REPUBLIC OF RWANDA

RWANDA NATIONAL WATER RESOURCES MASTER PLAN

MINIRENA-RNRA

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LIST OF ABBREVIATIONS AND ACRONYMS

ABAKIR	Lake Kivu and Rusizi River Basin Authority
BSC	Broadband Systems Corporation
CC	Catchment Committee
CLIMWAT	Program and database for the preparation of climate water balances from FAO.
CROPWAT	Program and database for the preparation of crop water balances from FAO
CWMO	Catchment Water Management Office
DC	District Committee
DDP	District Development Plan
DTM	Digital Terrain Model
DWRM	Directorate of Water Resources Management
EAC	East African Community
EC	European Commission
EDPRS	Economic Development Poverty Reduction Strategy
EIA	Environmental Impact Assessment
EICV	Integrated Household Living Conditions Survey (Enquête Intégrale sur les Conditions de Vie des ménages)
EWSA	Energy, Water and Sanitation Authority
FAO	Food and Agriculture Organisation (UN)
FONERWA	National Climate Change and Environment Fund
GB	Gigabyte
GIS	Geographic Information System
GoR	Government of Rwanda
GWP	Global Water Partnership
HFO	Heavy Fuel Oil
hm^3	Cubic hectometer - equal to 1 million cubic meter
ICLD	International Commission on Large Dams
ICT	Information Communication Technology
IRD	Institut de Recherche pour le Développement
IWMI	International Water Management Institute
IWRM	Integrated Water Resources Management
JICA	Japan International Cooperation Agency
KML	Keyhole Markup Language (file extension: .kml)
LVBC	Lake Victoria Basin Commission
LVEMP	Lake Victoria Environmental Management Project
LWH	Land Husbandry Water Harvesting and Hillside irrigation
MAR	Mean Annual Runoff
MB	Megabyte
MCM	Million Cubic Meter
MDGs	Millennium Development Goals
MIDIMAR	Ministry of Disaster Management and Refugee Affairs
MIGEPROF	Ministry of Gender and Family Promotion

MINAFFET	Ministry of Foreign Affairs and Cooperation
MINAGRI	Ministry of Agriculture and Animal Resources
MINALOC	Ministry of Local Government
MINECOFIN	Ministry of Finance and Economic Planning
MINEDUC	Ministry of Education
MINICOM	Ministry of Trade and Industry
MININFRA	Ministry of Infrastructure
MINIRENA	Ministry of Environment and Natural Resources
MINISANTE	Ministry of Health
MIS	Management Information System
MODIS	Moderate Resolution Imaging Spectro radiometer
MoU	Memorandum of Understanding
MPF	Maximum Probable Flood
NAEB	National Agricultural Export Development Board
NBI	Nile Basin Initiative
NELSAP	Nile Equatorial Lakes Subsidiary Action Program
NGO	Non-governmental Organization
NISR	National Institute of Statistics Rwanda
NWCC	National Water Consultative Commission
NWRMP	National Water Resources Master Plan
PAIGELAC	Inland Lakes Intergrated Development and Management Support Project
PGNRE	National Program for Water Resource Management
PNEAR	Rural Water and Sanitation Programme (Programme National d'Alimentation en eau Potable et assainissement en milieu rural)
RAB	Rwanda Agriculture Board
RAB	Rwanda Agriculture Board
RARDA	Rwanda Animal Resources Development Authority
RBC	Rwanda Biomedical Center
RDB	Rwanda Development Board
RDMS	Relational Database Management System
REMA	Environment Management Authority
RIMP	Rwanda Irrigation Master Plan
RIWSP	Rwanda Integrated Water Security Program
RMF	Regional Maximum Flood
RNRA	Rwanda Natural Resources Authority (Authority operating under MINIRENA)
RSSP	Rural Sector Support Program
RURA	Rwanda Utilities Regulatory Agency
RWA	Rwanda Water Authority
RWH	Rainwater Harvesting
RWRIS	Rwanda Water Resources Information System
RWU	Registered Water User
SC	Sector Committees
SRTM	Shuttle Radar Topography Mission
TCM	Thousand cubic meter
ToR	Terms of Reference

TRMM	Tropical Rainfall Measuring Mission
UICN	International Union for Conservation of Nature (Union internationale pour la conservation de la nature)
UNDP	United Nations Development Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
WA	Water Authority
WASH	Water and Sanitation Hygiene Promotion
Water MIS	Water Management Information System
WHO	World Health Organization
WIC	Water Interministerial Committee
WLA	Water Laboratory Alliance
WMO	World Meteorological Organization
WRM	Water Resources Management
WMS	Web Map Service
WUA	Water User Association

LIST OF TERMS

The terms in this list are used throughout the report and may be interpreted differently by different users. Without pretending to provide a true definition that can be agreed upon by all, the clarifications below try to bring a common understanding between authors and readers of these terms. Unless mentioned otherwise, all terms are described as used for this study.

CATCHMENT MASTER PLAN

A Catchment Master Plan defines the timely development of natural water resources for primary or commercial use purposes while aiming at a careful combination of least effort and costs for optimum benefits in terms of financial, economic, social and environmental parameters. The Master Plan relates to both the resources supply and demand side and may consequently comprise demand management measures. The goal of the 'catchment master plan' is the rational development of water resources. A series of nine indicative Catchment Master Plans has been formulated within the framework of the NWRMP study; it is recommended that these are further developed with stakeholder participation.

CATCHMENT WATER MANAGEMENT PLAN

A catchment water management plan defines the management of water resources both in the natural hydrological cycle and in and between numerous primary - and commercial use cycles in order to secure, under all hydrological conditions, maximum benefits in terms of financial, economic, social and environmental parameters. The goal of the 'catchment water management plan' is the rational exploitation of water resources. The catchment water management plan is especially important for highly committed catchments. No such plans have been formulated within the framework of the NWRMP study

DAM VOLUME

This is the volume of dam material (diverse materials) that is required to built a dam assuming upstream and downstream slope and strict linear interpolation of lateral valley slopes. The dam volumes in this report are mostly very approximate and over estimated. The ratio between reservoir and dam volume is nevertheless a useful indicator of the relative effectiveness of potential surface water storage sites. (also see Reservoir Volume).

ENVIRONMENTAL FLOW (OR DEMAND)

Environmental flows describe the quantity, timing, and quality of water flows required to sustain freshwater and estuarine ecosystems and the human livelihoods and well being that depend on these ecosystems. Through implementation of environmental flows, water managers strive to achieve a flow regime, or pattern, that provides for human uses and maintains the essential processes required to support healthy river ecosystems.

The concept of the term 'environmental flow' in the Master Plan report mostly refers to surface flow exclusively but the concept should in fact refer to both the hydrological surface- and groundwater flow that should remain available in terms of water quantity and quality over time for the 'benefit' of the natural environment.

EQUITABLE ACCESS

A term mostly associated with the right to (drinking) water and sanitation for all hence relating to primary use. The terms can also be considered for commercial use. It does not imply equitable distribution (see below).

EQUITABLE DISTRIBUTION

A term associated with distribution of scarce water resources. It is often wrongly presented as an ideal distribution mode under conditions of scarcity when all users would obtain an equal fraction of their normal water allocation. Strict equitable distribution is likely to engender substantial economic, social and environmental costs as compared with a distribution that is tailor made for normal, excess and drought conditions. A tailor made rational distribution for normal and extreme conditions should be specified in a catchment water management plan and in the water permits issued for that catchment.

GROWTH SCENARIOS (LOW, MEDIUM AND HIGH)

This report considers three water demand growth scenarios labeled 'low', 'medium' and 'high'. These growth scenarios are based on projections of population increase, a water supply service level per person and water dependant development opportunities. The aspired growth scenario as per Rwandan strategy documents (Vision 2020, EDPRS, ...) is a combination of low population growth (driving primary water use) with strong growth of water dependant development opportunities (industrial use, irrigation, etc., or commercial water use) and the least favorable scenario would be the combination of highest population growth with stagnant development.

The population growth is an extension of the growth scenarios that have been developed by the NISR up to 2022 and which are the result of gradual reduction of population growth rates.

The fraction urban population is inspired by UN projections and yields significant growth of urban population and very moderate growth of rural population (a tendency that can be observed when comparing 2002 and 2012 census data for predominantly rural sectors).

The per capita daily water demand is estimated from typical values for developing countries. Because the two elements of the growth scenarios (population growth and water related development) counteract from most favorable to least favorable scenario, they have been dissociated for the following combinations:

- high water demand growth scenario: a combination of high population growth and high flight of the water dependant development opportunities
- medium water demand growth scenario: a combination of medium population growth and average increase of water dependant development opportunities
- low water demand growth scenario: a combination of low population growth and moderate increase of the water dependant development opportunities:

Further details on population growth are provided in annex C4_2 of the Exploratory phase report and details on the growth scenarios are provided in the same report chapters 4.2. and 4.4.

IWRM

A process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems." (from: Technical Committee of the Global Water Partnership)

RESERVOIR VOLUME

This is the volume of water that can be effectively stored upstream of a dam. The reservoir volumes in this report are mostly very approximate and under estimated because based on strict linear interpolation of longitudinal and lateral valley slopes. (also see Dam Volume)

WATER PERMIT

A water permit is a written agreement (or a contract) between a water user and the Rwandan government in the person of the Minister of State in charge of Water and conveys rights and obligations to both parties.

The water user obtains the right to intervene in a precisely specified manner (location, method, calendar, other conditions may apply) in the natural hydrological cycle. It is not a right to abstract a specific volume of water, the risk of resources availability remains with the water user and the government nor any other party can guarantee abstraction success.

WATER USE AND DEMAND (AND A SERIES OF RELATED TERMS)

WATER USE: a real quantity of water that has been used for a specific purpose. The use may be within the natural hydrological cycle (e.g. fishing) or it may require a local and temporary abstraction (hydropower) or a complete shift in the natural hydrological cycle (drinking water abstracted from a well for consumptive use with fractional drainage to surface flow).

Water use may depend on water qualities like flow regime, location, level and physical, biological and chemical water qualities; water use is likely to alter these qualities to some extent (from marginally to very substantially)

CONSUMPTIVE WATER USE: the fraction of water use that is not returned to the abstraction location in the natural hydrological cycle. Water used for beer production is consumptive, water used for washing the beer bottles is non consumptive and can be returned to the natural hydrological cycle after treatment to contain impact on the natural resource and downstream water users.

PRIMARY WATER USE: water use which is needed to directly sustain livelihood and comprises drinking water supply, environmental demand and possibly other demand categories; the lack of provision for this use will lead to the untimely demise of a living being.

COMMERCIAL WATER USE: water use which is intended to generate financial benefits; the lack of provision for this use will lead to the loss of income to the user

WATER DEMAND: this is a virtual quantity of water that is needed to satisfy some perceived need from a user, either for primary use (drinking water, household requirements, small garden, etc.) or for commercial purposes.

CONSUMPTIVE WATER DEMAND: the fraction of water demand that is not returned to the abstraction location in the natural hydrological cycle (analogous to consumptive water use)

UNADJUSTED (CONSUMPTIVE) WATER DEMAND: this term is exclusively valid for this study and should be understood to be the demand in a catchment irrespective of i) resources availability and ii) proper investigation of the viability of the use process.

ADJUSTED (CONSUMPTIVE) WATER DEMAND: this term is exclusively valid for this study and should be understood to be the demand in a catchment after investigation of the (financial, economic, social and environmental) viability of the use processes and adjustment to available resources. Adjusted water demand may be increased or decreased from the unadjusted water demand.

1 INTRODUCTION

1.1 CONTEXT OF THE NWRMP

Water is a key issue to be addressed and solved in order to meet a number of the Millennium Development Goals (MDGs). About 300 million people in Africa, a third of the continent's population, are living under "water scarcity" conditions. To address this, the African Water Vision for 2025 has set to develop the full potential of Africa's water resources for sustainable growth in the region's economic and social development.

The National Policy for Water Resources Management has been recently reviewed (04/2011). The scope and purpose of this new policy states that [page 2] "*Water is a key resource in the socio-economic development of Rwanda. The availability of an adequate quantity of water of good quality is an important factor in development. Its proper management is a national development imperative which requires putting in place appropriate water resources management, development and utilization frameworks and measures. This would facilitate the setting of priorities and the optimal utilization of the water resources of the country.”*

The central role of water resources as a key driver for Rwanda’s social and economic development and poverty reduction is fully acknowledged in Rwanda’s flagship policy documents, government program, joint sector review reports and political goals.

In this respect Rwanda’s Vision 2020 states as follows:

“The country is endowed with reserves that could provide enough water for both human consumption and agricultural purposes. These include substantial rainfall (900 to 1800 mm per year) and the abundance of lakes, streams and watercourses…” [p. 17].

The Economic Development and Poverty Reduction Strategy (2013-2018) sets priority on full coverage of quality water and sanitation services and irrigation expansion to increase productivity and enhance food security. It recognizes the imminent pressure from this expansion on water resources management [§ 3.35].

The national policy presents the approach of Rwanda’s Environment and Natural Resources sector on the way that the water resources of the country will contribute to the achievement of the overarching national policy objectives as stipulated in Vision 2020, the EDPRS and other similar high level national policies, and breaks them down into concrete principles, objectives and statements.

The policy is formulated with a view to implementation. Its objectives and statements are formulated so as to be directly translatable into activities, implementation responsibilities and associated indicators. The implementation of the National Water Resources Master Plan is one of the first steps towards the translation of the national policy for Water Resources Management into concrete actions.

1.2 OBJECTIVES OF THE MASTER PLAN

The objectives of the *National Water Resources Master plan* are defined by a single general objective complemented with a number of specific objectives. These are presented and commented in the next paragraphs.

1.2.1 GENERAL OBJECTIVE

The general objective of this Master Plan is to ensure a sustainable water resources development, utilization and management in the country.

The National Policy for Water Resources Management emphasizes [p. 15] that "*water is a cross-cutting natural resource, whose use cuts across all sectors, including domestic consumption, agriculture, commerce and industry, as well as ecological uses for environmental conservation, such as forests, fisheries and wildlife. The management of water resources therefore is best undertaken within a framework that provides for decision making in an integrated manner*."

Integrated Water Resources Management (IWRM) has been defined by the Technical Committee of the Global Water Partnership as "*a process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems.*"

Operationally, the IWRM approach involves applying knowledge from various disciplines as well as the insights from diverse stakeholders to devise and implement efficient, equitable and sustainable solutions to water and development problems. As such, IWRM is a comprehensive, participatory planning and implementation tool for developing and managing water resources in a way that balances social and economic needs, and that ensures the protection of ecosystems for future generations.

Water's many different uses—for agriculture, for healthy ecosystems, for people and livelihoods—demands coordinated action. An IWRM approach is an open, flexible process, bringing together decision-makers across the various sectors that impact on water resources, and bringing all stakeholders to the table to set policy and make sound, balanced decisions in response to specific water challenges faced. In the Dublin Principles it has been agreed to consider water as an 'economic commodity' in order to emphasize its scarcity. One of the major fields of focus has been to increase women's involvement in drinking water and sanitation projects, especially in the developing countries. International Water Management Institute (IWMI), UNESCO and International Water and Sanitation Centre are some of the institutes that have undertaken research in this area.

In conclusion, the development of a Master plan for sustainable water resources development should not just be limited to the assessment of national water resources and national water resources needs and uses over time. The Master plan shall be a blueprint for a process of sustainable water, land and related resources development and management with the aim to maximize economic and social welfare in an equitable manner while safeguarding the environment.

1.2.2 SPECIFIC OBJECTIVES

The specific objectives of the Master Plan are to:

- Quantify available water resources (surface and groundwater, in time and space)
- Quantify water resources demand by sector and catchment

- Identify surplus and deficit areas both in time and space
- Propose a management plan for optimal and rational utilization of available quantity of water resources
- Qualify all available water resources in the study area

1.3 SCOPE OF THE MASTER PLAN

The scope of the study is defined by the geographical coverage and the temporal horizon and resolution; these are briefly discussed in the next paragraphs.

GEOGRAPHICAL COVERAGE

The principal focus of the Master Plan will be the territory of Rwanda, administratively subdivided in four provinces and the city of Kigali, and at a lower tier, in 30 districts.

In hydrological terms, Rwanda is located at the pinnacle of two major basins (Nile and Congo basins). It is consequently indispensable that Rwanda shares at least some of its water resources with its downstream neighbors. Also, several catchments are shared between Rwanda and its neighbors notably Burundi for the Rusizi, Akanyaru and Akagera Rivers, Tanzania for the Akagera River, Uganda for the Muvumba River and finally the DRC for the Lake Kivu and the Rusizi River. These shared catchments need special consideration and cooperation. Some institutional arrangements are operational either bilateral (*Commission Mixte* between Rwanda and Burundi) or regional (e.g. EAC, NBI, ABAKIR; these latter two are specifically on water resources).

The hydrological analysis will take into account complete physical catchments in Rwanda and its neighbors until the exit of the water body from the Rwandan national territory.

TEMPORAL HORIZON AND RESOLUTION

The time horizon of this Master Plan will cover the period up to 2040 with intermediate planning steps for 2020, 2030 and 2040.

As regards resources availability and current and projected demand, a monthly temporal resolution has been applied. This is especially crucial where irrigation demand is intended to be developed because this demand is increasing during the dry season months when resources availability is at its lowest.

CONCLUSION

In conclusion, the Master Plan has been conducted over a time span of almost 30 years with two intermediate planning dates and a monthly time resolution on the basis of hydrological boundaries which extend beyond the strict countries borders: 2 river basins, 9 catchments adjusted as per study findings for surface and groundwater resources, water use, soil characteristics, existing administrative boundaries and water management requirements.

