 733.9 million Maloti in 2013/14 to 794 million Maloti in 2016/17.

8. CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusions

This report presents the work that covered significant part of the objectives of the project as stipulated in the study terms of reference. This study has therefore established trends in water quantity of the national water resources.

The report has proposed data sheets to guide collection and reporting of the field observed water resources data as well as water utilities record. With these data sheets to guide field data collection as well as intra-sectoral data collection and reporting, this approach would help to minimise gaps in the collected data, thereby providing opportunity to enhance the quality of reporting in the next state of water resources reports.

The physical water resources and the related socio-economic accounts were compiled against the potential growth in domestic water demands due to population growth. This report also proposes data collection and reporting formats that facilitate compiling water accounts for other economic sections of the society that are self-supplied with water or supplied by WASCO or by the DRWS.

The WEAP model was used to perform water balance at catchment levels in relation to water-related socio-economic status and growth, advising on the best options for adoption to address the current and future threats to water security for socio-economic development. As presented in Section 3.3.6, at national level, available water by far exceeds the national water demands (including evapotranspiration losses) for the reporting year of 2016/17. This is the case even though most of the received rain volumes are lost through evaporation for the whole reporting year 2016/17.

The total water demand exerted on the Senqu catchment was 843.08 MCM in 2016/17. After this demand had been fully met, the Senqu catchment still had the excess water amounting to 3591.39 MCM in 2016/17. The Makhaleng catchment had the total water demand of 4.41MCM in 2016/17. After this Makhaleng catchment's demand had been fully met, the excess water amounting to 161.76 MCM in 2016/17 was still available for further exploitation. Lastly, the Mohokare catchment had the water demand of 22.91 MCM in 2016/17. The amount of water still available for further exploitation in the Mohokare catchment had been 833.65 MCM in 2016/17.

The appropriate options for driving the aspirations of Government in terms of water use for socio-economic development, taking cognizance of the Long Term Water and Sanitation Strategy and the intended water resources management and development actions and the existing institutional setup in the water sector, are recommended for strict following as depicted in Figure 6-1.

This study recommends good use of the Watercourses Monitoring Framework Report that was produced in the recent project of Watercourses Classification Guidelines and Environmental Flows. In that report, all the necessary systems (human resources, the necessary equipment, etc.) that need to be in place and functional for data collection (also

included in this report) and analyses for the report of 2017/18 which should have been produced by June 2018, are recommended.

8.2 Recommendations

This report identifies the following recommendations:

1- The Ministries responsible for these activities should have clear strategic plans with time-bound targets on the outputs.
2- The incentives for officers responsible for the above activities should be linked to achievement of Departmental/ Organizational objectives.
3- All surface water gauging stations, groundwater (well-fields) and water quality monitoring stations should be maintained at functional state manned by well-trained hydrometric observers.
4- The Commissioner of Water (CoW) should implement the data collection and reporting formats recommended in this report for the whole of Water and Sanitation Sector.
5- Modalities for collection of water resources records should be devised for regular capturing, analyses and reporting.
6- Recruitment of hydrometric observers should be based on their proximity to the gauging station, and should be `done in liaison with regional officer in charge.
7- Resources allocation for officers responsible for monitoring of water resources activities (e.g. vehicles) should not be part of pooled resources.
8- Geographic coordinates for all water abstraction points (for domestic, industrial and agricultural uses) be recorded, water meters installed at abstraction sites, and withdrawn waters recorded. Similarly, coordinates for effluent discharge points should be recorded, and waste-water meters be installed to record the actual amount of waste water discharged. These components should be recorded and stored in the database along with meter numbers. During data reporting and / or sharing, all these three components should be in the data (refer to Appendix 9.4-A to Appendix 9.4-L).
9- An independent comprehensive review of the current structure of the Policy, Planning and Strategies Unit (PPSU) in terms of responsibilities, staffing and "best" placement is critical for its effectiveness in supporting the office of the CoW. This would ensure that periodic data inflow and management from relevant member institutions of the Water and Sanitation Sector, is analysed and reported monthly.
10- Review processes, guidelines and inter-ministerial responsibilities enshrined in the legal framework that establishes those institutions. For instance, the problem that is associated with adoption and implementation of the 2013 Water Quality Standards and Guidelines which were drafted by the Commissioner of Water without legal powers to adopt as they are legislated under the Environment Act of 2008.
11- The Ministry of Water should revise the policy wording (for ease of application) on basic water of 30 litres per person per day to mandate it as free water regardless of level of income of the user. This should then be reflected in the tariff structure for water.
12- According to Water Act 2008, Section 8 (2) (d), the Commissioner of Water is the custodian of the water resources data on behalf of the Minister. This implies that the Commissioner of Water should have a well-managed database and provide the water

metrics (quantity, quality, abstractions, consumptions, non-revenue water, waste-water disposal, etc.) that will serve as the national dashboard real-time. It is therefore recommended that this obligation be observed as to facilitate future compilations of the annual state of water resources reports.

13- The CoW should, on quarterly basis, receive information relating to metered monthly volume of water for every extraction point, distribution lines, feeder lines and household meters. The CoW should validate this information by spontaneous random spot checking of the metered points.

14- The utility regulating authority (e.g. LEWA) should not be reporting to the same Government Ministry with the regulated utility. This is because this presents conflict of interest for the Ministry.

15- It is recommended that IT infrastructure such as computing hardware and software be seriously supported. The best suited hardware for water resources modelling tasks is one of the highest specifications in the market, i.e. latest and very high performance processors, graphics cards and highest available RAM of the minimum of 32GB. In short, the best suited hardware are the top-of-the-range computers of the type called "Workstations".

16- As the custodian of water resources (Figure 3-1), the Commissioner of Water should monitor and ensure that WASCO complies with the Environment Act (2008) regarding acquisition of disposal permits from the Department of Environment.

17- Management of wetlands should be enhanced to ensure availability of water for extended period of time.