1.4 BRIEF OUTLINE OF THE MASTER PLAN PHASE REPORT

This paragraph presents an overview of the content of this report. This content responds to the tasks specified in the work plan for the Master plan phase:

- task 2_1: Development Water MIS
- task 2_2: Cross cutting issues
- task 2_3: Operation and maintenance plan
- task 2_4: Legal and institutional strengthening
- task 2_5: Knowledge transfer and capacity building
- task 2_6: Implementation plan
- task 2_7: Detailed cost estimate
- task 2_8: Draft/Final report NWRMP and workshop

In response, the Master Plan report presents the following elements:

- the National Water Resources Master plan is presented in chapter **Error! Reference source not found.**. During the course of the preparation of the national master plan it became evident that this national master plan could not be reasonable made without the preparation of corresponding master plans at the catchment level. These are produced as separate documents appendixes 01 up to 09 for each catchment and compiled for the national master plan. The Master plan presents the resources (per catchment with monthly time resolution), consumptive water demand over the planning period up to 2040 with intermediate demand projections for 2020 and 2030, catchment water balances and national flow schedules for the entire planning period with demand adjustments as per available resources, a national investment program and a listing of issues and recommendations. This element addresses the tasks 2_6 (implementation plan), 2_7 (detailed cost estimate) and 2_8 (NWRMP report).

- chapter 3 provides detail on the Water MIS; the idea, the basic concept (modular design), and the limitations followed by an explanation of the resources -, the balances - and the water demand, use and permit modules (3 modules), the geo mapping server. The chapter is completed with a description of the architecture, installation, and operation and maintenance aspects, and a conclusion with recommendations for the way forward. A series of 4 manuals for installation and O&M of the software is presented as appendixes 10 up to 13. This element addresses the tasks 2_1 (development Water MIS) and 2_3 (operation and maintenance plan).

- the aspect of legal and institutional strengthening (task 2_4) is presented in chapter 4. From an analysis of the IWRM management requirements, an update on the existing institutional framework for water management in Rwanda and a comprehensive proposition for improvements, a road map for an IWRM compliant institutional structure and for the corresponding legal changes is presented. This element addresses the task 2_4 (legal and institutional strengthening).

- the crucial aspect of knowledge transfer and capacity building is presented in chapter 5. It gives detail of the training and knowledge transfer efforts provided during the master plan study which were almost exclusively directed to the RNRA-IWRM division, and the further requirements in this field for the benefit of the RNRA-IWRM as well as a series of other institutional entities involved in IWRM compliant water management. This element addresses the task 2_5 (knowledge transfer and capacity building).

- chapter 6 presents a discussion on cross cutting issues; most of these are very embedded in the study (ICT, environment, sustainable development) and do not require further discussion. On the contrary, the issue of gender which is understood as a coy term for disadvantaged groups, is discussed with some detail and suggestions for further study and an action plan are presented. This element addresses the task 2_2 (cross cutting issues).

The last chapter 7 is an executive summary of the master plan report with emphasis on necessary and recommended actions resulting from this Master Plan document.

1.5 Introduction on Rwanda National Water Resources Master plan

This chapter presents the National Water Resources Master Plan for Rwanda. This 'national' Master Plan could not be made without the formulation of a series of nine Master Plan at the catchment level. These Catchment Master Plan are presented as nine appendixes to this National Master Plan (see appendixes 01-09 with post fixes for the catchment code).

In effect, one of the first tasks that has been done within the framework of this study, is the review/update of the 'existing' (sub-)catchment division (task 1_3). The basic notion behind this review was to facilitate IWRM which requires knowledge on the incoming and outgoing water resources in a domain (catchment, sub catchment or smaller spatial unit) over a time step (day, week, month, season, year).

The original catchment division in Rwanda did not comply with this notion where:

- upper and lower Nyabarongo were merged which obscures the Mukungwa outflow
- the upper and lower Akagera were separated over Rweru Lake which obscures the very significant inflow from the Ruvubu river (Tanzania, Burundi)
- The Mulindi and Muvumba rivers were separated whereas this is essentially the same River with an extensive passage in Uganda

The results of the new catchment division are presented in Figure 1 on the next page. Details including justification for first level - and further subdivision of the catchments according to surface and groundwater hydrology are provided in previous reports including a technical note on catchment division and the exploratory phase report in its chapter 2.

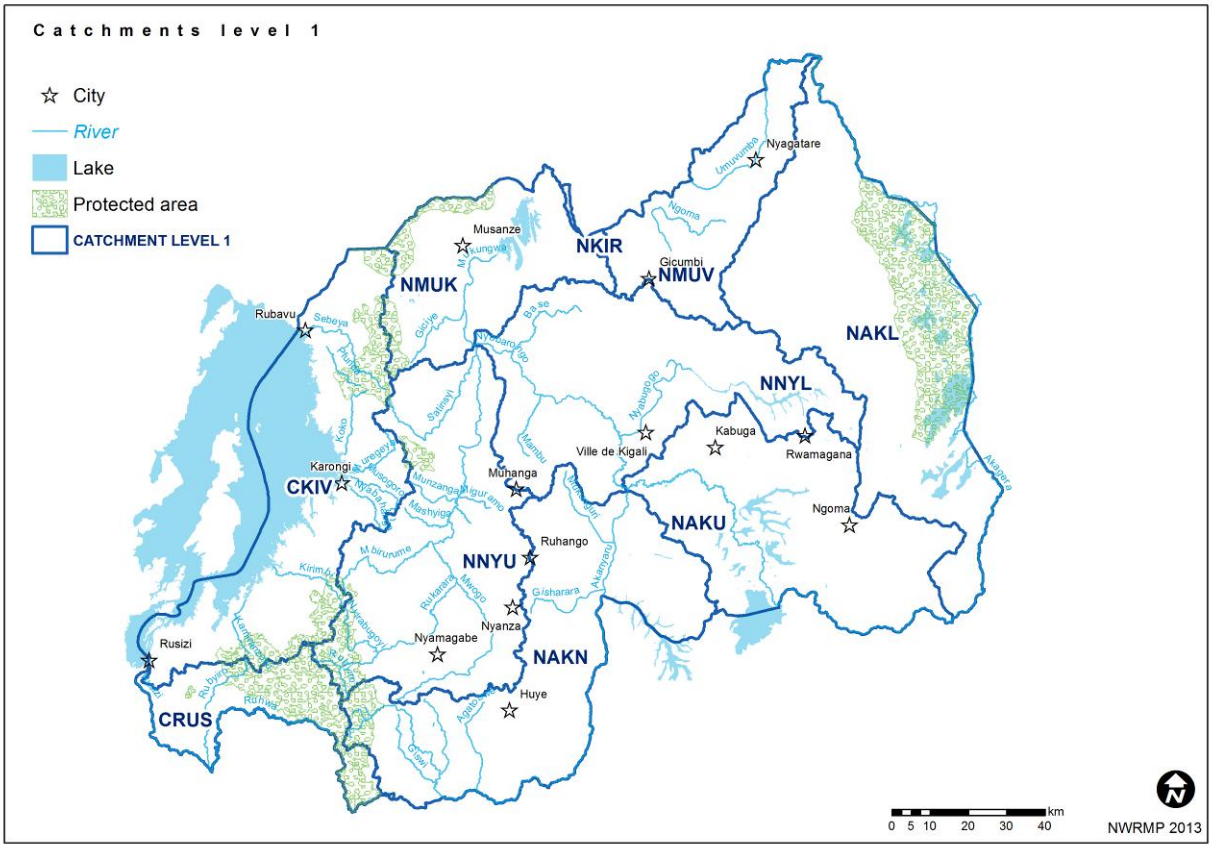
This chapter on the National Water Resources Master Plan is structured as follows:

- Paragraph 1.6 informs on the hydrological resources generated in the nine catchments with detail on rainfall, evaporation losses, surface water runoff and renewable groundwater up to monthly detail with a 5 step probability assessment varying from once in twenty year dry, once in three year dry, once in two year dry/wet, once in three year wet and once in twenty year wet. Additional information is provided on the generation of additional resources, on the protecting water resources availability and on the required approach for the resources assessment at level 3 which will be required for water management in highly committed catchments and areas.
- Water demand in the nine catchments is presented and interpreted in paragraph 1.7. It informs on current consumptive water use, unadjusted demand which is the water requirement when supply would be 'unlimited', and on adjusted demand which is the water requirement that can reasonably be provided from the available renewable resources (from the catchment's own or transferred resources).

- Paragraph 1.8 presents the government related investment costs for the development of water resources and the provision of water services at different future dates (2020, 2030 and 2040) for three assumed population and services growth scenarios (low, medium and high) and structured for total urban, rural, irrigation and other services (industries in the widest sense). Full details of these costs are available in annex C2_6 to this report and for each catchment in the already mentioned appendixes.
- The last paragraph 1.9 of this chapter gives a full listing of issues, conclusions and recommendations for each one of the nine catchments and, as regards the recommendations, also for the national level.

Here below the map with the updated catchment division for Rwanda (nine catchments)

Figure 1: Level 1 catchment division of Rwanda



1.6 RESOURCES ASSESSMENT

This sub paragraph focuses on the hydrological resources. The first section presents the key hydrological resources for each catchment complemented by their monthly distribution including probability in the next section. Further details are provided on enhanced resources mobilization, protection of resources and resources assessment at small catchments (level 3 with an indicative area of 50 to 200 km²)

1.6.1 ANNUAL RESOURCES ASSESSMENT AT LEVEL 1 CATCHMENTS

Key hydrological resources data for each level 1 catchment are presented in the table below.

Table 1: Hydrological information on the level I catchment units for NWRMP

Catchment Number	1	2	3	4	5	6	7	8	9
Code NWRMP	CKIV	CRUS	NNYU	NMUK	NNYL	NAKN	NAKU	NAKL	NMUV
Name:	Lake Kivu	Rusizi	Upper Nyaborongo	Mukungwa	Lower Nyabarongo	Akanyaru	Upper Akagera	Lower Akagera	Muvumba
Surface area [km²] in Rwanda	2 425 km²	1 005 km²	3 348 km²	1 887 km²	3 305 km²	3 402 km²	3 053 km²	4 288 km²	1 565 km²
Total surface area [km²]	7 323 km² incl. lake 2 695 km²	2 011 km², total basin: 9 334 km²	3 348 km²	1 949 km²	3 305 km²	5 328 km²	3 053 level 1 basin, total basin 30 632 km²	6 648 level 1 basin, total basin 37 288 km²	3 711 km²
Upstream national dependencies	none	Lake Kivu	none	none	Upper Nyaborongo & Mukungwa	none	Upper & Lower Nyabarongo & Akanyaru	Upper Akagera	none
Upstream international dependencies	none	Lake Kivu DRC	none	Insignificant (Uganda)	none	none	none	Ruvubu river Burundi	none

Catchment Number	1	2	3	4	5	6	7	8	9
Code NWRMP	CKIV	CRUS	NNYU	NMUK	NNYL	NAKN	NAKU	NAKL	NMUV
Shared catchment	2 203 km² DRC	368 km² DRC 638 km² Burundi	none	62 km² Uganda	none	1 926 km² Burundi	13 714 km² Burundi	2 354 km² Tanzania	2 146 km² Uganda
Av. annual rainfall [mm/yr]	1 240	1 295	1 365	1 315	1 191	1 225	925	835	995
Av. annual evaporation (water balance) [mm/yr]	870	865	980	851	919	990	760	624	872
Av. annual surface water runoff [mm/yr]	370	430	385	464	272	235	165	211	123
Base flow* [m³/s]	1.8°	3.8°	34.2	21.5	66.8+	16.4°	198.0+	200.0+	3.5
Av. annual ground water recharge [mm/yr]	250	350	292	322	165	227	115	125	71
Ground water volume storage [MCM]	2 425	5 025	25 110	4 870	8 673	5 103	4 580	4 820	1 570
Ground water mean resident time [year]	4	14	26	8	16	7	13	9	14
Ratio surface water / rainfall - annual [-]	0.30	0.33	0.28	0.35	0.23	0.19	0.18	0.25	0.12
Ratio ground water / rainfall - annual [-]	0.20	0.27	0.21	0.24	0.14	0.18	0.12	0.15	0.07

Catchment Number	1	2	3	4	5	6	7	8	9
Code NWRMP	CKIV	CRUS	NNYU	NMUK	NNYL	NAKN	NAKU	NAKL	NMUV
Population figure [1]	1 429 170	309 857	1 502 992	1 258 511	2 193 537	1 352 250	1 085 922	486 806	573 027

*: Base flow: when number marked with an ° it is for a partial catchment (Sebeya for CKIV, Rubyiro for CRUS and upstream for NAKN); when marked with a + the base flow comprises flow from upstream catchments.

[1] Population estimate for 2012 based on medium growth hypothesis from census 2002 sector data; source NISR.

Some explanations and interpretation on the table are as follows:

- total surface area (row 5) refers to the physical level 1 catchment area which may for a number of catchments comprise domain in neighboring countries. Those neighboring countries and the surface area concerned are indicated in row 8 'Shared catchment'. For non headwater catchments, the total basin area is also indicated.
- Upstream national dependencies refer to level 1 catchments within Rwanda; these upstream catchments may however be a 'shared catchment' i.e. not entirely Rwandan.
- Resources data are based on Rwandan territory only; i.e. average annual rainfall, evaporation, surface runoff etc., are determined from Rwandan data only.
- For 'base flow' so table footnote above; it may relate to a part of the catchment only or to the catchment with upstream catchments
- The ratio 'surface water / rainfall' (row 16) gives a first indication of 'resources rich' catchments (all in the West: CKIV, CRUS, NNYU and NMUK), average (NNYL and NAKL) and resources poor (NAKN, NAKU and NMUV). The NMUV stands out as very poor.
- The ratio 'groundwater / rainfall' (row 17) deepens this first insight by indicating the resources generation processed through groundwater (and thus stabilizing the intra-annual flow regime). Particularly good are CRUS, NNYU, and NAKN, average are CKIV, NMUK and NAKU, and poor are NNYL, NAKL and NMUV. This also depends on the ratio of groundwater over surface water runoff; good is about 80%, average about 70% and poor about 60%.
- The last 'referee' in this table is the ground water mean resident time (row 15) which is; in combination with the ratio of groundwater over surface water flow, an indicator of inter-annual flow regulation. The highest value is found for NNYU which guarantees very stable and significant resources generation.

1.6.2 MONTHLY RESOURCES ASSESSMENT AT LEVEL 1 CATCHMENT

The tables presented in this paragraph indicate the total annual and monthly values for the average or 50% reliability values for rainfall, actual or water balance evaporation and groundwater. Water balance evaporation is inferior to potential evaporation due to resources restrictions.

For surface water flow, probability values are presented which are needed to produce functional water balances that indicate both magnitude and frequency of resources deficits:

- $Rs_{5\%}$ stands for a probability of 5% that the indicated annual or monthly flow values will be exceeded. This corresponds with a once in twenty years (resources abundance) event (lots of resources but they are rarely available)
- $Rs_{35\%}$ stands for a probability of 35% that the indicated annual or monthly flow values will be exceeded. This corresponds approximately with a once in three years (resources abundance) event.
- $Rs_{50\%}$ stands for a probability of 50% that the indicated annual or monthly flow values will be exceeded. This corresponds with a once in two years event (one year it may be less, the next year it may be more; *please note the 'may*').
- $Rs_{65\%}$ stands for a probability of 65% that the indicated annual or monthly flow values will be exceeded. This corresponds approximately with a two in three years event. (there are only modest resources but they will mostly be available - on average twice in three years).
- $Rs_{95\%}$ stands for a probability of 95% that the indicated annual or monthly flow values will be exceeded. This corresponds with a ninteen out of twenty years event. (there are very little resources but they will almost always be available - on average 19 out of 20 years).

N.B.: The monthly probability value is a distribution of the annual value. The true monthly probability value would be extremer (higher and lower) and their cumulative occurrence would be very exceptional.

N.B.: For surface water hydrology, the 50% probability value is typically not identical to the average value because of the skewed probability distribution. The average value typically exceeds the 50% probability value because of extreme flow events (whether for an annual, monthly or other time step)

Table 2: Lake Kivu catchment monthly meteorological and hydrological data

volume data in '000 m³	annual total	oct	nov	dec	jan	feb	mar	apr	may	jun	jul	aug	sep
Rainfall $_{avge}$	3 007 000	390 985	402 898	247 030	243 143	273 489	320 513	396 879	221 951	65 206	46 898	111 352	286 656
ETa $_{avge}$	-2 109 408	-203 639	-197 070	-195 807	-203 639	-183 932	-195 807	-181 911	-172 310	-166 752	-109 652	-101 820	-197 070
$Rs_{5\%}$	1 417 336	83 101	81 156	84 013	82 855	128 614	117 495	156 967	130 919	117 975	156 485	164 763	112 992
$Rs_{35\%}$	895 407	72 544	71 553	71 675	62 498	78 047	78 185	96 092	92 687	74 746	67 442	66 545	63 393
$Rs_{50\%}$	810 129	64 543	67 339	62 048	58 089	70 341	72 761	85 407	83 324	65 669	59 102	61 504	60 003
$Rs_{65\%}$	762 033	59 982	61 875	59 614	56 590	64 768	69 613	75 506	78 760	63 128	56 980	56 640	58 577
$Rs_{95\%}$	633 986	51 828	57 346	50 777	50 931	52 479	50 229	64 280	60 631	51 807	48 458	47 734	47 486
gr.w.$_{50\%}$	606 250	51 679	52 360	50 777	50 931	51 612	50 229	51 612	53 108	51 612	48 458	47 498	46 376

Table 3: Rusizi catchment monthly meteorological and hydrological data

volume data in '000 m³	annual total	oct	nov	dec	jan	feb	mar	apr	may	jun	jul	aug	sep
Rainfall $_{avge}$	1 301 475	148 682	185 142	132 921	140 700	107 893	149 494	163 293	105 322	21 105	10 891	33 484	102 549
ETa $_{avge}$	-869 288	-83 920	-81 213	-80 692	-83 920	-75 799	-80 692	-74 966	-71 009	-68 718	-45 188	-41 960	-81 213
$Rs_{5\%}$	785 627	59 189	80 191	95 900	53 534	51 018	62 242	110 416	103 210	48 591	29 330	48 891	43 115
$Rs_{35\%}$	459 635	29 794	39 700	45 539	44 455	36 725	53 036	61 698	53 676	32 766	22 267	17 641	22 338
$Rs_{50\%}$	379 596	25 524	34 947	39 539	30 975	32 244	38 875	45 122	47 330	28 500	20 045	16 279	20 217
$Rs_{65\%}$	335 702	22 201	29 933	37 421	23 399	27 965	32 954	41 388	41 352	26 120	18 102	15 828	19 038
$Rs_{95\%}$	205 632	17 448	15 743	20 720	17 698	20 678	17 588	16 719	29 014	17 607	10 808	11 050	10 558
gr.w.$_{50\%}$	269 036	21 609	22 330	23 410	23 050	23 770	23 410	25 211	29 173	25 211	18 008	15 847	18 008

Table 4: Upper Nyabarongo catchment monthly meteorological and hydrological data

volume data in '000 m³	annual total	oct	nov	dec	jan	feb	mar	apr	may	jun	jul	aug	sep
Rainfall $_{avge}$	4 570 020	402 451	443 896	468 254	396 271	433 898	488 613	687 112	619 128	103 976	47 989	125 425	353 008
ETa $_{avge}$	-3 280 198	-316 665	-306 450	-304 486	-316 665	-286 020	-304 486	-282 877	-267 948	-259 304	-170 512	-158 333	-306 450
$Rs_{5\%}$	1 858 415	138 436	136 591	143 245	163 932	178 526	183 368	185 509	206 542	142 537	123 629	122 377	133 725
$Rs_{35\%}$	1 397 023	98 741	124 979	119 083	112 942	116 062	125 847	143 764	141 071	118 539	101 229	99 054	95 711
$Rs_{50\%}$	1 202 282	93 734	100 109	99 927	96 617	97 539	107 570	126 569	129 294	101 163	87 014	78 548	84 198
$Rs_{65\%}$	1 060 332	84 857	88 299	89 847	82 106	82 537	86 997	117 140	119 050	81 118	74 991	74 612	78 779
$Rs_{95\%}$	884 495	66 953	72 108	72 734	72 187	74 505	72 843	90 663	93 948	76 374	64 894	64 219	63 066
$gr.w._{50\%}$	977 616	74 002	79 700	80 392	79 787	82 349	80 512	100 208	103 840	84 415	71 726	70 980	69 706

Table 5: Mukungwa catchment monthly meteorological and hydrological data

volume data in '000 m³	annual total	oct	nov	dec	jan	feb	mar	apr	may	jun	jul	aug	sep
Rainfall $_{avge}$	2 563 290	236 636	269 023	174 629	180 000	216 211	283 671	387 342	345 515	113 436	44 756	104 322	207 749
ETa $_{avge}$	-1 658 081	-160 069	-154 905	-153 912	-160 069	-144 578	-153 912	-142 989	-135 443	-131 074	-86 191	-80 034	-154 905
$Rs_{5\%}$	1 518 572	131 749	164 627	178 394	98 713	100 871	110 822	157 046	146 911	127 432	104 583	92 474	104 951
$Rs_{35\%}$	886 599	68 467	87 657	69 652	57 517	62 176	63 545	95 396	105 610	88 052	63 913	59 728	64 887
$Rs_{50\%}$	766 459	62 255	70 863	62 308	55 621	58 885	59 070	77 944	95 686	66 335	49 251	51 673	56 569
$Rs_{65\%}$	678 644	55 832	58 885	55 174	48 804	54 016	55 621	67 546	81 603	55 042	47 408	47 777	50 936
$Rs_{95\%}$	511 148	34 826	48 303	47 172	42 223	41 775	34 431	52 252	57 174	43 065	39 301	36 116	34 510
$gr.w._{50\%}$	627 665	45 453	56 196	53 717	50 412	49 585	45 453	64 461	66 113	53 717	49 585	47 519	45 453

Table 6: Lower Nyabarongo catchment monthly meteorological and hydrological data

volume data in '000 m³	annual total	oct	nov	dec	jan	feb	mar	apr	may	jun	jul	aug	sep
Rainfall $_{avge}$	3 935 064	364 081	427 255	294 257	297 249	387 522	471 975	685 270	436 232	107 562	69 824	112 050	281 788
ETa $_{avge}$	-3 035 774	-293 069	-283 615	-281 797	-293 069	-264 708	-281 797	-261 799	-247 982	-239 982	-157 806	-146 535	-283 615
$Rs_{5\%}$	1 326 684	94 382	116 797	129 692	112 083	119 469	116 557	163 914	156 350	99 833	78 173	64 834	74 599
$Rs_{35\%}$	929 046	62 576	84 225	73 718	68 738	73 252	87 327	117 368	117 145	73 290	59 153	54 749	57 504
$Rs_{50\%}$	848 870	58 585	75 168	72 133	62 985	69 387	72 348	101 115	107 112	69 155	53 382	52 050	55 450
$Rs_{65\%}$	786 114	57 373	71 344	66 814	57 528	63 222	64 380	95 325	96 483	64 215	51 009	46 721	51 700
$Rs_{95\%}$	633 802	45 188	54 583	52 307	49 586	51 934	53 577	75 826	75 628	48 402	42 429	40 508	43 833
gr.w.$_{50\%}$	544 628	41 858	50 561	48 452	45 932	48 107	48 593	49 287	48 593	45 816	39 303	37 523	40 603

Table 7: Akanyaru catchment monthly meteorological and hydrological data

volume data in '000 m³	annual total	oct	nov	dec	jan	feb	mar	apr	may	jun	jul	aug	sep
Rainfall $_{avge}$	4 167450	414 508	492 280	408 796	353 858	358 493	460 370	716 197	408 780	106 141	26 616	122 587	298 824
ETa $_{avge}$	-3 369589	-355 939	-331 856	-331 093	-338 587	-309 732	-338 722	-297 526	-291 804	-289 897	-102 227	-119 773	-262 433
$Rs_{5\%}$	1 248 658	74 172	109 085	128 465	89 581	118 511	113 420	167 240	170 708	79 532	61 315	68 819	67 810
$Rs_{35\%}$	866 158	59 890	77 863	73 058	73 575	68 228	80 707	111 251	112 898	64 086	50 843	42 392	51 367
$Rs_{50\%}$	774 661	54 490	68 652	69 979	67 758	62 281	70 365	96 823	100 495	54 783	43 937	39 988	45 110
$Rs_{65\%}$	706 238	51 682	62 774	65 558	59 873	58 473	64 345	86 703	89 091	49 217	38 868	39 093	40 562
$Rs_{95\%}$	430 507	32 783	33 200	34 551	39 433	32 230	50 611	63 623	46 054	32 720	22 384	21 414	21 503
gr.w.$_{50\%}$	531 701	36 569	38 563	39 893	51 861	49 866	56 515	63 623	47 872	45 212	36 569	33 244	31 914

Table 8: Upper Akagera catchment monthly meteorological and hydrological data

volume data in '000 m^3	annual total	oct	nov	dec	jan	feb	mar	apr	may	jun	jul	aug	sep
Rainfall $_{avge}$	2 824 025	295 911	333 080	204 216	198 431	326 572	355 787	475 395	291 572	45 124	35 000	50 476	212 460
ETa $_{avge}$	-2 320 280	-223 996	-216 771	-215 381	-223 996	-202 319	-215 381	-200 096	-189 535	-183 421	-120 613	-111 998	-216 771
Rs$_{5\%}$	673 170	48 331	57 528	60 128	56 777	57 305	61 020	63 323	67 324	61 353	53 412	41 207	45 463
Rs$_{35\%}$	531 383	39 194	45 497	49 594	46 844	45 537	47 169	52 143	54 762	51 294	35 623	30 154	33 573
Rs$_{50\%}$	502 501	35 147	43 340	46 852	44 265	44 003	44 342	51 118	53 228	48 053	33 576	27 096	31 481
Rs$_{65\%}$	478 721	32 941	40 081	44 896	42 082	42 116	42 754	50 314	52 144	45 871	30 856	25 153	29 512
Rs$_{95\%}$	350 708	26 089	31 449	28 983	32 004	35 245	33 536	36 804	41 338	27 453	21 543	16 322	19 941
gr.w.$_{50\%}$	351 095	26 118	31 484	29 015	32 039	35 284	33 573	36 845	41 384	27 484	21 567	16 340	19 963

Table 9: Lower Akagera catchment monthly meteorological and hydrological data

volume data in '000 m^3	annual total	oct	nov	dec	jan	feb	mar	apr	may	jun	jul	aug	sep
Rainfall $_{avge}$	3 580 480	393 260	470 944	326 708	218 289	325 014	438 273	640 590	312 672	85 912	75 506	63 890	229 422
ETa $_{avge}$	-2 673 845	-258 129	-249 802	-248 201	-258 129	-233 149	-248 201	-230 587	-218 417	-211 371	-138 993	-129 065	-249 802
Rs$_{5\%}$	1 285 266	73 080	82 640	97 397	98 981	105 763	115 277	136 037	142 848	134 544	114 129	106 544	78 026
Rs$_{35\%}$	964 603	59 628	65 017	72 784	78 192	78 205	90 840	102 955	107 707	96 775	82 500	68 334	61 665
Rs$_{50\%}$	874 040	56 391	60 588	69 081	71 164	71 196	76 402	91 208	97 439	86 018	75 166	62 834	56 553
Rs$_{65\%}$	814 376	52 479	57 393	61 835	64 558	69 924	71 661	84 199	92 047	79 178	70 200	60 077	50 823
Rs$_{95\%}$	593 775	35 191	40 411	42 008	50 423	56 371	56 287	59 817	68 756	58 442	48 887	40 876	36 306
gr w $_{50\%}$	536 000	31 767	36 479	37 921	45 517	50 886	50 810	53 997	62 066	52 756	44 130	36 899	32 773

Table 10: Muvumba catchment monthly meteorological and hydrological data

volume data in '000 m³	annual total	oct	nov	dec	jan	feb	mar	apr	may	jun	jul	aug	sep
Rainfall $_{avge}$	1 557 175	150 113	186 348	122 989	87 238	73 159	186 486	259 368	182 068	52 453	27 952	67 637	161 363
ETa $_{avge}$	1 364 335	-131 711	-127 462	-126 645	-131 711	-118 965	-126 645	-117 657	-111 448	-107 853	-70 921	-65 855	-127 462
$Rs_{5\%}$	290 071	22 974	34 164	26 179	18 623	20 148	20 605	36 243	36 165	20 772	18 006	17 761	18 433
$Rs_{35\%}$	198 480	16 342	17 065	16 883	15 839	15 739	16 398	18 235	18 018	16 420	15 951	15 683	15 907
$Rs_{50\%}$	185 593	15 314	16 080	15 957	14 706	14 901	15 337	17 124	16 990	15 169	14 694	14 666	14 655
$Rs_{65\%}$	172 744	14 287	15 169	14 923	14 007	13 656	14 169	16 063	15 962	14 141	13 403	13 400	13 564
$Rs_{95\%}$	108 685	8 662	11 025	10 689	8 358	6 390	7 572	13 716	13 684	8 423	5 602	6 246	8 320
gr w $_{50\%}$	110 376	8 797	11 196	10 855	8 488	6 490	7 690	13 929	13 896	8 554	5 689	6 343	8 449

Further to the catchment 'quality' assessment discussed in the previous paragraph (the ratios 'surface water - rainfall', 'groundwater - rainfall' and the ground water residence time) the monthly surface flow distribution tables are an excellent means to appreciate renewable resources intra annual (comparing between wet and subsequent dry season values for different probabilities) and inter annual (comparing between 50% and 95% respectively 5% probability) flow stability.

For instance, when comparing the ratio of lowest over highest monthly values for the NNYU (upper Nyabarongo) with those of NMUV (Muvumba), the values for NNYU are of the order of 0.6 to 0.7 irrespective of the probability, but vary between 0.4 up to 0.85 depending on the monthly flow probability (0.8 for average events, 0.5 for wet events and 0.4 for dry events).

When comparing the ratio of monthly volume data at 50 and 95 % reliability for NNYU with those of NMUV we see ratios of the order of 1.3 for the upper Nyabarongo against values of 1.5 up to 2.5 for Muvumba.

This indicates that the flow stability for Muvumba is poor with a reduced ability to store wet season excess resources and a near collapse of the dry season resources during a dry year. The flow generated from the Nyabarongo catchment remains significant under all circumstances as this catchment has storage and infiltration rates to store and regulate extreme flow events.

A systematic appreciation and a graphical representation of these tables is presented in each of the Catchment Master Plan (see appendixes 01 - 09)

1.6.3 WATER QUALITY SITUATION AT LEVEL 1 CATCHMENT

The surface - and ground water quality situation has been examined in the Exploratory Phase report chapter 4.5. Available and new water quality data have been collected and contamination levels have been assessed for the following categories:

- chemical composition (major ions, salts, pollutants and heavy metals)
- nutrient level (specifically N and P containing molecules) such as degrable organic matter
- micro biological contamination
- sediment load and morphological quality of rivers

The chemical water quality has been studied based on data from several campaigns organized by RNRA and NUR that were made available[1] and own sampling campaigns carried out in 2012 and 2013 on different river sections. These samples were analyzed for in situ parameters (- pH, - electric conductivity, - temperature, - oxygen in mg/L and as saturation, - turbidity, - total suspended solids), - major chemical constituents such as total nitrogen, total phosphorus, some heavy metals (Cu, Zn, As) and non-toxic metals indicative of strong reduction (Fe).

The results of these findings are presented in the two figures below.

[1] N.B. NUR data consisted of 3, 14, 8 and 7 batches or combined 32 samples taken. An additional 14 samples were taken by the client. Parameters characterize the physico-chemical quality, nutrient status and organic load adequately. Copper (Cu), Zink (Zn) and Arsenic (As) are good indicators for pollution with heavy metals. Investigations of mining impact requires site specific sampling at a scale of 10-100 of meters due to the high sorption of heavy metals and a specific choice of parameters according to site and mine mineralogy. Thresholds as indicated in NUR data agree with WHO and EPA regulations for some parameters but needed to be adjusted for Phosphorus, Nitrogen, BOD_5 and COD. The acceptable threshold for total Phosphorus was lowered to 0.05 mg/L according to EPA regulations instead of 5 mg/L. The threshold for BOD_5 at 30 mg/L is still considered a very high value according to EPA and WHO recommendations and was therefore used as an upper threshold for satisfactory conditions while very good quality requires a BOD_5 of < 5 mg/L and good quality at least a BOD_5 of < 10 mg/L. The threshold values in Table 11 have been adjusted accordingly.

Figure 2: Chemical surface water quality situation in Rwanda (total nitrogen and phosphorus)

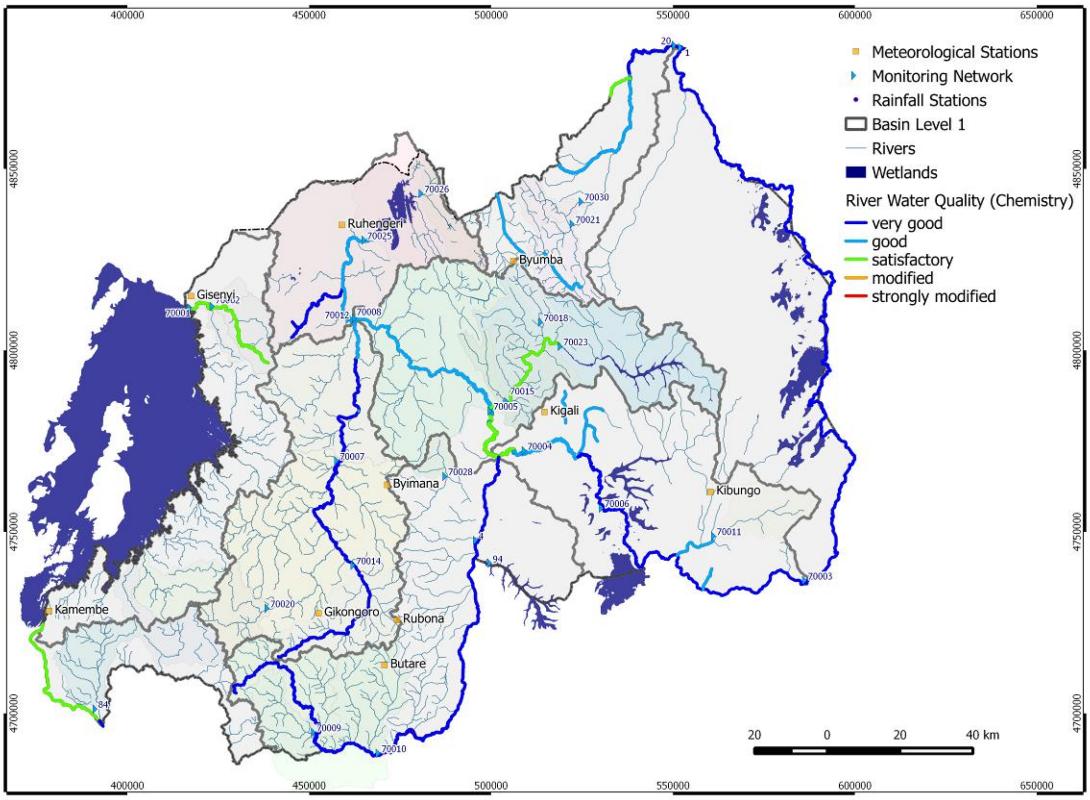
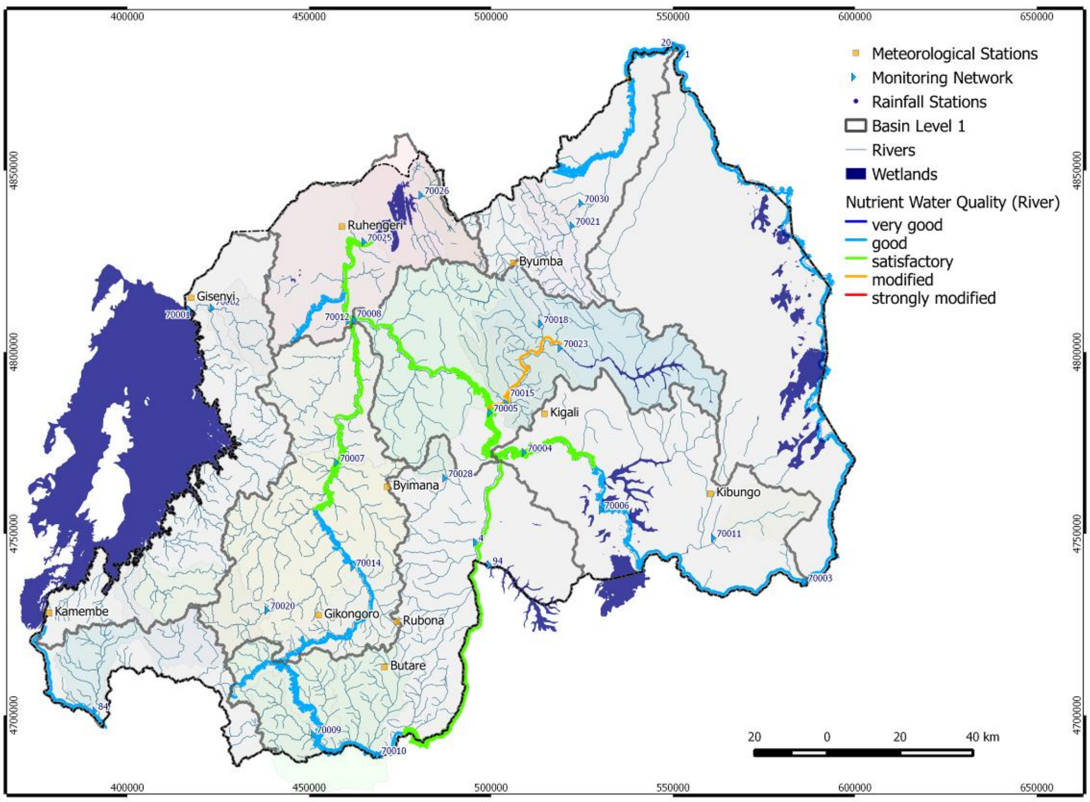


Figure 3: Nutrient water quality situation in Rwanda (BOD_5, COD)



The chemical and nutrient water quality is divided into 5 classes ranging from very good, good, satisfactory, modified to strongly modified. The target for water quality management should aim at a good water quality.