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9. Appendices

9.1 Appendix 1: Evapotranspiration derivatives

Appendix 9.1-A: Reference evapotranspiration, ETo (mm)

Date	LO	SG3	SG4	SG5	SG6	SG7	SG8	SG9	SG17	SG18	CG22	MG23	CG24	CG25	SG36	SG42	CG55	CG69	CG75	CG77	SG80	CG84	SG100	CG77us	CG70	D1H006	D1H009
4/1/2013	159	126	156	126	123	144	123	96	132	129	138	138	126	132	117	117	135	144	132	129	117	132	117	126	150	147	153
5/1/2013	115	99	140	99	105	121	115	74	96	99	99	99	84	93	96	96	105	112	90	99	90	90	99	96	105	105	112
6/1/2013	126	111	141	114	114	141	108	78	99	111	99	135	87	87	102	96	105	117	90	84	93	90	108	93	114	120	126
7/1/2013	121	105	130	109	115	127	102	71	96	102	102	102	81	87	99	96	105	115	93	99	87	93	105	96	118	112	115
8/1/2013	171	143	155	143	146	174	136	109	140	146	146	149	127	127	127	124	140	152	136	130	124	136	133	127	140	161	167
9/1/2013	216	189	207	192	162	219	183	153	189	189	195	198	177	174	159	168	177	198	183	174	168	186	180	171	216	210	219
10/1/2013	236	198	226	205	183	214	140	177	214	211	205	223	205	211	171	177	198	208	214	195	189	214	192	192	242	229	236
11/1/2013	267	216	252	225	195	237	210	186	156	219	219	240	234	231	183	195	213	222	225	207	210	228	204	204	261	261	264
12/1/2013	229	195	229	195	164	202	186	167	208	177	211	208	205	233	174	186	192	198	192	189	183	195	180	186	217	208	220
1/1/2014	236	260	226	245	217	223	245	220	257	233	233	248	233	226	211	211	229	229	208	229	248	211	229	229	239	226	239
2/1/2014	174	146	182	154	137	174	146	132	160	151	168	250	202	171	134	140	154	162	157	151	148	160	143	148	168	176	185
3/1/2014	183	158	189	167	146	174	167	124	164	167	167	260	149	167	149	130	136	146	155	121	152	152	155	140	174	189	174
4/1/2014	138	117	144	117	117	138	114	96	120	120	126	129	111	120	108	111	108	117	120	111	108	120	111	108	132	129	132
5/1/2014	124	118	146	118	124	146	115	90	109	118	115	112	96	105	118	99	118	127	102	102	102	99	118	115	118	118	133
6/1/2014	111	117	138	108	120	141	108	78	96	108	105	142	84	87	105	96	105	117	93	96	93	90	105	93	108	108	111
7/1/2014	118	152	133	109	121	136	99	84	90	99	99	136	84	87	105	93	109	118	84	99	87	84	105	96	112	109	112
8/1/2014	158	164	155	127	130	158	121	93	127	127	149	136	118	121	121	152	130	143	127	124	112	130	124	118	158	143	143
9/1/2014	195	217	210	186	174	207	180	153	183	180	183	189	165	171	168	168	171	150	180	165	165	180	174	156	195	186	198
10/1/2014	248	192	236	205	177	229	205	167	217	198	229	229	208	208	183	189	189	198	217	186	198	220	180	183	251	236	242
11/1/2014	234	186	228	198	174	213	186	168	210	186	210	400	210	213	177	177	180	195	195	177	180	201	183	171	231	219	228
12/1/2014	223	198	254	229	186	226	220	183	211	192	214	211	208	226	195	202	192	229	198	189	198	205	189	186	223	220	245
1/1/2015	220	183	242	195	174	211	180	167	214	180	202	220	211	205	174	171	183	192	189	174	171	174	214	171	220	217	226
2/1/2015	207	179	216	204	165	182	179	168	185	185	204	210	196	204	168	176	188	202	196	179	182	202	165	176	207	207	207
3/1/2015	161	149	198	158	149	183	149	130	155	152	171	200	164	164	143	140	152	164	149	146	143	155	186	143	171	161	174
4/1/2015	144	123	165	132	135	150	129	105	135	132	141	150	129	132	126	129	135	144	132	123	138	132	141	120	141	144	141
5/1/2015	133	158	133	112	136	149	105	93	105	115	118	112	90	99	118	105	124	140	96	109	133	96	130	102	115	127	130
6/1/2015	120	102	120	84	108	117	87	69	81	90	105	93	78	84	99	90	99	108	84	90	102	87	102	84	108	96	99

7/1/2015	124	99	118	99	115	127	87	71	87	99	118	96	78	90	102	90	102	121	87	93	90	90	84	87	112	146	109
8/1/2015	130	112	177	130	146	167	121	121	130	136	155	146	130	127	133	121	140	155	130	124	105	130	93	121	161	183	155
9/1/2015	204	159	225	183	183	216	180	156	189	186	207	211	180	183	183	177	183	195	183	171	120	186	120	174	216	231	207
10/1/2015	245	198	264	217	214	242	214	202	226	217	254	245	214	233	233	214	217	229	226	208	130	233	180	211	260	260	248
11/1/2015	291	225	264	243	228	258	240	222	252	231	288	267	264	261	237	234	240	252	246	231	186	255	204	234	303	315	288
12/1/2015	301	257	257	260	236	282	251	229	267	248	301	288	270	273	245	242	257	273	273	251	248	285	242	248	310	223	316
1/1/2016	285	226	267	229	195	245	220	205	245	236	267	267	254	248	202	211	226	233	245	220	251	257	248	220	288	279	279
2/1/2016	189	162	226	197	160	180	131	160	154	151	191	183	200	200	168	177	191	200	168	189	206	186	183	194	197	180	189
3/1/2016	90	102	136	109	84	105	93	78	90	81	105	180	87	105	87	78	96	102	78	96	183	93	87	96	99	84	112
4/1/2016	132	135	159	138	141	165	138	114	138	132	159	144	129	138	135	129	150	162	135	138	84	138	129	132	141	123	120
5/1/2016	118	87	96	84	96	105	78	65	78	96	93	84	74	84	84	74	87	96	78	84	136	81	81	78	87	81	81
6/1/2016	90	87	99	90	99	117	81	63	72	78	81	78	63	72	84	78	165	93	69	78	69	72	81	72	81	84	84
7/1/2016	130	171	133	140	198	192	158	140	136	174	167	152	136	130	115	171	136	180	121	161	78	127	164	158	158	152	158
8/1/2016	124	143	152	130	155	155	140	130	127	127	133	136	118	127	143	143	171	140	109	130	81	118	143	127	136	118	115
9/1/2016	180	159	210	186	153	192	168	147	156	153	177	171	165	165	156	156	228	177	153	153	183	159	165	156	153	174	183
10/1/2016	205	273	273	257	257	254	264	254	233	229	217	229	229	239	260	279	171	233	180	236	205	189	282	248	220	183	223
11/1/2016	201	177	222	195	147	180	162	180	150	129	168	183	219	192	153	153	174	171	147	174	159	168	174	171	186	180	195
12/1/2016	208	223	251	236	198	211	211	223	248	180	177	208	220	223	205	211	195	177	146	208	183	152	242	205	186	177	202
1/1/2017	198	174	214	192	146	180	171	171	161	143	112	189	205	198	202	161	171	171	149	177	152	171	167	171	189	171	198
2/1/2017	151	126	168	148	120	146	129	129	126	115	90	143	154	154	123	126	137	143	115	137	115	129	132	132	140	140	154
3/1/2017	164	130	171	149	121	140	133	127	127	118	84	158	161	158	133	124	143	146	118	143	115	140	130	130	143	149	158