The benchmark for water quality and the target of good quality are conditions corresponding to a natural state of the river. Good water quality is characterized by conditions in which the river section fulfills all hydrological and ecological functions. Very good conditions exceed these standards significantly. The river section of very good quality has a high ecological value in terms of purification, storage and provision of recources exceeding standards. Satisfactory conditions are above the recommended conditions but indicate already a noticable anthropogenic impact. A modified section does not reach the water quality standards given by national law or by WHO and indicates anthropogenic impact that affects the hydrological or ecological functioning of the river. Strongly modified sections are far from the water quality standars and objectives set and require significant action to restore natural and good conditions.

Table 11: Classification thresholds for water quality

Classification for chemical quality	**Description**	**Physico-chemical water quality especially (N & P)**	**Nutrient status and impact of organic load (BOD_5, DOC)**
Very good	All parameters are better than standards or recommended values, all hydrological and ecological functions of storing, filtering, purifying and providing water are vital	N < 3 mg/L and P < 0.05 mg/L	BOD < 5 mg/L and COD < 10 mg/L and E. coli < 4 cts. and Faecal Coliforms <100 cts.
Good	Parameters reach or are better than standards or recommended values, hydrological and ecological functions of storing, filtering, purifying and provision are intact	N: 3-5 mg/L and P: 0.05-0.1 mg/L	BOD < 10 mg/L and COD < 20 mg/L and E. coli < 4 cts. and Coliforms 100-400 cts. Per 100 ml
satisfactory	Most but not all parameters correspond to recommended values, river section is partly affected by anthropogenic impact but still mostly responding to its ecosystem functions	N: 5-10 mg/L and P: 0.1-0.25 mg/L	BOD 10-30 mg/L and COD 20-50 mg/L or E. coli 4-10 cts. or Coliforms 100-400 cts.
Modified	Anthropogenic impacts are evident, some parameters exceed recommended values or regulations, some ecosystem functions of filtering, puriying or provisioning are affected	N 5-10 mg/L or P 0.25-0.5 mg/L	BOD 30-50 mg/L and COD 50-75 mg/L or E. coli > 10 cts. and Coliforms > 400 cts.
Strongly modified	Several key parameters indicate strong anthropogenic impact,	N > 10 mg/L and P > 0.5 mg/L	BOD > 50 mg/L and COD >75 mg/L

	several ecosystem functions are affected, major measures need to be taken to restore ecosystem functions in the river section		and E. coli > 10 cts and Coliforms > 400 cts.

A classification needs to take into account the natural and original state. High organic load is not natural in upland rivers but natural for the outflow of a wetland. Such baseline studies of the natural state of rivers need to be carried out before anthropogenic impact can be assessed and are not available for Rwanda. Therefor indicators for the natural state of rivers need to be derived from studies of unpolluted tropical rivers and international recommendations. For river chemical quality two main parameters are considered: Nitrate and phosphate.

Nitrogen is a limiting factor and nutrient in freshwater aquatic systems. It is recommended that total nitrogen is lower than 3 mg/L in rivers draining into reservoirs, for running waters not draining into lakes and reservoirs a natural threshold of 5-10 mg/L is recommended and natural. As nitrogen forms part of a complex cycle, it can be transformed to nitrate, nitrite, ammonium and nitrogen (gas) depending on environmental conditions.

For the surface water quality mapping presented in Figure 2, the nitrogen threshold for very good quality was 3 mg/L, 3-5 mg/L was considered a good and 3-10 mg/L a satisfactory value, values above 10 mg/L indicate anthropogenic impact. Sources stem from sewage and fertilizers in agriculture. Any organic material contains nitrogen and can be transformed to nitrate by mineralization. Therefore land use changes also release nitrates. Tropical soils however, have a higher anions exchange capacity and can partially store nitrate. If concentrations above 10 mg/L are observed, it is evident that fertilizers or sewage have modified the nitrogen concentration. Sources can be reduced and limited by water treatment and careful administration and use of fertilizers.

The EPA (Environmental Protection Agency, United States) water quality criteria states that phosphates should not exceed .05 mg/l or 50 µg/L if streams discharge into lakes or reservoirs, .025 mg/l or 25 µg/L within a lake or reservoir, and .1 mg/l or 100 µg/L in streams or flowing waters not discharging into lakes or reservoirs to control algal growth (USEPA, 1986). Surface waters that are maintained at 10 to 30 µg/l of total phosphorus tend to remain uncontaminated by algal blooms. Phosphate itself does not have notable adverse health effects. Phosphate levels greater than 1.0 may interfere with coagulation in water treatment plants and deteriorate the result of water treatment and microbiological removal. Phosphate is a limiting factor for plant growth in freshwater aquatic systems and high phosphate concentrations stimulate primary production in lakes and reservoirs such as algae. The natural background levels of total phosphorus are generally less than 0.05 mg/l. Sources of phosphate are natural (weathering and erosion of material) and anthropogenic from fertilizers or sewage. Thus settlements and agriculture are the main sources. There is strong sorption of phosphate and therefore transport takes place in particulate form attached to sediments. Erosion control and water treatment can reduce phosphate concentrations.

In the second map presented in Figure 3 indicators of pollution with organic material or sewage such as the chemical oxygen demand by slow degradation with strong reductants (COD), the biochemical oxygen demand by rapid degradation (BOD) and lastly - biological indicators of pollution such as feacal coliforms and e. coli bacteria have been analyzed and visualized per river section on a national map. Biochemical Oxygen Demand (BOD_5) is defined as the amount of oxygen required by bacteria to decompose organic matter for a specified time (usually 5 days) under aerobic conditions.

BOD_5 is commonly used to measure natural organic pollution. This value is important as it controls the level of oxygen in rivers which in turn controls the living conditions for higher organisms. Main sources for organic loads are sewage from settlements, sewage from breweries and slaughterhouses, but also regionally specific sources such as coffee washing sites. The natural oxygen concentration of tropical rivers ranges from 5 to 10 mg/L oxygen. A BOD_5 exceeding this threshold would have the capacity to annihilate the oxygen content in a natural river water within 5 days. Fortunately, rivers are aerated and dissolve oxygen from the atmosphere. This aeration capacity depends on the turbulence of rivers and is higher in high mountain reaches and lower in low mountain reaches. Combining all aspects the acceptable BOD depends on the reaeration capacity. As a rule of thumb BOD_5 of < 5 mg/L is very good, < 10 represents good conditions and satisfactory conditions are given by BOD_5 of 10-30 mg/L.

Chemical Oxygen Demand is defined as the oxygen equivalent of the organic portion of the sample that is susceptible to oxidation by a strong chemical oxidant. However, this oxidation is slower and not fully realized in natural rivers. COD is therefore higher and accordingly the thresholds for very good (10 mg/L), good (20 mg/L and satisfactory conditions (50 mg/L) are higher. Sources of COD can be anthropogenic but also natural and include dissolved organic matter from wetlands. Especially particulate organic matter that is not easily dissolved (lignine) contributes to COD. COD can be reduced by controlling erosion and by the same measures that reduce $BOD_{5.}$

The water quality index for organic pollution contains 4 indicators and parameters, chemical oxygen demand (COD), biological oxygen demand (BOD), the counts and number of e. coli bacterio per 100 ml sample and of faecal coliforms per 100 ml water. For E. coli and faecal coliforms the number of counts per 100 ml sample are indicators of the hygienic conditions. High counts indicate a direct pollution by sewage (anthropogenic) or other sources of faecies (cattle, animals). They pose a direct health risk for human activities and need to be kept as low as possible.

In summary, heavy metals only occur locally. Elevated concentrations of Arsenic were found in one geothermal source at Burambo and is of geogenic origin – still this source cannot be used without further treatment. Elevated concentrations of copper (Cu) were found in 5 samples in e.g. Muvumba, Nyabugogo, and Nyabarongo water. Elevated Zinc (Zn) was found in some instances. These can result from natural sources but often they result from mining activities and ore washing facilities. It is important to monitor these facilities and to develop regulations, procedures and technology to limit pollution from the planning phase of the mining operation by an environmental impact assessment (E.I.A) for each operation and phase. It is even more important to watch the nexus between industries or other polluting activities, water and agriculture as an indirect use or drinking water as a direct use. Heavy metal pollution of irrigated fields common in Rwanda downstream of mining or industrial operations can lead to an enrichment of metals. Therefore, also remote connections of water quality impacts need to be accounted for.

The main problems of water quality are:

- high loads of e. coli and coliform bacteria (and others not measured) from untreated sewage
- high organic loads and high biological oxygen demands (BOD) and chemical oxygen demands and resulting low concentrations of oxygen (mg/L)
- very high sediment loads and turbidity

A river that is strongly affected is Sebeya river with high loads of sediments and high bacteria counts. The Nyabugogo carries high loads of nutrients (total nitrogen and phosphorus). It is important to continue monitoring sediment loads, chemical status and nutrient load. Based on these findings sources need to be identified and measures identified to reduce these loads.

The percentage of households with access to sanitation and then treatment needs to be increased, especially for areas with high density of population (Nyabugogo and Sebeya, Musanze). The Nyabarongo being also an indirect recharge source for the water supply of Kigali it is important to monitor, protect and reduce loads of organic matter and nutrients to this river too. No specific problems with fluoride were noted. Fluoride can be a problem in volcanic rock aquifers and needs to be monitored in the north (Musanze, Mukungwa) and in the South-West (Rusizi). Fluoride concentrations should not exceed 1 mg/L.

1.6.4 ADDITIONAL RESOURCES OPPORTUNITIES AT LEVEL 1 CATCHMENT

For the mobilization of additional resources at the level 1 catchment two methods are commonly applied:

- the construction of surface water storage facilities and
- the reuse of waste water from any use process

These modalities of these methods will be briefly discussed in this section.

ARTIFICIAL SURFACE WATER STORAGE RESERVOIRS

The impact of an artificial surface water storage reservoirs on the natural hydrological cycle is a redistribution of the surface water availability from the wet months to the dry months (catchment regulation) at the cost of an increase of the water balance evaporation losses over the redistributed volume. The precise impact depends on a series of meteorological, catchment and reservoir parameters including operation rules as applied for the specific reservoir in question.

Within the context of the Irrigation Master Plan, a list of 107 potential surface water storage reservoir sites was identified and a further 36 sites were identified by the LWH project (1 or 2 sites are identical - details are available in annex C2_3_5). Within the context of the catchment Master Plan formulations, these potential dam sites have been considered for their relevance for the purpose of irrigation as well as for the enhancement of dry season resources availability.

While essential characteristics of these sites were mostly not available, a very approximate yet systematic assessment of sites has been done which permitted to present a number of evaluation criteria for all the potential sites. Because the evaluation is largely based on the interpretation of data from 1 on 50 000 topographic maps with 25 meter contour lines, the precision of the method is not very high. However, it is assumed that the method is good enough to differentiate between good and poor sites in a catchment. The assessment did not comprise any geotechnical consideration of dam or reservoir site. Particularly the following indicators were used:

- dam height at which irrigation command area water demand can be reasonably served; there is interest to remain below the 15 m large dam threshold of the ICLD (International Commission on Large Dams); dams heights were raised or lowered by

5 m steps from 14 m starting point with a minimum of 6 and a maximum of 24 meters.

- reservoir effective volume; the higher the better; volumes below 1 MCM are of little interest
- the ratio of the reservoir effective volume over the MAR (Mean Annual Runoff); when the reservoir volume exceeds the 60 or 70 % of MAR, the reservoir operation may become gradually less efficient for intra annual flow regulation contributing more to evaporation losses than to effective dry season water use;
- the ratio of reservoir volume over irrigation demand; the indicator is calculated but for most catchments additional capacity is very useful (see reservoir effective volume)
- the ratio of reservoir volume over dam volume; this indicator is without a doubt very imprecise but excellent to identify and discard poor dam sites.

Details of the method and results are indicated in each of the catchment Master Plans (see appendixes 01 - 09°

Especially in the more undulating hills of the Eastern catchments (NAKU, NAKL, NMUV) and considering the significant projected demand in combination with limited resources, a number of important sites has been endorsed. These sites can be used for dam irrigation but are evenly relevant for other uses (hydropower, DWS, industrial use, other irrigation, etc.)

It is expected that the reservoir storage capacities defined from the 1 in 50 000 topographic maps, are significantly underestimated. In the context of resources assessment and the formulation of catchment master plans with monthly water balance, this is only prudent.

REUSE OF WASTE WATER

A further prospect for the generation of additional resources is the realization of **water reuse** activities. Opportunities are available where large amounts of water are used that are not entirely consumptive. These conditions are typically found in urban water supply, sizeable industrial users, mining, coffee washing stations, hydropower installations, and the irrigation sector. For all opportunities that are identified there are a number of aspects to consider:

- what is the used water availability over time? Is it sufficient or can it be developed as a complementary resource?
- where is the used water available? Is it at a convenient location? Does it need conveyance? Does it need lift?
- what is the used water quality? Is the quality acceptable for restitution in the natural hydrological cycle? Is the quality satisfactory for the intended water use? Does it need treatment? Does it need treatment after the water use for restitution in the natural hydrological cycle?
- what are the alternative options for mobilizing the necessary resources? What are the long term financial, social and environmental consequences of the water reuse option in comparison with the alternative solution or solutions?

As for any other water resources development activity, potential water reuse opportunities should be processed through a normal project cycle of i) identification of demand, ii) inventory of possible solutions, iii) selection of best solution, iv) validation of best solution (is the solution good enough?), v) design, implementation and exploitation of validated best solution.

Hence, water reuse opportunities should not be implemented per se because it sounds in agreement with the IWRM approach. On the other hand, when assessing water reuse opportunities, they should be validated in a holistic context, considering (environmental) costs of the non-reused waste water in the equation (irrespective of whoever may be responsible for the waste water and its costs).

For the national and catchment Master Plans, and the water balances that define the foundation of these Master Plans, water reuse opportunities have not been considered other than by disregarding water demand for non consumptive hydropower water use, and recommending less water efficient irrigation infrastructure at specific locations.

It is expected that future catchment balances and more in depth catchment master plans in highly committed catchments will have ample opportunity for the development of water reuse solutions.

1.6.5 SUSTAINING WATER RESOURCES AT LEVEL 1 CATCHMENT

Several pressures may affect water resources sustainability at all catchment levels: Pressure changes can be internal when they result from changes in land use, pollution, impacts from water sectors such as agriculture or be external for instance climate change. The key objective of water resources management in Rwanda is to assure a sustainable use of water resources. In order to achieve this objective, specific strategies need to be adopted for dealing with internal and external pressures:

- Implementation of monitoring programs for operational, surveillance and investigative monitoring to assure sustainable water resources in terms of quantity and quality
- Environmental impact assessment for activities from all sectors affecting water resources, such as mining, agriculture and urbanization
- Development of capacities of strategic planning of water resources and continuous update of the Masterplan of Water Resources of Rwanda for increasing resilience of the water resources systems and water supplies to climate change and other changes (global change)

1.6.5.1 IMPLEMENTATION OF MONITORING PROGRAMS

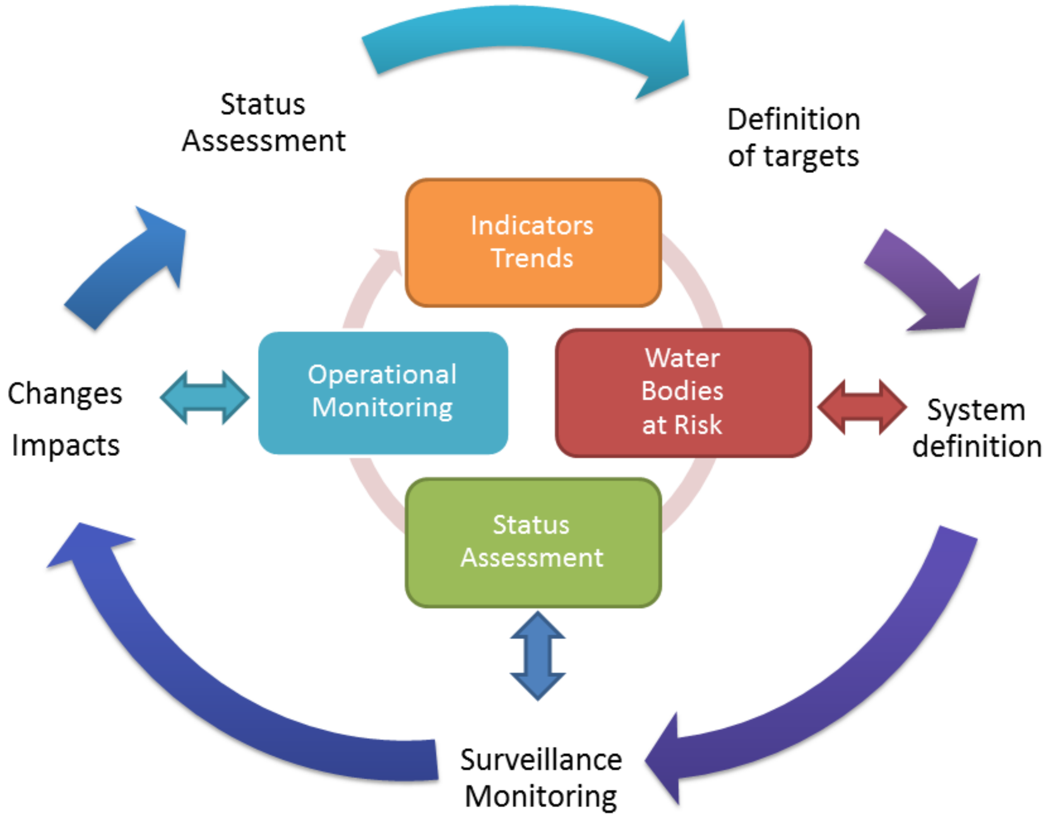
The status of water resources needs to be monitored continuously by an efficient and comprehensive monitoring program covering surface and groundwater and both quantity and quality.

The Masterplan provides a division of catchments at three levels (1, 2 and 3) and a definition of surface and groundwater bodies. These are the surface and groundwater systems to be monitored. Monitoring must be based on indicators as well as benchmarks with which the indicators are compared. The Rwanda National Water Resources Masterplan provides benchmarks for both surface and groundwater quantity and quality. The benchmark are based on the analysis of all available records of surface water levels and discharges and on new investigations on groundwater levels and water quality in rivers and groundwater.

Operational monitoring of water resources in level 1 catchments provides a continuous track-record of surface and groundwater levels and discharge and of water quality parameters. The data obtained from operational monitoring programs indicate whether water resources indicators remain within the bounds of variability or whether they trend indicating changes to hydrological systems. The work done for the Masterplan and a status assessment based on these investigations already indicate that some water bodies and basins are at risk.

These water bodies at risk are affected by land use changes and suffer actual or imminent depletion of water resources. Water bodies at risk can also be affected by pollution or are at risk of being affected in the near future. For these basins monitoring needs to be intensified and a closer surveillance monitoring of changes needs to be carried out. Impacts and resulting changes can be tracked by surveillance monitoring programs that lead to a status assessment and a definition of water management targets and time frames. Once these management targets are defined, adequate measures can be developed and implemented to revert changes and achieve environmental or hydrological targets. This management cycle (Figure 4) leads to a continuous monitoring of water resources.

Figure 4: Management cycle for water resources assessment in Rwanda



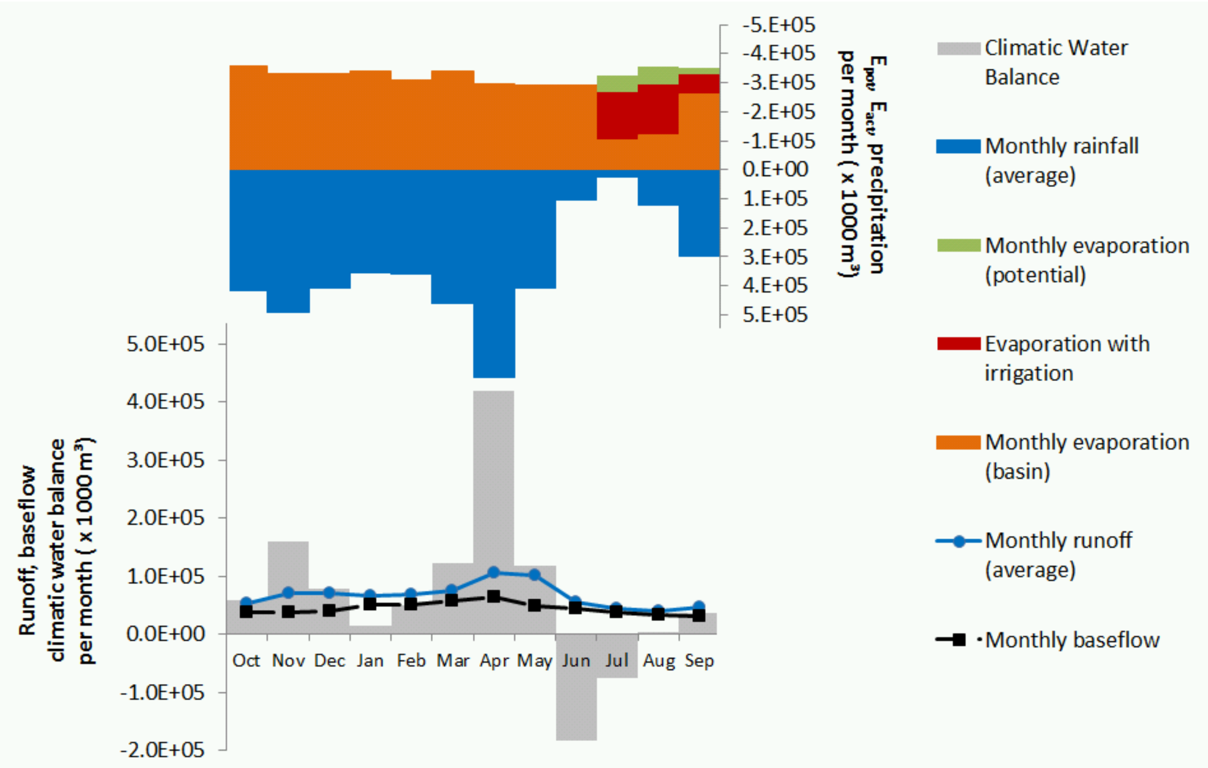
In some cases investigative monitoring is needed to develop regional expertise and knowledge on potential impacts and risks for water resources. Some special investigations have been carried out during the Masterplan study:

- Groundwater recharge assessment using isotope methods has been carried out for the first time defining the replenishment and sustainable yield of aquifers
- Flood risk assessments have been carried out for topographic flood risk and for the Mpazi basin in Kigali proposing a flood mitigation plan
- Monitoring in small basins has been launched and carried out for the first time to monitor floods from small basins.

Further investigative monitoring programs need to follow up in the future in order to provide a basis for IWRM in Rwanda:

- The impact of different irrigation schemes on water resources must be assessed by special investigation programs. This is of paramount importance. Because of the ambitious irrigation program defined in the Irrigation Master Plan of Rwanda, even small impacts on the hydrological cycle may have significant consequences on water services. This is especially important for the eastern part of Rwanda (Akagera) with a balanced or even seasonally negative water balance. An example is given in Figure 5. Different types of irrigation need to be investigated in terms of their impact on water resources, water quality and sediment transport. Irrigation practice needs to be improved and adapted in a way to sustain water resources.
- The impact of urbanization of flood risk needs to be investigated. The case of Mpazi - Nyabugogo for Kigali showed that flood production can increase by orders of magnitude in urbanized basins. Urbanization schemes need to take heed of their footprint on flood generation.

Figure 5: Requirement for special investigations on impact of irrigation (Akanyaru basin)



1.6.5.2 ENVIRONMENTAL IMPACT ASSESSMENT

Internal pressures need to be controlled and the RNRA-IWRM needs to assure that developments and envisaged interventions affecting sustainable water resources use are anticipated, where possible entirely avoided or otherwise controlled by Integrated Water Resources Management. A thorough analysis of developments that may affect water resources needs to be carried out regularly.

Changes in land use practice and developments in all sectors that may or will affect water resources need to be evaluated by environmental impact assessment (EIA): Major construction works infrastructure development, mining, development of irrigation schemes, urbanization and the impact these activities have on water resources in terms of quantity and quality need to be assessed by EIAs. EIAs need to follow thorough standards and be carried out with public participation and independent institutions not having specific interest in the results or outcomes of EIAs (avoiding conflicts of interest).

Monitoring data indicate that there are several activities that may cause local or even regional impacts:

- Mining activities are on the increase and, unless corrective measures are implemented systematically, these mines will have an impact on the aquatic environment by releasing heavy metals from the mined ore and from chemicals used in the mining process. Mining infrastructure, such as tailings dams, need to be assessed for their impact on the hydrological cycle in terms of water quantity and water quality. This includes two aspects: For each mine a 'mine water balance' must be established defining in and outgoing water needs for all mining activities (also indirect ones). The source of water and the treatment of release of water need to be described in detail in an EIA and the anticipated impact on the environment and on other sectors must be assessed. This sector integration is crucial as heavy metals may enter the food chain (use of water for irrigation and pollution of food grown from irrigated agriculture). Environmental assessment of activities needs to be carried out for mine infrastructure and include an evaluation of floods and risks from failure of infrastructure and measures to control these risks.

- Irrigated agriculture may have an impact on water resources. It is fully recognized that it is of paramount importance to develop food production. Still, the development must also take into account impact on water resources and on other irrigation schemes. The need for special investigations has been mentioned in the previous chapter. It is strongly recommended that impact assessments on flow regime of downstream basins becomes part of every feasibility study for irrigation schemes and that irrigation schemes be equipped with monitoring facilities to monitor and document the impact.

The EIA process involves a sequence of steps starting from social baseline studies, involving a detailed project description and thorough study and impact analysis. It is important that the predicted outcomes be monitored as well. The results must be reviewed in the beginning for re-assessed and continued approval (or additional corrective measures) after some time (1, 3 or 5 years) based on the monitoring results.

Figure 6: Requirement for special investigations on impact of irrigation

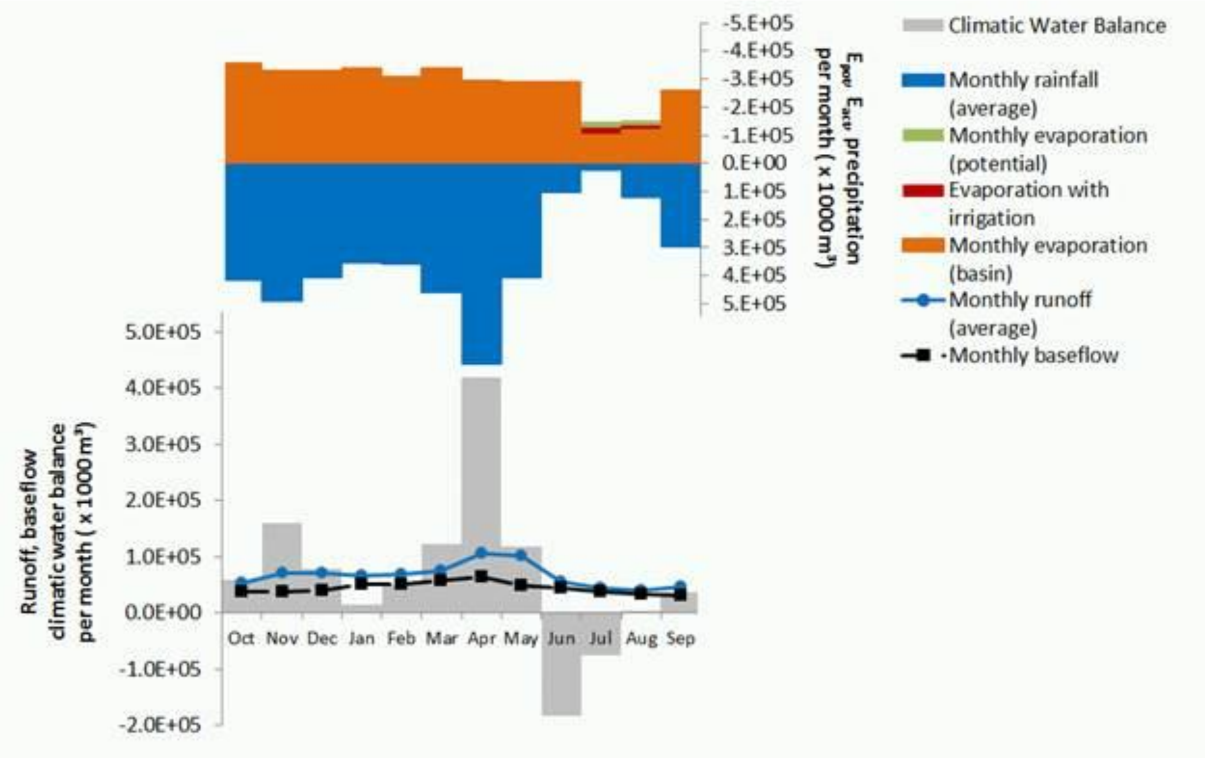
1.6.5.3 STRATEGIC PLANNING AND INCREASING RESILIENCE

It is not clear yet which climate impacts will occur in Rwanda and estimates and predictions for the impact of climate change on rainfall and evaporation are highly uncertain. At the same time other global changes such as population growth, intensification of agriculture and food production, land use changes, increase of water abstraction and urbanization are very strong factors. We therefore recommend to adopt a strategy to increase resilience of systems and to assure that strategic reserves are developed and kept. The results of the Masterplan of Water Resources provide a detailed basis for strategic planning:

- The total reserves of groundwater are specified.
- The resources-demand tables indicate when deficits occurs and how these can be mitigated by storage.

It is therefore proposed to initiate a program on strategic water resources planning with the aim of increasing the resilience of the overall hydrological system especially in regions in which seasonal scarcity occurs and in which groundwater resources are small compared to needs and to variability. The approach is based on analyzing the monthly and seasonal water balance including its variability and comparing it to the total of groundwater reserves and storage available per basin. The ratio of seasonal deficit (Figure 7 below, grey bars) and total available storage indicates the vulnerability of each basin for climate change but also for all other impacts and pressures that may occur in the future. This assessment will also provide a timeframe for management actions and measures to mitigate the situation.

Figure 7: Strategic Planning of Water Resources (Mukungwa basin)



The analysis carried out for the masterplan indicates that level 1 basins Lower Nyabarongo, Akanyaru, Upper and lower Akagera and Muvumba will require a specific strategic planning. In order to increase the resilience of the entire water resources system strategic reserves in the Mukungwa basin and in the Upper Nyabarongo should be developed and kept. Redistribution systems such as a 'natural flow path - water carrier' from Mukungwa can further improve the resilience. The strongest impact on resilience however, will result from demand management. Demand management is based on knowing resources in real time and on the capacity of implementing actions timely and based on the analysis of monitoring data.

1.6.6 RESOURCES ASSESSMENT OF LEVEL 3 SURFACE CATCHMENT

The estimation of water resources for level 3 is generic. The Water MIS includes all data from rainfall stations and from climatological stations. Based on these data rainfall maps and evaporation data, catchment climatic water balance models on a monthly basis have been established. In addition, runoff, peak flow, 100 year floods, 50 year floods, 10 year floods, mean annual flow, low flow for different quantiles (95%, 65%, 50%, 35% and 5%) have been determined and estimated for all available stations and for all basins as reported in the exploratory phase report. All runoff values have been transformed to specific values, e.g. mean annual runoff, peak flow or quantiles in l/s*km² or in mm/m² or in m³/s per 100 km². Based on the relationships presented in the Exploratory Phase report, rainfall, evaporation, runoff and recharge can now be estimated for any basin based on catchment size, location, landuse, and geology.

1.7 DEMAND ASSESSMENT

This sub-chapter on demand assessment will present the volumes of consumptive use for the current (2012) situation, the unadjusted, and finally the adjusted consumptive water demand per catchment for 2012, 2020, 2030 and 2040.

The volume of consumptive use is rather approximate and only available as an annual sum. The 'unadjusted' consumptive water demand per month per catchment is based on assumptions that are mostly applied uniformly for all catchments and which ignore water resources availability. For the 'adjusted' consumptive water demand per month per catchment the catchment's own renewable water resources (again per month and per catchment) have been considered as well as possible transfers of supplemental resources from upstream catchments.

The adjusted water demand for the different time horizons form the basis for a water resources development program which will be presented in the next sub-chapter 1.8.

1.7.1 CURRENT CONSUMPTIVE WATER USE AT LEVEL 1 CATCHMENT

Information on actual water use in Rwanda is scarce and incomplete. Information could be obtained from EWSA on water supply production capacities for urban centers and on presumably operational water supply infrastructure in rural areas (protected springs, boreholes and piped water supply systems.

Information on the current command areas under different types of irrigation (rain water harvesting irrigation ponds, marshland development, irrigation from surface water sources (lake and river sources) and from dams) could be obtained from the Ministry of Agriculture. This ministry also provided a specification of the water use from coffee washing stations.

Water use for other purposes (all industrial, ecological, administrative, emergency, ornamental, etc.) when not included in the EWSA production systems, remains unaccounted for.

Notwithstanding the delicate basis for the estimation of current water use this has been assessed for each catchment on the basis of the following water use assumptions:

- protected spring at 0.25 l/s continuously unless other discharge is specified
- borehole at 6.5 m³/day
- urban or rural piped water supply system at indicated production capacity
- rainwater harvesting irrigation pond at 1000 m³/year
- marshland development at 2000 m³/ha/year (this is additional to water use from undeveloped marshland)
- irrigation from surface or groundwater resource between 6 000 m³/ha/year for the western areas an 8 000 m³/ha/year for the eastern areas
- irrigation from dam site a maximum of two filling cycles per year or if unknown dependant on catchment area expressed in km² which will yield a volume when multiplied with inflow estimated between 800 mm/year for the eastern areas and 1200 mm/year for the western areas.