Appendix 9.1-B: WEAP calibrated effective evapotranspiration (%)

Date	LO	SG3	SG4	SG5	SG6	SG7	SG8	SG9	SG17	SG18	CG22	MG23	CG24	CG25	SG36	SG42	CG55	CG69	CG75	CG77	SG80	CG84	SG100	CG77us	CG70	D1H006	D1H009
4/1/2013	93.31	50	50	50	50	50	50	50	50	50	90.64	100.00	90.64	90.64	50	50	90.64	90.64	90.64	90.64	50	90.64	50	90.64	90.64	100.00	50
5/1/2013	94.76	50	50	50	50	50	50	50	50	50	92.66	100.00	92.66	92.66	50	50	92.66	92.66	92.66	92.66	50	92.66	50	92.66	92.66	100.00	50
6/1/2013	80.89	10	10	10	10	10	10	10	10	10	80.00	83.12	80.00	80.00	10	10	80.00	80.00	80.00	80.00	10	80.00	10	80.00	80.00	83.12	10
7/1/2013	71.07	40	60	40	40	40	40	40	40	40	79.50	50.00	79.50	79.50	40	40	79.50	79.50	79.50	79.50	40	79.50	40	79.50	79.50	50.00	40
8/1/2013	98.11	87	70	87	87	87	87	87	87	87	97.35	100.00	97.35	97.35	87	87	97.35	97.35	97.35	97.35	87	97.35	87	97.35	97.35	100.00	87
9/1/2013	99.09	89	90	89	89	89	89	89	89	89	98.72	100.00	98.72	98.72	89	89	98.72	98.72	98.72	98.72	89	98.72	89	98.72	98.72	100.00	89
10/1/2013	98.78	97	97	97	97	97	97	97	97	97	98.29	100.00	98.29	98.29	97	97	98.29	98.29	98.29	98.29	97	98.29	97	98.29	98.29	100.00	97
11/1/2013	99.43	93	93	93	93	93	93	93	93	93	99.20	100.00	99.20	99.20	93	93	99.20	99.20	99.20	99.20	93	99.20	93	99.20	99.20	100.00	93
12/1/2013	95.89	75	75	75	75	75	75	75	75	75	94.25	100.00	94.25	94.25	75	75	94.25	94.25	94.25	94.25	75	94.25	75	94.25	94.25	100.00	75
1/1/2014	95.71	70	70	70	70	70	70	70	70	70	94.00	100.00	94.00	94.00	70	70	94.00	94.00	94.00	94.00	70	94.00	70	94.00	94.00	100.00	70
2/1/2014	85.00	60	60	60	60	60	60	60	60	60	79.00	100.00	79.00	79.00	60	60	79.00	79.00	79.00	79.00	60	79.00	60	79.00	79.00	100.00	60
3/1/2014	79.18	50	50	50	50	50	50	50	50	50	70.85	100.00	70.85	70.85	50	50	70.85	70.85	70.85	70.85	50	70.85	50	70.85	70.85	100.00	50
4/1/2014	97.94	85	85	85	85	85	85	85	85	85	97.12	100.00	97.12	97.12	85	85	97.12	97.12	97.12	97.12	85	97.12	85	97.12	97.12	100.00	85
5/1/2014	93.93	90	90	90	90	90	90	90	90	90	91.50	100.00	91.50	91.50	90	90	91.50	91.50	91.50	91.50	90	91.50	90	91.50	91.50	100.00	90
6/1/2014	75.81	50	50	50	50	50	50	50	50	50	87.50	46.58	87.50	87.50	50	50	87.50	87.50	87.50	87.50	50	87.50	50	87.50	87.50	46.58	50
7/1/2014	32.28	97	97	97	97	97	97	97	97	97	45.00	0.47	45.00	45.00	97	97	45.00	45.00	45.00	45.00	97	45.00	97	45.00	45.00	0.47	97
8/1/2014	96.43	100	100	100	100	100	100	100	100	100	95.00	100.00	95.00	95.00	100	100	95.00	95.00	95.00	95.00	100	95.00	100	95.00	95.00	100.00	100
9/1/2014	98.71	100	100	100	100	100	100	100	100	100	98.20	100.00	98.20	98.20	100	100	98.20	98.20	98.20	98.20	100	98.20	100	98.20	98.20	100.00	100
10/1/2014	99.16	100	100	100	100	100	100	100	100	100	98.83	100.00	98.83	98.83	100	100	98.83	98.83	98.83	98.83	100	98.83	100	98.83	98.83	100.00	100
11/1/2014	91.07	80	80	80	80	80	80	80	80	80	87.50	100.00	87.50	87.50	80	80	87.50	87.50	87.50	87.50	80	87.50	80	87.50	87.50	100.00	80
12/1/2014	92.75	75	75	75	75	75	75	75	75	75	89.85	100.00	89.85	89.85	75	75	89.85	89.85	89.85	89.85	75	89.85	75	89.85	89.85	100.00	75
1/1/2015	92.50	80	80	80	80	80	80	80	80	80	89.50	100.00	89.50	89.50	80	80	89.50	89.50	89.50	89.50	80	89.50	80	89.50	89.50	100.00	80
2/1/2015	96.64	60	60	60	60	60	60	60	60	60	95.29	100.00	95.29	95.29	60	60	95.29	95.29	95.29	95.29	60	95.29	60	95.29	95.29	100.00	60
3/1/2015	93.57	80	80	80	80	80	80	80	80	80	91.00	100.00	91.00	91.00	80	80	91.00	91.00	91.00	91.00	80	91.00	80	91.00	91.00	100.00	80
4/1/2015	92.86	55	55	55	55	55	55	55	55	55	90.00	100.00	90.00	90.00	55	55	90.00	90.00	90.00	90.00	55	90.00	55	90.00	90.00	100.00	55
5/1/2015	86.50	100	100	100	100	100	100	100	100	100	81.10	100.00	81.10	81.10	100	100	81.10	81.10	81.10	81.10	100	81.10	100	81.10	81.10	100.00	100
6/1/2015	98.57	90	90	90	90	90	90	90	90	90	98.00	100.00	98.00	98.00	90	90	98.00	98.00	98.00	98.00	90	98.00	90	98.00	98.00	100.00	90