The assumptions for potable water supply are likely to lead to a substantial overestimation of actual water use but there is likely a significant component of unregistered water use from (unsafe) water sources. Irrigation water use is assuming full exploitation of developed areas which is not always the case. Results are presented in the table below.

Table 12: Overview of current water use in the different catchments of Rwanda

Level 1 basin code	Surface area level 1 basin [km²]	renewable resource ['000 m³]	Potable water supply use ['000 m³]	Irrigation water use ['000 m³]	Total water use in ['000 m³]	% 2012 Total water use over resource
CKIV	2,180	898,000	5,917	440	6,357	0.71%
CRUS	504	432,000	954	890	1,844	0.43%
NNYU	3,162	1,290,000	8,400	1,193	9,593	0.74%
NMUK	1,586	905,000	3,659	0	3,659	0.40%
NNYL	3,269	899,000	11,983	7,983	19,967	2.22%
NAKN	3,265	798,000	10,815	21,195	32,010	4.01%
NAKU	2,939	504,000	9,776	16,034	25,809	5.12%
NAKL	3,223	907,000	880	8,404	9,284	1.02%
NMUV	1,587	193,000	875	9,742	10,617	5.50%

Higher water use is registered for lower Nyabarongo (NNYL) and upper Akagera (NAKU) catchments which is related to the water use for the city of Kigali and irrigation development in the Nyabarongo valley. Akanyaru catchment (NAKN) features both significant potable water supply and irrigation development (mainly tributaries of Akanyaru valley). Muvumba catchment (NMUV) indicates the highest water use which is exclusively related to irrigation development.

Although the registration of actual water use is virtually absent and actual water use will exceed these recorded data, the table permits to conclude that water use is still very low. The further and accelerated development of water resources constitutes both a requirement in terms of attaining millennium development goals with respect to water supply and sanitation as well as a major development opportunity for water dependant commercial ventures of any type in the fields of agriculture and industry.

1.7.2 UNADJUSTED WATER DEMAND PROJECTIONS AT LEVEL 1 CATCHMENT

The water demand projections have been discussed and proposed in chapter 4.4 of the exploratory phase report for the 2012, 2020, 2030 and 2040 time horizons. It was presented that the consumptive water demand is based on three foremost and interrelated drivers i.e. population growth, increased standards of living, and economic development:

- **population growth** is a major driver of water demand either directly through urban and rural water supply and sanitation services, as well as indirectly through services (e.g. energy, housing, transport, etc. that may likely require water) and a variety of economic activities (food production, services, etc.) at household level or larger industrial units. Population growth projections up to 2022 are based on a study by NISR[2] which presented annual population growth rates from 2007 (with an observed

[2] NISR- 2009: National Population Projection 2007 - 2022.

annual growth rate of about 2,7 % and preceding trend data) up to 2022 (with projected annual growth rates of 2, 2,5 and 2,8 % according to low, medium and high population growth scenarios). The trends of these annual population growth rates have been extrapolated by this Master Plan study up to 2040 to decline to annual growth rates of 0.5, 1.3 and 2% according to the low, medium and high population growth scenarios. The population peak will consequently be reached beyond the Master Plan planning period (2040).

A further important tendency is the likelihood that the main part of the population increase will be absorbed by urban centers almost exclusively. This tendency is confirmed when analyzing the 2002 - 2012 census data for urban and rural sectors. In fact, when a thriving commercial farming population needs to evolve from the current self-sufficiency status quo, the area per farming family needs to increase which will prevent (or even reverse!) further population growth in rural areas.

Detailed explanations on these population data have been presented in annex C4_2 (Population extrapolation data) of the Exploratory Phase Report.

The population extrapolation data for the different projection dates and growth scenarios are presented in Table 13 below.

Table 13: Overview of population extrapolation date for Rwanda

Level 1 basin code and population category	Population extrapolation data in thousands											
	2012			2020			2030			2040		
	low	med.	high	low	med.	high	low	med.	high	low	med.	high
CKIV-rural		1 431		1 552	1 637	1 664	1 701	1 887	1 993	1 635	1 929	2 166
CKIV-urban		108		266	280	285	470	521	550	757	893	1 002
CKIV-total		1 539		1 818	1 918	1 949	2 171	2 408	2 544	2 391	2 821	3 168
CRUS-rural		327		370	390	396	409	454	480	407	480	539
CRUS-urban		20		40	42	43	80	89	94	132	156	175
CRUS-total		347		410	432	439	490	543	573	539	636	714
NNYU-rural		1 421		1 515	1 599	1 625	1 615	1 791	1 892	1 604	1 893	2 126
NNYU-urban		165		358	378	384	623	691	730	860	1 015	1 139
NNYU-total		1 586		1 873	1 976	2 009	2 238	2 482	2 621	2 464	2 907	3 265
NMUK-rural		1 095		1 096	1 157	1 176	1 183	1 312	1 385	1 198	1 413	1 587
NMUK-urban		249		491	518	526	713	791	836	890	1 050	1 179
NMUK-total		1 344		1 587	1 675	1 702	1 896	2 103	2 221	2 088	2 464	2 766
NNYL-rural		1 420		1 326	1 399	1 422	1 354	1 502	1 586	1 238	1 460	1 640
NNYL-urban		881		1 392	1 469	1 493	1 893	2 100	2 218	2 339	2 759	3 098
NNYL-total		2 301		2 719	2 868	2 915	3 247	3 602	3 804	3 576	4 220	4 738
NAKN-rural		1 181		1 267	1 337	1 359	1 325	1 469	1 552	1 327	1 566	1 758
NAKN-urban		309		494	521	529	778	863	912	989	1 167	1 311
NAKN-total		1 490		1 761	1 857	1 888	2 103	2 333	2 464	2 316	2 733	3 069
NAKU-rural		865		854	901	916	878	974	1 028	719	848	952
NAKU-urban		320		545	575	585	793	880	929	1 122	1 324	1 487
NAKU-total		1 184		1 399	1 476	1 500	1 671	1 854	1 958	1 841	2 172	2 439

Level 1 basin code and population category	Population extrapolation data in thousands											
	2012			2020			2030			2040		
	low	med.	high	low	med.	high	low	med.	high	low	med.	high
NAKL-rural		514		555	585	595	585	648	685	515	608	682
NAKL-urban		39		98	103	105	195	216	228	343	405	455
NAKL-total		552		652	688	700	779	864	913	858	1 013	1 137
NMUV-rural		556		595	628	638	627	696	735	628	741	832
NMUV-urban		77		153	161	164	266	295	312	356	419	471
NMUV-total		633		748	789	802	893	991	1 047	984	1 161	1 304
TOTAL-rural		8 809		9 130	9 632	9 790	9 677	10 733	11 336	9 271	10 937	12 282
TOTAL-urban		2 167		3 837	4 047	4 114	5 812	6 447	6 809	7 788	9 188	10 318
TOTAL-total		10 976		12 967	13 680	13 904	15 490	17 180	18 145	17 059	20 126	22 600

Overall the population is expected to increase by a minimum 55 to more than 100% over the planning period and depending on the growth scenario. There is overall a very significant increase in urban population from less than 20% as of 2012 to about 50% by 2040. This seems to be particularly significant at the lower Nyabarongo and upper Akagera catchments that host the predominantly urban districts of Gasabo, Kicukiro and Nyarugenge. By 2040, about two third of the population of these catchments will be city dwellers!

- **<u>living standards</u>** are very complementary to the population growth projections in the sense that they have a direct effect on the average per capita daily water demand / consumption and an indirect effect through increased consumption of other goods and services. Previous growth of livings standards in Rwanda can be gained from a further NISR[3] report that provides statistical information on levels of poverty (i.e. consumption poverty), levels of extreme poverty (i.e. lack of basic necessities) and the evolution of inequality based on EICV surveys in 2000/01, 2005/06 and 1010/11.

Table 14: Evolution of poverty in Rwanda

Province	2000/01	2005/06	2010/11
Kigali City	22.7%	20.8%	16.8%
Southern Province	65.5%	66.7%	56.5%
Western Province	62.3%	60.4%	48.4%
Northern Province	64.2%	60.5%	42.8%
Eastern Province	59.3%	52.1%	42.6%
Urban		28.5%	22.1%
Rural		61.9%	48.7%
Total	58.9%	56.7%	44.9%

[3] NISR - 2012: The evolution of poverty in Rwanda from 2000 to 2011: results from the household surveys (EICV).

Table 15: Evolution of extreme poverty in Rwanda

Province	2000/01	2005/06	2010/11
Kigali City	14.5%	12.9%	7.8%
Southern Province	44.7%	44.9%	31.1%
Western Province	40.4%	37.7%	27.4%
Northern Province	46.5%	39.1%	23.5%
Eastern Province	39.4%	29.9%	20.8%
Urban		16.0%	10.4%
Rural		39.5%	26.4%
Total	40.0%	35.8%	24.1%

Table 16: Evolution of inequality in Rwanda - based on Gini coefficient and 90th to 10th percentile method.

	2000/01	2005/06	2010/10
Kigali City	0.559	0.586	0.559
Southern Province	0.425	0.446	0.373
Western Province	0.445	0.492	0.395
Northern Province	0.457	0.431	0.438
Eastern Province	0.403	0.436	0.362
National	0.507	0.522	0.490
Ratio of 90th to 10th percentile	7.066	7.100	6.36

Source for Table 14, Table 15 and Table 16 *: NISR - 2012: The evolution of poverty in Rwanda from 2000 to 2011: results from the household surveys (EICV).*

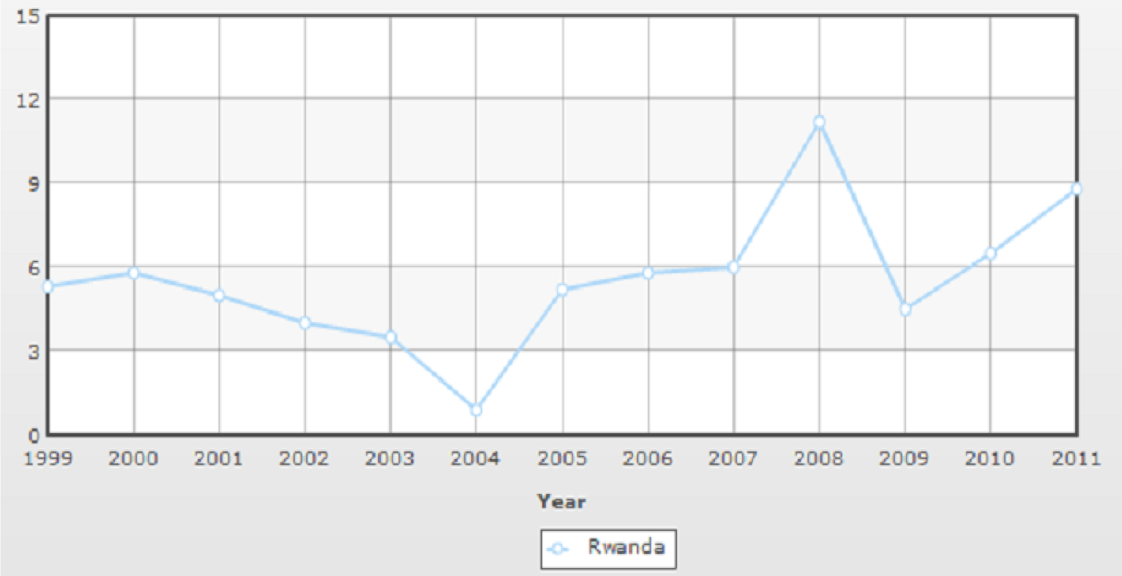
Whilst further details can be obtained in the referenced report, it is clear that Rwanda's strategies for poverty reduction are effective with significant reductions of poverty, extreme poverty and inequality especially over the period from 2005/6 to 2010/11. Although there is no guarantee that such past successes will continue unabatedly over the entire planning period of the NWRMP, this study on poverty and inequality reduction provide ample proof that a significant increase of living standards needs to be considered for especially the Water Supply and Sanitation sector through increased per capita daily water demand consumption.

The living standards are expected to increase over the entire duration of the Master Plan planning period.

- **economic development** is a major driver of additional water demand through the implementation of a number of commercial ventures that depend on water resources. The essential role of water in economic development is found either as a mostly consumptive component (e.g. potable water supply[4], irrigation sector, beer production, etc.) or as an indispensable process element (cooling water, energy, heat exchange, etc.) in a wide variety of production processes and further opportunities.

Rwanda has registered significant growth of its GDP over the past years (see Figure 8 below). Considering its status as a resources poor country with severe infrastructure limitations and extreme population density, this is quite a feat. In fact, Rwanda is highlighted in the IMF Regional Economic Outlook for Sub-Saharan Africa[5] as one in a group of six resources poor countries[6] that show significant economic growth over the past two decades. Although there is differentiation in growth 'engines' between these six countries, the common denominator for all is a comprehensive policy vision and strategic framework.

Figure 8: Annual GDP (real growth rate) for Rwanda from 1999 - 2011[7]



The Rwandan policy vision and strategic approach are defined in its 'Vision 2020' and the 'Economic Development and Poverty Reduction strategy 2013-2018' respectively. The principal thematic areas and priorities for EDPRS2 are listed in the table below (source: Economic Development and Poverty Reduction Strategy 2013 - 2018 - Shaping our Development - Government of Rwanda).

[4] It may be clear from the listing of potable water supply as an economic activity, that the boundaries between the three discussed drivers for water demand is not very strict; they tend to reinforce each other.

[5] IMF Regional Economic Outlook - Sub-Saharan Africa - Keeping the pace - October 2013

[6] Burkina Faso, Ethiopia, Mozambique, Rwanda, Tanzania, Uganda

[7] source: http://www.indexmundi.com/g/g.aspx?c=rw&v=66

Table 17: Summary of thematic areas and priorities for EDPRS2

Economic transformation for rapid growth	Rural Development	Productivity and youth employment creation	Accountable Governance
1. Increasing the domestic interconnectivity of the economy through investments in hard and soft infrastructure 2. Increasing the external connectivity of the economy and boosting exports 3. Transforming the private sector by increasing investment in priority sectors 4. Transform the economic geography of Rwanda by facilitating and managing urbanisation and promoting secondary cities as poles of economic growth 5. Pursuing a 'green economy' approach to economic transformation	1. Integrated approach to land use and rural settlements 2. Increasing the productivity of agriculture 3. Enabling graduation from extreme poverty. 4. Connecting rural communities to economic opportunity through improved infrastructure.	1. Improving skills and attitudes 2. Applying technology and ICT. 3. Enhancing entrepreneurship and business development 4. Improving labour market interventions	1. Strengthening citizen participation in delivery and demand for accountability 2. Service delivery

The principal growth sectors of this strategy are the agriculture sector (building on major export crops coffee, tea, horticulture) with a focus on irrigation and land husbandry, the construction sector (transport, housing, construction materials), mining sector (clean mining), industry sector (food processing and any further options in and around urban centers that help absorbing surplus labor force from rural areas), tourism, education, service sector (including finance industry), and energy sector (hydropower and other green energies). The private sector will be actively engaged in the realization of this strategy.

From this strategy it is clear that water for economic development is principally required for the agriculture sector and more precisely the irrigation sector. Demand for the hydropower sector is important yet almost entirely non consumptive so that their impact on water resources availability is none. Demand for the industry sector is currently minor and the above listed orientations do not foretell major forays in available water resources. However, if left without supervision, some industrial operators may significantly affect water resources quality even when their actual demand is limited at the scale of a catchment's water resources.

As regards irrigation water demand, the indications of the IMP (Irrigation Master Plan) will be adjusted in each catchment for the probable water resources availability minus demand from other categories. This means that a number of identified potential irrigation command areas cannot be realized and an optimization process should be implemented to pick the best options for actual development.

For the timing of water dependant economic development the approach is to implement as soon as possible.

The preceding reflection on the possible progression of principal water demand drivers (population, living standards and economic development) has led to the formulation of three demand growth scenarios (low, medium and high) combining population growth rates and improving standards of living that drive water demand for primary use, with development scenarios that require water demand for commercial ventures (for economic development and poverty reduction).

Where the national strategy aspires a combination of sustainable (in other words low) population growth with vigorous economic growth, this combination of demand drivers tends to offset their respective impacts resulting in converging water demand scenarios. In order to prevent this the low, medium and high water demand scenarios have been set up as follows:

- low water demand growth scenario: a combination of low population growth with modestly paced economic development (
- medium demand growth scenario: a combination of average population growth and economic development
- high demand growth scenario: a combination of high population growth with vigorous economic development.

For details on the consumptive demand projections under these three scenarios, the reader is referred to the already mentioned chapter 4.4. of the Exploratory Phase Report. Details on the population growth projections and the urban rural division are provided in annex C2_1_2 of the Exploratory Phase report.

The principal assumptions for water demand for the different demand categories over the planning period are summarized here below.

- Consumptive demand for urban water supply

  Consumptive demand for urban water supply is based on the population growth data for 2012, 2020, 2030, and 2040 for three scenarios (low, medium and high growth) and a division between urban and rural population of respectively 20, 30, 38 and 46 % urban population for those time horizons. Details of the projections of these population data are presented in the report in annex to the Exploratory Phase Report.

  Following gradually improving living standards, the per capita water demand for potable water supply of the urban population (in l/person/day) during the lifetime of the Master Plan is assumed to be as follows:

2012	*2020*	*2030*	*2040*
60	70	80	100

  Demand is assumed entirely consumptive and evenly distributed throughout the year.

- For the purpose of the Masterplan (investment and operation of WTP), collective treatment of waste water from urban water supply is foreseen at the following percentage rates:

2012	*2020*	*2030*	*2040*
0%	10%	30%	50%

- Consumptive demand for rural water supply

  Consumptive demand for this use group is complementary to the urban demand with the same projections and distribution over the level 1 and 2 catchments.

  Following gradually improving living standards, the per capita water demand over the life time of the master plan is initially different but gradually converges between rural and urban population as presented in the following table:

2012	*2020*	*2030*	*2040*
40	60	80	100

  Demand is assumed entirely consumptive and evenly distributed throughout the year.

  Collective waste water treatment is not considered necessary over the life time of the master plan.