7/1/2015	98.57	93	93	93	93	93	93	93	93	93	98.00	100.00	98.00	98.00	93	93	98.00	98.00	98.00	98.00	93	98.00	93	98.00	98.00	100.00	93
8/1/2015	92.36	99	99	99	99	99	99	99	99	99	89.50	99.50	89.50	89.50	99	99	89.50	89.50	89.50	89.50	99	89.50	99	89.50	89.50	99.50	99
9/1/2015	98.39	95	95	95	95	95	95	95	95	95	97.90	99.60	97.90	97.90	95	95	97.90	97.90	97.90	97.90	95	97.90	95	97.90	97.90	99.60	95
10/1/2015	99.21	100	100	100	100	100	100	100	100	100	99.00	99.75	99.00	99.00	100	100	99.00	99.00	99.00	99.00	100	99.00	100	99.00	99.00	99.75	100
11/1/2015	98.89	97	97	97	97	97	97	97	97	97	98.50	99.85	98.50	98.50	97	97	98.50	98.50	98.50	98.50	97	98.50	97	98.50	98.50	99.85	97
12/1/2015	96.25	99	99	99	99	99	99	99	99	99	94.95	99.50	94.95	94.95	99	99	94.95	94.95	94.95	94.95	99	94.95	99	94.95	94.95	99.50	99
1/1/2016	96.46	95	95	95	95	95	95	95	95	95	95.05	100.00	95.05	95.05	95	95	95.05	95.05	95.05	95.05	95	95.05	95	95.05	95.05	100.00	95
2/1/2016	95.00	85	85	85	85	85	85	85	85	85	93.00	100.00	93.00	93.00	85	85	93.00	93.00	93.00	93.00	85	93.00	85	93.00	93.00	100.00	85
3/1/2016	95.00	75	75	75	75	75	75	75	75	75	93.00	100.00	93.00	93.00	75	75	93.00	93.00	93.00	93.00	75	93.00	75	93.00	93.00	100.00	75
4/1/2016	97.29	77	77	77	77	77	77	77	77	77	96.20	100.00	96.20	96.20	77	77	96.20	96.20	96.20	96.20	77	96.20	77	96.20	96.20	100.00	77
5/1/2016	97.79	75	75	75	75	75	75	75	75	75	96.90	100.00	96.90	96.90	75	75	96.90	96.90	96.90	96.90	75	96.90	75	96.90	96.90	100.00	75
6/1/2016	97.86	75	75	75	75	75	75	75	75	75	97.00	100.00	97.00	97.00	75	75	97.00	97.00	97.00	97.00	75	97.00	75	97.00	97.00	100.00	75
7/1/2016	97.68	94	94	94	94	94	94	94	94	94	96.75	100.00	96.75	96.75	94	94	96.75	96.75	96.75	96.75	94	96.75	94	96.75	96.75	100.00	94
8/1/2016	96.09	36	36	36	36	36	36	36	36	36	94.52	100.00	94.52	94.52	36	36	94.52	94.52	94.52	94.52	36	94.52	36	94.52	94.52	100.00	36
9/1/2016	99.36	80	80	80	80	80	80	80	80	80	99.30	99.50	99.30	99.30	80	80	99.30	99.30	99.30	99.30	80	99.30	80	99.30	99.30	99.50	80
10/1/2016	96.75	98	98	98	98	98	98	98	98	98	95.45	100.00	95.45	95.45	98	98	95.45	95.45	95.45	95.45	98	95.45	98	95.45	95.45	100.00	98
11/1/2016	96.04	80	80	80	80	80	80	80	80	80	94.45	100.00	94.45	94.45	80	80	94.45	94.45	94.45	94.45	80	94.45	80	94.45	94.45	100.00	80
12/1/2016	96.50	97	97	97	97	97	97	97	97	97	95.10	100.00	95.10	95.10	97	97	95.10	95.10	95.10	95.10	97	95.10	97	95.10	95.10	100.00	97
1/1/2017	100.00	60	60	60	60	60	60	60	60	60	100.00	100.00	100.00	100.00	60	60	100.00	100.00	100.00	100.00	60	100.00	60	100.00	100.00	100.00	60
2/1/2017	100.00	95	95	95	95	95	95	95	95	95	100.00	100.00	100.00	100.00	95	95	100.00	100.00	100.00	100.00	95	100.00	95	100.00	100.00	100.00	95
3/1/2017	93.57	50	50	50	50	50	50	50	50	50	91.00	100.00	91.00	91.00	50	50	91.00	91.00	91.00	91.00	50	91.00	50	91.00	91.00	100.00	50

9.2 Appendix 2: Surface water resources quantity and quality

Appendix 9.2-A: The observed and simulated monthly volume in Million Cubic Metres (MCM) and their ratio for selected gauging stations