- Consumptive demand for environmental water use

  The consumptive demand for this use sector is de facto zero. However, a minimum flow of about one third of the surface flow should remain available on a monthly basis. This will be duly considered in the next chapter on the water balance.

- Consumptive demand for industrial water use

  Lacking any workable information on consumptive water use from industrial units, an industrial water demand per population head in l/cap/day has been applied for different growth scenarios as follows:

scenario	*2012*	*2020*	*2030*	*2040*
low	2	3	5	8
medium	2	4	7	15
high	2	5	10	20

  Demand is assumed entirely consumptive and evenly distributed during the year.

  The initial demand (2 l/cap/day) reflects the assessment that current supply for industrial use is essentially included in the water supply statistics of EWSA, that the demand for a number of industrial uses are developed separately (non hydropower energy, coffee washing stations, etc.). and that the level of industrial production in Rwanda is very low. The growth projections between the scenarios (factor 4 versus factor 10 demand increase) is impossible to substantiate. The safest approach here is to start monitoring the major industrial users with EWSA or exclusive supply through the Water MIS and adjust the demand growth projections if ever they proof to be very insufficient.

Heat exchange based power generation (non hydro / solar)

Separate from this demand for industrial processes, the government policy for the energy sector foresees a very substantial increase of power production from hydropower and other means. As these other means are generally based on heat exchange (whether methane gas (300 MW in Kivu), geothermal (310 MW in Rusizi and Mukungwa), diesel generation (diesel or HFO, current 47 MW installed capacity plus 20 MW additional located in lower Nyabarongo) or peat (capacity not listed, opportunities in Rusizi, Akanyaru)). A list of existing and potential (non hydro / solar based) power generation installations is presented in annex to the Exploratory Phase Report.

For the current and potential installations it is assumed that operation time is 90% and that the water demand is 2 000 m³/GWh generated which is assumed entirely consumptive and evenly distributed over the year.

Current production capacity (of diesel and HFO based production) is considered for 2012, while the full additional production capacity is considered for 2020 remaining constant thereafter.

Coffee washing stations

Another group that we could identify with specific demand is for coffee washing stations. These stations operate essentially during the months of March, April and sometimes early May and require natural waters which are mostly obtained from natural springs which are developed for this specific purpose. The table below gives the actual and potential water consumption from the installed coffee washing machines to which we have added a suggested annual demand for future years 2020, 2030 and 2040 at 90% of potential capacity unless actual consumption is higher. We assume all water to be consumptive with abstraction of 40% in March, 40% in April and 20% in May. Total demand is not very important on the scale of the Master Plan.

Level 1 basin code	Actual consumption ['000 m³/annum]	Potential consumption ['000 m³/annum]	Future consumption ['000 m³/annum
CKIV	27.216	41.620	37.5
CRUS	10.584	10.080	10.0
NNYU	3.961	8.320	7.5
NMUK	0.084	0.940	0.9
NNYL	10.790	22.280	20.1
NAKN	5.054	10.480	9.5
NAKU	7.486	10.010	9.0
NAKL	1.461	1.940	1.8
NMUV	0.102	0.300	0.3

- Consumptive demand for mining and quarries

Also for mining and quarries there is no workable information available. In line with the demand from the industrial use group, we suggest the following demand projections:

scenario	*2012*	*2020*	*2030*	*2040*
low	1	2	3	4
medium	1	2	4	7
high	1	3	5	10

Demand is assumed entirely consumptive and evenly distributed during the year.

The initial demand (1 l/cap/day) is a mere token water use and reflects the observation that current water supply for mining is an entirely unregistered recirculation of surface water, or even a 'negative' use when extracting excess water from mines. The growth projections between the scenarios (factor 4 versus factor 10 demand increase) is impossible to substantiate. The safest approach here is to start monitoring the major industrial users with EWSA or exclusive supply through the Water MIS and adjust the demand growth projections if ever they proof to be very insufficient.

- Consumptive demand for livestock

Demand for livestock is based on the number of cattle per catchment. The table below indicates the daily water consumption for the different kind of cattle commonly raised in Rwanda.

Cattle type	*Assumed daily water demand [l/head/day]*	*Number of cow equivalent*
Cow - local	20	1
Cow - improved - milk	50	2.5
Goat	8	0.4
Sheep	8	0.4
Swine	15	0.75
Chicken / Rabbit	0.5	0.025

Although the records of the number of cattle per administrative unit are notoriously imprecise (fear for taxation, jealousy, ...), we have used the records at district level and converted them to animals per catchment and then the animals to 'cow equivalents' (see table above).

Water demand is entirely consumptive and considered evenly distributed over the year.

As we couldn't obtain data on the number of cows of improved race for milk production, we assume for 2012 that some 10 % of the bovines is of improved race and requires effectively 50 l/head/day.

Considering the availability of grazing and fodder land and the limits of the carrying capacity of such land (~1.2 cow/ha), we assume that the number of cattle remains more or less constant over the life time of the Master Plan. There is however an increase in the ratio of improved milk cows over total cow population as follows:

% bovine type	2012	2020	2030	2040
Cow - improved - milk	10	25	40	55
Cow - local	90	75	60	45

- Consumptive demand for rain dependant agriculture

This water use is considered integral part of the natural hydrological cycle and does not qualify as 'consumptive' water demand over the full time horizon of the Masterplan (2012 - 2040).

- Consumptive demand for irrigated agriculture

  The consumptive demand per hectare for the irrigation methods commonly applied in Rwanda is based on the same assumptions as presented for water use for irrigated agriculture (see preceding paragraph 1.7.1; more details are available in the Exploratory Phase Report).

  The demand for irrigation is considered entirely consumptive with the distribution over the year concentrated during the dry season (at a minimum 50% of annual demand). Further details are indicated in chapter 4.3.1 of the Exploratory Phase Report under the bullet '*Water use for irrigated agriculture'*.

- Consumptive demand for hydropower generation

  Irrespective of the actual realization of potential hydropower projects, the consumptive demand for this use sector is and remains zero.

- Consumptive demand for fisheries

  Consumptive demand for fisheries in natural water bodies (mostly lakes) as well as in artificial ones (irrigation reservoirs) is considered zero throughout the Master Plan lifetime.

  For fish in basins a consumptive demand in thousands of cubic meters per month per hectare is considered as follows (consumptive demand in 1 000 m³/month/ha pond):

oct	*nov*	*dec*	*jan*	*feb*	*mar*	*apr*	*may*	*jun*	*jul*	*aug*	*sep*
1.0	1.0	1.0	2.0	1.0	0.5	0.5	1.0	2.0	2.0	2.0	1.0

  This is based on a water demand of 7 mm/day (evaporation and seepage) during 365 days, about 1 000 mm of rainfall or an annual demand of 1 500 mm/year or 15 000 m³/ha/year.

  The demand for 2012 is based on the actually exploited pond areas as given by the PAIGELAC project (104 ha).

  For the potential situation as regards fisheries in ponds we suggest 2% of the potential irrigation domain in marshlands. After reaching 0.5% in 2020 (1 100 ha) and 1% in 2030 (2 200 ha) , the potential of 2 % (4 400 ha) will be attained in 2040.

- Consumptive demand for recreational purposes

  Notwithstanding that this demand may require occasional flow regulation for adjustment of water levels, consumptive water demand for this use is rated zero over the full time horizon of the Master Plan (2012 - 2040)

- Consumptive demand for navigation / transport

  Notwithstanding that this demand may require occasional flow regulation for adjustment of water levels, consumptive water demand for this use is rated zero over the full time horizon of the Master Plan (2012 - 2040)

- Consumptive demand for reserved areas and eco-tourism

  This water use is considered integral part of the natural hydrological cycle and does not qualify as 'consumptive' water demand over the full time horizon of the Masterplan (2012 - 2040).

Details of the unadjusted water demand projections are presented in chapters 3.3.1. of each of the nine Catchment Master Plans presented in appendixes 01 up to 09. Based on this unadjusted demand, the unadjusted water balance is reproduced from the exploratory phase report in chapters 3.3.2. of the nine Catchment Master Plans. The main conclusions for each of the nine catchments is presented in the paragraphs below.

1.7.2.1 MAIN OBSERVATIONS ON WATER USE AND THE UNADJUSTED DEMAND AND WATER BALANCE FOR CKIV

Current registered demand is insignificant with less than 1% of the annually renewable resources which stand at almost 900 MCM/yr.

Under full development by 2040 the main demand categories are expected to be:

- with a demand of 124 MCM/yr, irrigation from surface water stands at 14% of the renewable resource. It is noted that this irrigation demand is foreseen to be provided from Lake Kivu waters which are alkaline (pH 9) and less suitable for irrigation. The large scale development of this resource for this purpose as proposed in the RIMP, may be questioned. Further irrigation demand from dam, marshland development and rainwater harvesting may raise water demand to about 150 MCM/yr or about 17% of the renewable resources.
- rural drinking water supply may reach a demand of almost 80 MCM per year or 9% of the renewable resources. Urban water supply reaches almost half the rural demand to claim 4% of the renewable resources.
- water supply for industries and mining may reach 23 and 11.5 MCM/yr to claim together less than 4% of the renewable resource.
- while important for economic development, other demand categories (coffee washing stations, livestock, fishponds, hydropower, other power, etc.) present only marginal demand (10 MCM or about 1 ‰).

In terms of its unadjusted water balance, the Lake Kivu catchment seems to have ample resources overall at a monthly time interval for the unadjusted projected demand up to the 2040 all demand scenarios (low medium and high). It is only at this planning horizon and under the assumption of a once in twenty year dry year, that the environmental flow criterion is partially compromised during the months of January and June, July and August.

The overall water demand is scheduled to reach about 35% of the average renewable resource (313 over 898 MCM). Apart from the issue of water quality suitability for irrigation, or otherwise less realistic or feasible ventures, there seems little need to adjust water demand from a water balance point of view.

1.7.2.2 MAIN OBSERVATIONS ON WATER USE AND THE UNADJUSTED DEMAND AND WATER BALANCE FOR CRUS

Current registered demand is insignificant with less than 1% of the annually renewable resources which stand at almost 432 MCM/yr.

Under full development by 2040 the main demand categories are expected to be:

- rural drinking water supply may reach a demand of almost 20 MCM per year or almost 5% of the renewable resources. Urban water supply requires about a third of the rural demand to claim 1.5 % of the renewable resources.
- with a demand of about 8 MCM/yr, irrigation in marshland remains under 2 % of the renewable resource. There is a slight increase from irrigation from rainwater harvesting and dam sites. Opportunities for the development of irrigation from surface water and from groundwater resources have not been identified.
- water supply for industries and mining is expected to reach 8 MCM/yr to claim together less than 2% of the renewable resource.
- while important for economic development, other demand categories (coffee washing stations, livestock, fishponds, hydropower, other power, etc.) present only marginal demand (under 3 MCM/year or less than 1 %).

In terms of its unadjusted water balance, the Rusizi catchment seems to have ample resources overall at a monthly time interval for the unadjusted projected demand up to the 2040 all demand scenarios (low medium and high). It is only at this planning horizon and under the assumption of a once in twenty year dry year, that the environmental flow criterion is partially compromised during the months of April and July and September.

The overall water demand is scheduled to reach about 10% of the average renewable resource (46 over 432 MCM/year). For reasons of correction of the water balance, there seems little need to adjust water demand.

1.7.2.3 MAIN OBSERVATIONS ON WATER USE AND THE UNADJUSTED DEMAND AND WATER BALANCE FOR NNYU

Current registered demand is insignificant with less than 1% of the annually renewable resources which stand at almost 1.290 MCM/yr.

Under full development by 2040 the main demand categories are expected to be:

- the combined irrigation sector demand for this catchment stands at about 190 MCM/yr which represents about 15% of the average renewable resource and more than half of the potential water demand.
- with a demand of 78 MCM/year rural drinking water supply claims about 6% of the resource which reaches about 9% (120 MCM/year) in combination with urban water demand.
- water supply for industries and mining is expected to reach 36 MCM/yr to claim together less than 3% of the renewable resource.
- while important for economic development, other demand categories (coffee washing stations, livestock, fishponds, hydropower, etc.) present rather insignificant demand in

comparison with the catchment's renewable resources (under 12 MCM/year or less than 1 %).

In terms of its unadjusted water balance, the Upper Nyabarongo catchment seems to have ample resources overall at a monthly time interval for the unadjusted projected demand up to the 2040 all demand scenarios (low medium and high). It is only at this planning horizon and under the assumption of a once in twenty year dry year, that the environmental flow criterion is partially compromised during the months of June up to September.

The overall water demand is scheduled to reach about 28% of the average renewable resource (356 over 1,290 MCM/year). For reasons of correction of the water balance, there seems little need to adjust water demand.

1.7.2.4 MAIN OBSERVATIONS ON WATER USE AND THE UNADJUSTED DEMAND AND WATER BALANCE FOR NMUK

Current registered demand is insignificant with less than 0.5 % of the annually renewable resources which stand at almost 905 MCM/yr.

Under full development by 2040 the main demand categories are expected to be:

- rural drinking water supply may reach a demand of almost 60 MCM per year or some 6% of the renewable resources. With a demand of 43 MCM/year urban water supply is also significant and the two categories combined claim about 11% of the renewable resources.
- water supply for industries and mining may reach about 30 MCM/year which represents about 3% of the renewable resource.
- irrigation demand is relatively insignificant with just 13 MCM/year or about 1.5% of the renewable resource. Irrigation of marshland is the largest category.
- other demand categories (coffee washing stations, livestock, fishponds, hydropower, other power, etc.) present only marginal demand (under 7 MCM/year or less than 1 %) but are important for economic development opportunities.

In terms of its unadjusted water balance, the Mukungwa catchment seems to have ample resources overall at a monthly time interval for the unadjusted projected demand under all conditions.

The overall water demand is scheduled to reach about 17 % of the average renewable resource (152 over 905 MCM/year). For reasons of correction of the water balance, there seems little need to adjust water demand.

1.7.2.5 MAIN OBSERVATIONS ON WATER USE AND THE UNADJUSTED DEMAND AND WATER BALANCE FOR NNYL

Current registered demand in the lower Nyabarongo catchment is rather insignificant reaching just over 2% of the annually renewable resources which stand at almost 899 MCM/yr.

Under full development by 2040 the main demand categories are expected to be:

- the combined irrigation sector demand for this catchment is rather extreme with a demand of 170 MCM/year from surface water irrigation, almost 110 MCM/year from groundwater irrigation, 60 MCM/year due to marshland development and almost 25 MCM/year from the development of storage reservoirs. The total demand is about 370 MCM/year which represents about 41% of the average renewable resources.
- urban water demand is important with a maximum demand of 113 MCM/year which may be complemented by rural water supply to the tune of 60 MCM/year for a total demand of 173 MCM/year or some 19% of the renewable resource.
- water supply for industries and mining is expected to reach 52 MCM/yr to claim together some 6% of the renewable resource.
- other demand categories (coffee washing stations, livestock, fishponds, hydropower, other power, etc.) present limited demand (under 15 MCM/year or close to 2 %) but are economically important.

In terms of its unadjusted water balance which is based on an implementation rate of the development opportunities at about a third per decade (2014-2020, 2021-2030, 2031-2040), the Lower Nyabarongo catchment is bound to come under stress from 2030 onwards. For the 2040 planning situation (full development), the water balance indicates that demand during some months of the dry season cannot even be satisfied under the assumption of a once in twenty year wet year. This may be attributed to the unbridled development of the irrigation sector which requires important resources during the least favorable time (dry season).

The overall water demand is scheduled to reach about 68% of the average renewable resource (607 over 899 MCM/year). It is absolutely imperative that the different water demand categories are examined with the intend to obtain a workable water balance for this catchment.

1.7.2.6 MAIN OBSERVATIONS ON WATER USE AND THE UNADJUSTED DEMAND AND WATER BALANCE FOR NAKN

Standing at about 4% of the annually renewable resources which reach almost 800 MCM/yr (798 MCM/yr), current registered demand is modest.

Under full development by 2040 the main demand categories are expected to be:

- the combined irrigation sector demand for this catchment is rather extreme with a demand of 195 MCM/year from surface water irrigation, almost 120 MCM/year from marshland irrigation, 38 MCM/year from the development of surface water storage reservoirs and 17 MCM/year from ground water resources. The total demand is about 370 MCM/year which represents about 46% of the average renewable resources.
- rural water demand is scheduled to reach 64 MCM/year which may be complemented by urban water supply to the tune of 48 MCM/year for a total demand of 112 MCM/year or some 14% of the renewable resource.
- water supply for industries and mining is expected to reach 34 MCM/yr to claim together some 4% of the renewable resource.
- With 18 MCM/year, the demand from fishponds becomes somewhat significant at about 2% of the average renewable resource.

- other demand categories (coffee washing stations, livestock, hydropower, other power, etc.) present limited demand (under 15 MCM/year or close to 2 %) but are significant for economic development.

In terms of its unadjusted water balance which is based on an implementation rate of the development opportunities at about a third per decade (2014-2020, 2021-2030, 2031-2040), the Akanyaru catchment is bound to come under stress from 2020 onwards. For 2030 the situation becomes difficult whereas for the 2040 planning situation (full development), the water balance indicates that demand during some months of the dry season cannot even be satisfied under the assumption of a once in twenty year wet year. This may be attributed to the unbridled development of the irrigation sector which requires important resources during the least favorable time (dry season).

The overall water demand is scheduled to reach about 68% of the average renewable resource (541 over 798 MCM/year). It is absolutely imperative that the different water demand categories are examined with the intend to obtain a workable water balance for this catchment.

1.7.2.7 MAIN OBSERVATIONS ON WATER USE AND THE UNADJUSTED DEMAND AND WATER BALANCE FOR NAKU

Standing at about 5% of the annually renewable resources which reach some 500 MCM/yr (504 MCM/yr), current registered demand is modest.