Date	CG22			MG23			SG3		
	Obs.	Sim.	Sim./Obs.	Obs.	Sim.	Sim./Obs.	Obs.	Sim.	Sim./Obs.
Apr-13	35.448	37.642	1.1	21.021	20.880	1.0	394.858	428.365	1.1
May-13	10.199	11.244	1.1	18.963	18.817	1.0	156.981	142.108	0.9
Jun-13	2.609	2.605	1.0	5.832	7.477	1.3	67.904	63.844	0.9
Jul-13	1.404	1.231	0.9	15.508	16.605	1.1	51.403	41.701	0.8
Aug-13	0.701	0.685	1.0	8.223	8.077	1.0	40.552	41.446	1.0
Sep-13	0.028	0.027	1.0	2.644	2.503	0.9	36.114	44.633	1.2
Oct-13	7.733	8.845	1.1	32.810	32.665	1.0	32.438	33.732	1.0
Nov-13	5.042	4.630	0.9	41.602	41.461	1.0	105.885	110.206	1.0
Dec-13	55.103	58.183	1.1	34.900	37.893	1.1	469.184	534.365	1.1
Jan-14	50.253	49.312	1.0	22.766	22.621	1.0	559.249	612.620	1.1
Feb-14	146.674	174.673	1.2	23.781	23.649	1.0	683.024	771.486	1.1
Mar-14	161.726	201.664	1.2	9.482	9.336	1.0	786.369	743.992	0.9
Apr-14	8.643	6.737	0.8	1.659	1.517	0.9	93.313	87.957	0.9
May-14	2.566	2.878	1.1	1.152	1.006	0.9	48.841	58.570	1.2
Jun-14	1.330	1.566	1.2	6.039	9.427	1.6	38.407	43.548	1.1
Jul-14	6.105	5.115	0.8	3.964	6.538	1.6	29.561	37.004	1.3
Aug-14	4.228	4.356	1.0	1.339	1.193	0.9	39.256	57.823	1.5
Sep-14	0.749	0.768	1.0	3.421	3.280	1.0	20.638	27.130	1.3
Oct-14	1.369	1.523	1.1	7.312	7.166	1.0	26.094	26.761	1.0
Nov-14	167.525	181.336	1.1	6.558	6.416	1.0	426.581	459.419	1.1
Dec-14	63.995	79.413	1.2	2.250	2.104	0.9	485.938	451.392	0.9
Jan-15	75.192	82.412	1.1	0.696	0.550	0.8	492.906	371.444	0.8
Feb-15	12.817	15.205	1.2	2.516	2.384	0.9	247.963	307.719	1.2
Mar-15	67.741	80.681	1.2	38.248	42.445	1.1	319.702	335.693	1.1
Apr-15	19.922	20.741	1.0	14.515	14.373	1.0	158.234	180.797	1.1
May-15	4.646	5.469	1.2	2.732	2.586	0.9	41.345	52.321	1.3
Jun-15	2.237	2.399	1.1	1.633	1.491	0.9	42.862	49.902	1.2
Jul-15	2.362	2.334	1.0	0.911	0.764	0.8	80.879	74.899	0.9
Aug-15	2.179	2.625	1.2	0.509	0.435	0.9	50.884	62.735	1.2
Sep-15	2.892	3.286	1.1	0.285	0.322	1.1	44.025	50.175	1.1
Oct-15	2.062	1.604	0.8	0.241	0.283	1.2	23.795	29.357	1.2
Nov-15	3.206	3.117	1.0	0.259	0.251	1.0	26.647	31.863	1.2
Dec-15	4.318	3.718	0.9	0.536	0.481	0.9	19.025	19.316	1.0
Jan-16	28.354	31.107	1.1	1.634	1.487	0.9	112.198	106.397	0.9
Feb-16	42.840	41.396	1.0	5.888	5.553	0.9	276.176	296.482	1.1
Mar-16	32.522	32.282	1.0	4.526	4.380	1.0	226.087	231.921	1.0
Apr-16	17.577	20.027	1.1	3.033	2.891	1.0	171.187	176.051	1.0
May-16	7.167	7.705	1.1	5.464	5.317	1.0	152.016	148.309	1.0

Jun-16	2.535	2.451	1.0	3.240	3.098	1.0	58.879	57.280	1.0
Jul-16	15.643	19.220	1.2	1.393	1.246	0.9	103.469	107.404	1.0
Aug-16	8.406	6.525	0.8	0.696	0.550	0.8	316.295	243.752	0.8
Sep-16	0.687	0.547	0.8	0.415	0.465	1.1	99.495	84.879	0.9
Oct-16	16.867	18.590	1.1	23.757	23.611	1.0	31.282	38.254	1.2
Nov-16	50.848	42.114	0.8	12.882	12.740	1.0	345.218	352.542	1.0
Dec-16	25.986	29.182	1.1	3.053	2.907	1.0	47.559	44.993	0.9
Jan-17	105.361	100.878	1.0	1.928	1.782	0.9	719.913	818.031	1.1
Feb-17	242.187	260.312	1.1	14.201	14.068	1.0	1265.045	1117.508	0.9
Mar-17	39.826	35.892	0.9	23.650	23.503	1.0	353.986	402.386	1.1

Appendix 9.2-B: Total Dissolved Solids (TDS) in mg/L for river water

Catchment		2012/13	2013/14	2014/15	2015/16	2016/17
Senqu (SG) *(Recommended annual sample size is 564)*	Sample size	-	-	-	-	-
	Minimum (mg/L)	-	-	-	-	-
	Median (mg/L)	-	-	-	-	-
	Mean (mg/L)	-	-	-	-	-
	Maximum (mg/L)	-	-	-	-	-
	Range (mg/L)	-	-	-	-	-
Makhaleng (MG) *(Recommended annual sample size is 168)*	Sample size	1	6	0	7	7
	Minimum (mg/L)	122.2	42	-	0	0
	Median (mg/L)	122.2	75.25	-	0	70.7
	Mean (mg/L)	122.2	86.0	-	39.8	53.5
	Maximum (mg/L)	122.2	147.9	-	95.2	88.0
	Range (mg/L)	0.0	105.9	-	95.2	88.0
Mohokare (CG) *(Recommended annual sample size is 948)*	Sample size	13	24	17	34	60
	Minimum (mg/L)	0	0	0.92	0	0
	Median (mg/L)	96.1	96.55	128.15	73.3	90.5
	Mean (mg/L)	91.3	96.0	133.2	66.1	80.4
	Maximum (mg/L)	226.0	221.0	395.0	231.0	252.0
	Range (mg/L)	226.0	221.0	394.1	231.0	252.0
National (Recommended annual sample size is 1680)	Sample size	14	30	17	41	67
	Minimum (mg/L)	0	0	0.92	0	0
	Median (mg/L)	88.6	92.15	129.9	62.1	85
	Mean (mg/L)	89.3	94.0	134.9	62.0	77.6
	Maximum (mg/L)	226.0	221.0	395.0	231.0	252.0
	Range (mg/L)	226.0	221.0	394.1	231.0	252.0

Appendix 9.2-C: pH for river water

pH		2013/14	2014/15	2015/16	2016/17
Senqu (SG) *(Recommended annual sample size is 564)*	Sample size				
	Minimum (µSm)				
	Median (µSm)				
	Mean (µSm)				
	Maximum (µSm)				
	Range (µSm)				
Makhaleng (MG) *(Recommended annual sample size is 168)*	Sample size	6	0	7	7
	Minimum (µSm)	6.9	-	7.0	7.0
	Median (µSm)	8.0	-	8.1	7.5
	Mean (µSm)	8.5	-	7.9	7.7
	Maximum (µSm)	12.1	-	8.3	8.2
	Range (µSm)	5.2	-	1.3	1.2
Mohokare (CG) *(Recommended annual sample size is 948)*	Sample size	24	15	34	57
	Minimum (µSm)	7.0	0.0	7.0	6.6
	Median (µSm)	7.9	7.0	8.1	7.9
	Mean (µSm)	8.1	6.8	8.0	7.8
	Maximum (µSm)	10.2	8.9	9.6	8.8
	Range (µSm)	3.3	8.9	2.6	2.2
National (Recommended annual sample size is 1680)	Sample size	30	15	41	64
	Minimum (µSm)	6.9	0.0	7.0	6.6
	Median (µSm)	7.9	7.0	8.1	7.9
	Mean (µSm)	8.2	6.7	8.0	7.8
	Maximum (µSm)	12.1	8.9	9.6	8.8
	Range (µSm)	5.2	8.9	2.6	2.2

9.3 Appendix 3: Spring water quality

Appendix 9.3-A: Spring water pH

Catchment		2013/14	2014/15	2015/16	2016/17
Senqu (SG) *(Recommended annual sample size is 564)*	Sample size	97	125	73	-
	Minimum	6.84	7	7.1	-
	Median	8	8	8	-
	Mean	7.66	7.75	8	-
	Maximum	8.9	9	8.72	-
	Range	2.06	2	1.62	-
Makhaleng (MG) *(Recommended annual sample size is 168)*	Sample size	15	0	4	-
	Minimum	7.65	-	7.6	-
	Median	8.27	-	7.715	-
	Mean	8.56	-	7.765	-
	Maximum	10.4	-	8.03	-

	Range	2.75	-	0.43	-
Mohokare (CG) *(Recommended annual sample size is 948)*	Sample size	130	13	6	-
	Minimum	6	6	7	-
	Median	8	11	7	-
	Mean	9	10.37	7	-
	Maximum	13	11	8	-
	Range	7	5	1	-
National (Recommended annual sample size is 1680)	Sample size	242	138	23	-
	Minimum	6.16	6.21	83	-
	Median	7.83	7.735	7	-
	Mean	8.31	8.00	8	-
	Maximum	12.8	11.4	8.72	-
	Range	6.64	5.19	1.72	-

Appendix 9.3-B: Spring water salinity (ppt)

Catchment		**2010/11**	**2011/12**	**2012/13**	**2013/14**	**2014/15**	**2015/16**	**2016/17**
Senqu (SG) *(Recommended annual sample size is 564)*	Sample size	3	34	24	97	125	74	-
	Minimum	0	0	0	0	0	0	-
	Median	0	0	0	0	0	0	-
	Mean	0.23	0.07	0.18	0.47	0.18	0	-
	Maximum	0.36	0.55	0.59	27	0	0.51	-
	Range	0.36	0.55	0.59	27	0	0.51	-
Makhaleng (MG) *(Recommended annual sample size is 168)*	Sample size	6	9	19	15	0	4	-
	Minimum	0	0	0	0	-	0	-
	Median	0	0.085	0	0.13	-	0	-
	Mean	0.02	0.08	0.06	0.18	-	0	-
	Maximum	0.13	0.16	0	1.15	-	0	-
	Range	0.13	0.16	0	1.15	-	0	-
Mohokare (CG) *(Recommended annual sample size is 948)*	Sample size	9	33	73	137	18	6	-
	Minimum	0	0	0.00	0	0	0	-
	Median	0	0	0.06	0.10	0	0	-
	Mean	0.12	0	0.07	0.14	0.19	0	-
	Maximum	0	0	0.33	0.62	0	0	-
	Range	0	0	0.33	0.62	0	0	-
National (Recommended annual sample size is 1680)	Sample size	18	76	116	249	143	23	-
	Minimum	0	0	0.00	0	0	84	-
	Median	0.05	0.05	0.07	0.14	0.16	0	-
	Mean	0.11	0.09	0.09	0.27	0.19	0	-
	Maximum	0.36	0.55	0.59	27	0.49	0.51	-
	Range	0.36	0.55	0.59	27	0.49	0.51	-

9.4 Appendix 4: Data collection and reporting formats

Appendix 9.4-A: Meteorological elements and their measuring instrumentation

Elements		Temporal variation	Spatial variation	Monitoring frequency	Instruments
Precipitation	Rainfall (mm)	Time series	Isohyets	Daily or continuous	Rain gauge
	Snow (m)			Event based	Snow sensor, meter stick
	Hail (m, size)		-	Event based	Meter stick, callipers
Temperature (Degree Celsius)	Instantaneous		Spatial interpolation	Continuous	Thermometers, sensors
	Mean			Daily	
	Minimum			Daily	
	Maximum			Daily	
Wind	Speed (m/s)		Spatial interpolation	Continuous	Wind anemometer
	Direction (Degree)			Daily	Wind vane
Humidity	Absolute (m^3)		Spatial interpolation	Daily	Wet & dry bulb thermometers and sensors
	Relative (%)			Daily	
Solar radiation (Watts/m^2)			-	Continuous	Sensors
Sunshine (Hours)			-	Daily	Sunshine recorder
Evaporation (mm)	Open-water evaporation		-	Daily	Piche Evaporimeter, Sunken Evaporation Pan and Class A Land Pan Evaporimeter
	Evapotranspiration		Spatial interpolation	Daily	No direct instrumentation (requires a complete weather station)

Appendix 9.4-B: River water quality parameters variation and their measuring instrumentation

Parameter		**Temporal variation**	**Monitoring frequency**	**Instrumentation**
Catchment size (km^2)		-	Once-off	Planimeter
Sampling location (lat., long., alt.)		-	Once-off	GPS
Physico-chemical	Temperature	Time series	Continuous or monthly	Temperature sensor
	pH		Monthly	pH meter
	Dissolved oxygen			DO sensor
	BOD			Lab tests
	Total Dissolved Solids			TDS sensors, lab tests
	Electrical Conductivity		Continuous	EC sensors
	Turbidity		Continuous	Turbidity meter, turbidity tube
	Hardness		Monthly	Lab tests
	Alkalinity / acidity			
	Heavy metals	Time series		
	Nutrients			
	Other toxic metals			
	Organic chemicals			
Biological	Macro-invertebrates	Time series	Seasonal	SASS5 equipment
	Pathogens		Monthly	Lab tests
	Fish		Seasonal	Electro-shockers, nets
Sediment transport	Suspended sediment (g/m^3)	Time series	Monthly or event-based	Sampling bottle or pump-sampler
	Bed load (kg/day)	Time series		Runoff tubes, bed-load trench, bed-load traps, etc.

Appendix 9.4-C: Borehole water monitoring parameters

Parameter		Temporal variation	Monitoring frequency	Instrumentation
Yield (l/s)		Time series	Once-off	Same as in springs
Location (lat., long., alt.)		-	Once-off	GPS
Vicinity land-use map		Time series	Seasonal	Remote sensing technology
Borehole's aquifer flow net		Time-varying pattern	Seasonal	Monitoring boreholes, borehole pumps, etc.
Borehole water levels (m)		Time-varying pattern	Daily or monthly	Water level sensors
Physico-chemical	Temperature	Time series	Same as in rivers (monthly)	Same as in rivers
	pH			
	Dissolved oxygen			
	BOD			
	Total Dissolved Solids			
	Electrical Conductivity			
	Turbidity			
	Hardness			
	Alkalinity / acidity			
	Heavy metals			
	Nutrients			
	Other toxic metals			
	Organic chemicals			
Biological	Pathogens	Time series	Monthly	Lab tests

Appendix 9.4-D: Spring monitoring parameters

Parameter		Temporal variation	Monitoring frequency	Instrumentation
Yield (l/s)		Time series	Monthly	Stop-watch and known volume bucket
Location (lat., long., alt.**)**		-	Once off	GPS
Physico-chemical	Temperature	Time series	Same as in rivers (monthly)	Same as in rivers
	pH			
	Dissolved oxygen			
	BOD			
	Total Dissolved Solids			
	Electrical Conductivity			
	Turbidity			
	Hardness			
	Alkalinity / acidity			
	Heavy metals			
	Nutrients			
	Other toxic metals			
	Organic chemicals			
Biological	Macro-invertebrates	Time series	Seasonal	Same as in rivers
	Pathogens		Monthly	

Appendix 9.4-E: Reservoir monitoring parameters

Parameter		**Temporal variation**	**Monitoring frequency**	**Instrumentation**
Catchment size	(km^2)	-	Once-off	Planimeter
Physico-chemical	Temperature profile	Time series	Monthly	Same as in rivers
	pH		Same as in rivers (monthly)	
	Dissolved oxygen			
	BOD			
	Total Dissolved Solids			
	Electrical Conductivity			
	Turbidity			
	Hardness			
	Alkalinity / acidity			
	Heavy metals			
	Nutrients			
	Other toxic metals			
	Organic chemicals			
Biological	Pathogens	Time series	Monthly	Same as in rivers
	Fish		Seasonal	
Sediment load	Suspended sediment (g/m^3)	Time series	Monthly	Engine boat, life-jackets and GPS-integrated echo-sounders
	Sedimentation rate (mm/yr)		Seasonal	
Live storage	Bathymetry	Time-averaged time series	Annual	
	Volume-elevation relationship		Annual	
	Water levels	Time series	Continuous	Data loggers

Appendix 9.4-F: WASCO Water demand data collection system

<table>
<tr><th colspan="2" rowspan="2">Supply type</th><th rowspan="2">Description</th><th colspan="4">Type of meters</th><th rowspan="2">Observation frequency</th></tr>
<tr><th>None</th><th>Conventional</th><th>Smart</th><th>GPS coordinates</th></tr>
<tr><td colspan="2">Abstraction</td><td>The permitted direct metered water abstraction quantities and sources for all gazetted urban areas.</td><td>?</td><td>?</td><td>?</td><td>?</td><td rowspan="3">Daily</td></tr>
<tr><td rowspan="2">Domestic</td><td>Potable</td><td rowspan="2">Households and public prepaid supplies</td><td>?</td><td>?</td><td>?</td><td></td></tr>
<tr><td>Sewage</td><td>?</td><td>?</td><td>?</td><td>?</td></tr>
<tr><td colspan="2">Demand type</td><td colspan="5">Description</td><td></td></tr>
<tr><td rowspan="2">Domestic</td><td>Location</td><td colspan="5">GPS coordinates of the centroid of the spring water demand</td><td>Once off</td></tr>
<tr><td>Potable</td><td colspan="5">Population per river catchment</td><td>Annual updates / projections</td></tr>
</table>

Appendix 9.4-G: Rural Water supply and demand data collection system

Supply type		**Description**	**Temporal variation**	**Observation frequency**	**Equipment used**
Springs	***Location***	Spring GPS coordinates (lat., long., & alt.)	-	Once-off	GPS
	Yield	Yield per spring per season	seasonal	Seasonal	Stopwatch, 2 or 5 litre bucket, 75mm x 1m hose pipe
Boreholes	***Location***	Borehole GPS coordinates (lat., long., & alt.)	-	Once-off	GPS
	Yield	Yield per borehole	-	Once-off	Pumping test equipment
Demand type		**Description**			
Springs	***Location***	GPS coordinates of the centroid of the spring water demand	-	Once-off	GPS
	Demand	Population per village	-	Annual	-
Boreholes	***Location***	GPS coordinates of the centroid of the borehole water demand	-	Once-off	GPS
	Demand	Population per village	-	Annual	GPS

Appendix 9.4-H: Institutional water supply and demand serviced by WASCO

Supply type		**Description**	**Type of meters**				**Frequency of observation**
			None	***Conventional***	***Smart***	***GPS coordinates***	
Institutional	***Potable***	Institutional bulk supply meters and tariffs data	?	?	?	?	Daily
	Sewage		?	?	?	?	

Demand type			
Institution type		**Demand**	
Missions / Parish centres		Number of residents	Annual
Schools	***Day scholars***	Annual student rolls	
	Boarding	Annual boarding registers	
	Warden /matron	Population	
Health Centres	***Outpatients***	Monthly numbers	Daily
	Admissions	Monthly # of days per admission	
Hotels, guesthouses and B&Bs	***Locals***	Monthly # of nights per guest	Daily
	Foreigners	Monthly # of nights per guest	Daily

Appendix 9.4-I: Other institutional water supply and demand

<table>
<tr><th colspan="2" rowspan="2">Demand type</th><th colspan="2">Description</th><th rowspan="2">Observation frequency</th></tr>
<tr><th>Supply</th><th>Demand</th></tr>
<tr><td colspan="2">LHDA villages / LHWP camps</td><td rowspan="8">Permitted metered abstractions and / or quantities (Water Use Permits from DWA)</td><td>Number of residents</td><td rowspan="3">Annual</td></tr>
<tr><td colspan="2">Missions / Parish centres</td><td>Number of residents</td></tr>
<tr><td colspan="2">Schools</td><td>Annual student rolls</td></tr>
<tr><td rowspan="2">Health Centres</td><td>Outpatients</td><td>Monthly numbers</td><td rowspan="5">Daily</td></tr>
<tr><td>Admissions</td><td>Monthly # of days per admission</td></tr>
<tr><td rowspan="2">Remote hotels, guesthouses and B&Bs</td><td>Locals</td><td>Monthly # of nights per guest</td></tr>
<tr><td>Foreigners</td><td>Monthly # of nights per guest</td></tr>
</table>

Appendix 9.4-J: Industrial water supply and demands data

Supply type		Description	Type of meter				Observation frequency
			None	*Conventional*	*Smart*	*GPS coordinates*	
Water Bottling	***Potable***	Permitted metered abstractions and / or quantities	?	?	?	?	Daily
	Sewage						
Mining consumptive uses	***Potable***	Permitted metered abstractions and / or quantities	?	?	?	?	
	Sewage						
Mining non-consumptive use (cooling and return flows)	***Raw***	Permitted metered hot-water disposal and treated waste disposal	?	?	?	?	
	Sewage						
Industrial (WASCO supplied)	***Potable***	WASCO's metered supplies (Application form & bulk metered supplies)	?	?	?	?	
	Sewage		?	?	?	?	
Recreation & rituals	***Raw***	Number of recreational reservoirs					
	Potable	Number of fountains	?	?	?	?	
	Ponds	Numbers of river / artificial ponds / pools					
Navigation	***Rivers***	Number of navigation ports					
	Reservoir	Number of reservoirs					
Demand type		**Description**					Daily
Water Bottling	***Potable***	Design plant production capacity in litres per day					
	Sewage	Plant workers population (from which to assume sanitary demand)					
Mining consumptive uses	***Potable***	Mineworkers population					
		Daily volume of water required to process / wash rocks					
	Sewage	Mineworkers population (from which to assume sanitary demand)					
		Daily volume discharged after process / wash rocks					

Mining non-consumptive use (cooling and return flows)	***Raw***	Daily volume of water required to cool machinery	Daily
	Discharge	Daily volume of heated water required to discharge into environment	
Industrial (WASCO supplied)	***Potable***	Factory workers population	
		Daily volume of water required to wash & iron linen	
	Sewage	Daily volume of linen washed water to dispose	
		Daily volume of wastewater required to discharge into sewer	
Recreation & rituals	***Raw***	Number of tourists per month	
	Potable	Volume of water required per fountain per day	
	Ponds	Numbers of traditional hears and Baptists	
Navigation	***Rivers***	Number of visitors per port per day	
	Reservoir	Number of visitors per port per day	

Appendix 9.4-K: Agricultural water supply and demands data sources

<table>
<tr><th rowspan="2">Water supply</th><th colspan="3">Water supply per source</th><th rowspan="2">Observation / estimation frequency</th></tr>
<tr><th colspan="2">Surface water</th><th>Groundwater (boreholes)</th></tr>
<tr><td>Animal husbandry</td><td colspan="2">Population x litres / day</td><td rowspan="2">Permitted metered abstraction</td><td>Daily</td></tr>
<tr><td>Irrigation</td><td colspan="2">Permitted metered abstraction</td><td>Daily</td></tr>
<tr><td colspan="5">Demand type</td></tr>
<tr><td colspan="3">Institution</td><td colspan="2">Demand</td></tr>
<tr><td rowspan="5">Animal husbandry</td><td rowspan="2">Livestock</td><td>Higher</td><td>Populations of cattle, horses, and donkeys (assuming 30L/day/ animal)</td><td rowspan="8">Annual</td></tr>
<tr><td>Lower</td><td>Populations of goats, sheep and pigs (assuming 3L/day/ animal)</td></tr>
<tr><td rowspan="2">Poultry</td><td>Higher</td><td>Populations of turkeys, duck, geese (assuming 3L/day/ bird)</td></tr>
<tr><td>Lower</td><td>Populations of chicken (assuming 50ml/day/ bird)</td></tr>
<tr><td colspan="2">Fishery</td><td>Annual populations of fish (assuming 50L/day/ animal)</td></tr>
<tr><td rowspan="3">Irrigation</td><td colspan="2">Cash crops</td><td>Annual heads of crops (assuming 1L/day/ head)</td></tr>
<tr><td colspan="2">Orchards</td><td>Annual fruit tree populations (assuming 50L/day/ tree)</td></tr>
<tr><td colspan="2">Lawns</td><td>Daily evapotranspiration demand per square meter (assuming 10L/sq.m/non-rainy day in growing season)</td></tr>
</table>

Appendix 9.4-L: River water quantity parameters variation and their measuring instrumentation

Parameter		Temporal variation	Monitoring frequency	Instrumentation
Catchment size / area (km^2)		-	Once-off	Planimeter
Gauging station location (lat., long., alt.**)**		-	Once-off	GPS
Flow	Discharge measurements (m^3/s)	Time series	Monthly or event-based	Current meters
	Cross-sectional profile	Time series	Seasonal	Survey equipment (GPS, theodolite, etc.)
	Longitudinal profile		Seasonal	
	Water levels (m)	Time series	Continuous	Staff gauges, pressure probes
	Stage-Discharge relationship	Time-averaged	Monthly	-
	Stream flow time series (m^3/s)	Time series	Continuous	-