Under full development by 2040 the main demand categories are expected to be:

- the combined irrigation sector demand for this catchment is rather extreme with a demand of 407 MCM/year from surface water irrigation, 72 MCM/year from marshland irrigation and 48 MCM/year from the development of surface water storage reservoirs. The total demand is about 458 MCM/year which represents about 92% of the average renewable resources.
- urban water demand is scheduled to reach 54 MCM/year which may be complemented by demand from urban water supply at a rate of 35 MCM/year for a total demand of 89 MCM/year or some 18 % of the renewable resource.
- water supply for industries and mining is expected to reach 27 MCM/yr to claim combined some 5 % of the renewable resource.
- With 11 MCM/year, the demand from fishponds becomes somewhat significant at about 2% of the average renewable resource.
- other demand categories (coffee washing stations, livestock, etc.) present limited demand (under 3 MCM/year or less than 1 %) but are significant for economic development.

In terms of its unadjusted water balance which is based on an implementation rate of the development opportunities at about a third per decade (2014-2020, 2021-2030, 2031-2040), the upper Akagera catchment is bound to come under stress from 2020 onwards. Already by 2030 the situation becomes very difficult whereas for the 2040 planning situation (full development), the water balance is completely unmanageable unless external resources are mobilized. The unmanageable water balance is largely due to the unbridled development of the irrigation sector which requires important resources during the least favorable time (dry season).

The (unadjusted) overall water demand is scheduled to reach about 130% of the average renewable resource (657 over 504 MCM/year). It is absolutely imperative that the different water demand categories are examined with the intend to obtain a workable water balance for this catchment. There may further be need to mobilize external resources.

1.7.2.8 MAIN OBSERVATIONS ON WATER USE AND THE UNADJUSTED DEMAND AND WATER BALANCE FOR NAKL

Current registered demand is very modes claiming just 1% of the annually renewable resources which stand at 907 MCM/yr.

Under full development by 2040 the main demand categories are expected to be:

- the combined irrigation sector demand for this catchment is very important with a demand of 263 MCM/year from surface water irrigation, 65 MCM/year from marshland irrigation, 68 MCM/year from groundwater irrigation and 12 MCM/year from the development of surface water storage reservoirs. The total demand is about 410 MCM/year which represents about 45% of the average renewable resources.
- rural water demand is scheduled to reach 25 MCM/year which may be complemented by demand from urban water supply at a rate of 17 MCM/year for a total demand of 42 MCM/year or some 5 % of the renewable resource.
- water supply for industries and mining is expected not to exceed 12 MCM/yr which represents just 1% of the renewable resource.
- demand from fish ponds is foreseen at a maximum 11 MCM/year; this demand becomes somewhat significant at about 1% of the average renewable resource.
- other demand categories (mainly livestock) present limited demand (under 3 MCM/year or some 3 ‰) but they are significant drivers for economic development.

In terms of its unadjusted water balance which is based on an implementation rate of the development opportunities at about a third per decade (2014-2020, 2021-2030, 2031-2040), the lower Akagera catchment is bound to undergo some limited stress during drier years from 2030 onwards. By 2040 the water supply situation becomes difficult at the end of the dry season for all but the wettest years (once in twenty years wet or better) whence rationing or other measures will be required.

The overall water demand is scheduled to reach about 53% of the average renewable resource (477 over 907 MCM/year). It is imperative that especially the irrigation sector demand be examined with the intend to secure a viable water balance for this catchment up to 2040. It is possible to mobilize external resources.

1.7.2.9 MAIN OBSERVATIONS ON WATER USE AND THE UNADJUSTED DEMAND AND WATER BALANCE FOR NMUV

Standing at about 5 to 6% of the annually renewable resources which reach only 193 MCM/year, current registered demand is modest.

Under full development by 2040 the main demand categories are expected to be:

- the combined irrigation sector demand for this catchment is important with a demand of 81 MCM/year from surface water irrigation, 51 MCM/year from marshland irrigation and about 11 MCM/year from the development of surface water storage reservoirs. The total demand is about 145 MCM/year which represents 75% of the average renewable resources.
- rural water demand is scheduled to reach 30 MCM/year which may be complemented by demand from urban water supply at a rate of 17 MCM/year for a total demand of 47 MCM/year or some 24 % of the renewable resource.
- water supply for industries and mining is expected not to attain a maximum level of 14 MCM/yr which represents nonetheless 7% of the renewable resource.
- demand from fish ponds may reach 8 MCM/year, this demand is significant at about 4% of the average renewable resource.
- other demand categories (mainly livestock, with some smaller hydropower sites in the NMUV_1 sub catchment - Gicumbi district) present limited demand (about 2 MCM/year or some 1 %) but they are significant drivers for economic development.

In terms of its unadjusted water balance which is based on an implementation rate of the development opportunities at about a third per decade (2014-2020, 2021-2030, 2031-2040), the Muvumba catchment already encounters limited stress during during the dry season for drier years. By 2020, environmental flow requirements will be routinely compromised during both the dry and wet season, by 2030 the water supply situation will be very difficult to manage, while by 2040 it will be impossible to correctly manage the water demand during most of the year for any hydrological year. With a potential demand at 75% of the average renewable resources, the irrigation sector is the main cause for this condition.

The overall water demand is scheduled to reach about 112% of the average renewable resource (216 over 193 MCM/year). It is imperative that especially the irrigation sector demand be examined with the intend to secure a viable water balance for this catchment up to 2040. The mobilization of external resources (interbasin transfer), is not very evident and most of the catchment is located outside of Rwanda (2 146 km² of the catchment is located in Uganda against 1 568 km² in Rwanda) with rather complex flow patterns.

1.7.2.10 SUMMARY OF WATER USE AND THE UNADJUSTED DEMAND AND WATER BALANCE FOR NNYL

Current water use is moderate or even insignificant for each of the nine identified catchments of Rwanda.

As regards the unadjusted water balances, the Muvumba (NMUV) and Akanyaru (NAKN) catchments show signs of imminent water stress conditions. Both of these catchments are headwaters so a interbasin transfer is not an obvious solution to complement resources.

When considering the circumstance that the Rubyiro catchment in Rusizi level 1 catchment (CRUS) generates about one third of the catchment resources but caters for almost all demand, this sub area (level 2 catchment CRUS_1) may also be put forward for special consideration. The required level of detail for such investigation is not envisaged under this national water resources Master Plan study.

The situation in the lower Nyabarongo (NNYL) and the upper and lower Akagera (NAKU and NAKL respectively) catchments, is less pressing but it is unmistakable that water supply problems will arise prior to 2040 if and when all envisaged development activities are implemented without further consideration. It is in principle possible to complement the resources of these catchments by means of a transfer from upstream catchments (interbasin transfer) with surplus resources.

The Upper Nyabarongo (NNYU) and Mukungwa (NMUK) catchments have abundant resources and constitute a true water tower for the entire Nile basin in Rwanda providing resources for future interbasin transfers backed by, especially for the upper Nyabarongo, major groundwater reserves. A similar condition is encountered for the Lake Kivu catchment (CKIV) where renewable resources exceed water demand up to 2040. This is also the case for the CRUS catchment with the exception for the particular conditions in the CRUS_1 subcatchment (Rubyiro river).

It should be mentioned that an analysis at level 1 catchment that reveals little or no stress condition, does not preclude possible stress conditions at specific locations and at specific times in smaller tributaries of the level 1 catchment.

1.7.3 ADJUSTED DEMAND ASSESSMENT OF LEVEL 1 CATCHMENT

The unadjusted demand discussed in the previous section (paragraph 1.7.2 and subparagraphs) is based on a set of assumptions which may present slight alterations as per the region (from East to West), but these assumptions are then applied without much consideration for catchment specific conditions including resources availability. This approach has proven very useful because it directly indicates which catchments are likely to encounter water supply difficulties sometime during the planning period of the Master Plan. The results have been presented in the preceding paragraph.

Based on this identification of possible stress conditions, the objective of this section is to 'resolve' the identified stress condition. This resolutions follows a logical process as follows:

- The first question to address is whether all projected demand is relevant and feasible? The demand in the group of primary use (urban and rural water supply, livestock to some extent) will only be curtailed when absolutely necessary. In the group of industrial demand it doesn't make sense to curtail a demand that is not very important in terms of quantity of water but which is known to contribute significantly to the national economy (e.g. coffee washing stations, other power, livestock, etc.). However, when resources are limited, it may be considered to adopt a strategy to refer new water intense industries (or even transfer existing industries) to other catchments that have a better balance between resources and demand. In the group of irrigation demand a number of development options has been identified as less likely to be financially and economically feasible. This specifically relates to hill side irrigation requiring significant lift from the water source to the irrigation command area. For this purpose, the lake and river command areas identified in the RIMP have been divided in four groups according to the required lift up to 25, from 25 - 50, from 50 to 100 and finally above 100 m lift (see annex C2_3_4 for details). It is not necessarily required that a command area requiring a lift above 100 m is not feasible but the exploitation costs rise to a level which imposes a very high exploitation standard which is unlikely to be easily obtained at a large scale.

It is also recommended to verify if the water allocation per demand category is correct; if not adjustments (increase or decrease of allocation per person, hectare, other driver) need to be made. Please note that the Master Plan operates at a larger scale and the allocation per demand category needs to be a representative value that is preferably not underestimated. The 'precision' of the allocation estimate is especially important for larger demand categories and in fact rather unimportant for smaller demand categories. The precision also refers to the time of the year when the allocation is likely to take place.

- The next step is to verify if catchment resources are generally sufficient to cater for the confirmed projected demand throughout the year up to the conclusion of the Master Plan planning period. If such is the case the implementation schedule of especially the commercial demand can be checked. If resources are available it makes sense to implement the feasible commercial opportunities as early as possible.
- if the catchment resources are not sufficient to cater for the projected demand there are a number of options:
  - curtailing on feasible demand. There are many possibilities; not developing a profitable commercial venture, developing a commercial venture which will not be fully supplied under more or less exceptional conditions (e.g. partial supply during part of the year occurring once in ten years); introducing allocation rules for water supply between primary and commercial use, applying demand management principles, etc.
  - regulation of catchment (surface water) resources. This applies typically to the development of surface water storage by means of larger dams that allow to carry water over from the wet season months to the following dry season months. When suitable conditions are available it is also possible to recharge groundwater reservoirs for later use.
  - reuse of used water. This may vary from very simple reuse of irrigation drainage waters to much more sophisticated collection, treatment and redistribution of urban water supply for any appropriate use either as an exclusive or complementary sources of water supply
  - transfer of resources from a lateral or upstream catchment. Again this may involve a very simple release of (stored) water through a natural river to be captured downstream, or capital intensive piped conveyance system possibly involving tunneling, pumping stations, etc.

  Depending on the situation of the catchment with respect to the ecological and environmental consequences of temporary stress conditions (limited, reversible temporary impact), the economic and social viability of occasional non- or limited supply to primary use and commercial water use ventures, the investment and operational costs of additional resources development works (resources regulation, reuse, transfer, etc.), and in general the water resources management skills that can be called upon, a blend of the above indicated solutions may be proposed.

The findings for this verification and adjustment process for each catchment are presented in the following subparagraphs.

1.7.3.1 ADJUSTED DEMAND AND WATER BALANCE FOR CKIV

Details of the demand analysis for the CKIV catchment are given in paragraph 3.3.3. of the Catchment Master Plan for the Lake Kivu catchment (appendix 01CKIV).

From paragraph 1.7.2.1 it is clear that the water balance of the catchment does not impose adjustment of the different demand categories.

Consequently, all demand for potable water supply, sanitation, industries, mining, livestock, fisheries, hydropower, non consumptive and other energy demand was reviewed and thereupon maintained as is. There are however a number of changes in the irrigation sector found necessary as follows:

- irrigation by means of rainwater harvesting ponds: increased demand (double from Exploratory phase report estimate) due to presumed higher intensity use of same number of ponds (from 1 000 m³/yr to 2 000 m³/yr)
- irrigation by means of marshland development: because of the interesting performance and reduced investment and operational costs of this method, the full development potential as identified in the RIMP has been put forward for development during the first stage of the Master Plan, the period prior to 2020. The per hectare water demand for this method (2 000 m³/ha/yr) has not been changed. The annual and monthly demand for 2020 and 2030 have been increased to the level initially foreseen for 2040. The 2040 water demand has not been changed.
- irrigation from surface water sources: this irrigation method is expensive in investment and exploitation costs; the latter especially when irrigating land at higher level from the water source level. For this reason, the 20 000 + ha foreseen in the RIMP report has been separated in 4 altitude classes and only the lower 2 altitude classes (0-25 and 25-50 m lift from source level) for a total of 6 100 ha command area, have been considered for gradual development during the lifetime of the Master Plan. The per hectare water demand for this method (6 000 m³/ha/yr) has not been changed. This resulted in a very substantial demand reduction from 124 MCM/year to 37 MCM/year. There is an issue with the alkaline water quality of Lake Kivu water which seems not very suitable for irrigation.
- irrigation with surface water storage reservoirs: this irrigation method is very expensive in investment cost (dam development and irrigation command area) and an effort has been made to assess the viability of the different sites identified in the RIMP. Out of 11 identified sites 4 have been judged as sufficiently interesting in terms of site configuration and storage volume. The water demand from this irrigation method was initially based on command area (assuming that storage was sufficient). The update of the demand (which comprises multipurpose use) has given the same results (from 17.1 MCM/year to 17.6 MCM/year).

The adjusted water balance for the CKIV catchment is presented in the table below.

Table 18: <u>Adjusted</u> water balance CKIV 2012 - 2020 - 2030 - 2040.

volume data in '000 m³	annual total	oct	nov	dec	jan	feb	mar	apr	mai	jun	jul	aug	sep
$Rs_{5\%}$	1,417,336	83,101	81,156	84,013	82,855	128,614	117,495	156,967	130,919	117,975	156,485	164,763	112,992
$Rs_{35\%}$	895,407	72,544	71,553	71,675	62,498	78,047	78,185	96,092	92,687	74,746	67,442	66,545	63,393
$Rs_{50\%}$	810,129	64,543	67,339	62,048	58,089	70,341	72,761	85,407	83,324	65,669	59,102	61,504	60,003
$Rs_{65\%}$	762,033	59,982	61,875	59,614	56,590	64,768	69,613	75,506	78,760	63,128	56,980	56,640	58,577
$Rs_{95\%}$	633,986	51,828	57,346	50,777	50,931	52,479	50,229	64,280	60,631	51,807	48,458	47,734	47,486
gr.w.$_{50\%}$	606,250	51,679	52,360	50,777	50,931	51,612	50,229	51,612	53,108	51,612	48,458	47,498	46,376
Dem 2012	28,189	2,308	2,308	2,308	2,317	2,308	2,314	2,314	2,313	2,427	2,427	2,427	2,418
Surpl @ $_{95\%}$	605,797	49,520	55,038	48,469	48,614	50,171	47,915	61,966	58,318	49,380	46,031	45,307	45,068
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%
Dem 2020-low	74,693	5,330	5,330	6,085	7,618	6,085	4,579	4,579	4,582	8,066	7,952	7,952	6,534
Surpl @ $_{95\%}$	559,294	46,498	52,016	44,692	43,313	46,393	45,650	59,702	56,049	43,741	40,506	39,782	40,952
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%
Dem 2020-med	77,816	5,590	5,590	6,346	7,878	6,346	4,839	4,839	4,843	8,326	8,212	8,212	6,794
Surpl @ $_{95\%}$	556,170	46,237	51,755	44,431	43,053	46,133	45,390	59,441	55,788	43,481	40,246	39,522	40,692
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%
Dem 2020-	80,012	5,774	5,774	6,529	8,061	6,529	5,022	5,022	5,026	8,509	8,395	8,395	6,977
Surpl @ $_{95\%}$	553,974	46,054	51,572	44,248	42,870	45,950	45,207	59,258	55,605	43,298	40,063	39,339	40,509
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%
Dem 2030-low	122,465	8,408	8,408	9,900	12,925	9,900	6,911	6,911	6,924	13,944	13,658	13,658	10,919
Surpl @ $_{95\%}$	511,521	43,420	48,938	40,877	38,006	42,579	43,319	57,370	53,707	37,863	34,800	34,076	36,567
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%
Dem 2030-med	132,713	9,262	9,262	10,754	13,779	10,754	7,765	7,765	7,778	14,798	14,512	14,512	11,773
Surpl @ $_{95\%}$	501,274	42,566	48,084	40,023	37,152	41,725	42,465	56,516	52,853	37,009	33,946	33,222	35,714
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%
Dem 2030-	140,918	9,946	9,946	11,438	14,463	11,438	8,448	8,448	8,462	15,482	15,196	15,196	12,456
Surpl @ $_{95\%}$	493,068	41,882	47,400	39,339	36,468	41,041	41,781	55,832	52,169	36,325	33,262	32,538	35,030
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%
Dem 2040-low	175,435	11,735	11,735	13,993	18,593	13,993	9,450	9,450	9,484	20,630	20,172	20,172	16,030
Surpl @ $_{95\%}$	458,551	40,093	45,611	36,784	32,338	38,486	40,780	54,831	51,147	31,177	28,286	27,562	31,456
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%
Dem 2040-med	203,308	14,057	14,057	16,316	20,915	16,316	11,772	11,772	11,806	22,953	22,495	22,495	18,353
Surpl @ $_{95\%}$	430,679	37,771	43,289	34,461	30,016	36,163	38,457	52,508	48,825	28,854	25,963	25,239	29,133
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%
Dem 2040-	228,000	16,115	16,115	18,373	22,973	18,373	13,830	13,830	13,864	25,010	24,553	24,553	20,411
Surpl @ $_{95\%}$	405,986	35,713	41,231	32,404	27,958	34,106	36,399	50,450	46,767	26,797	23,905	23,181	27,075
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%

In comparison with the unadjusted water balance discussed in section 1.7.2.1, the stress conditions that appeared during the dry season of the 'one in twenty year dry year', have vanished. At the scale of the level 1 catchment, the renewable resources are sufficient to cater for the projected demand over the next thirty year or so.

The graphs below highlight the importance of the different demand categories and the fraction consumptive demand over the average renewable resources, as well as the distribution of this demand during the months of the year for the maximum development condition for 2014. Intermediate graphs for 2012, 2020, and 2030 are presented in the CKIV Catchment Master Plan presented in appendix 01CKIV.

Table 19: Resources and demand pie chart graph for CKIV 2040 - high demand scenario

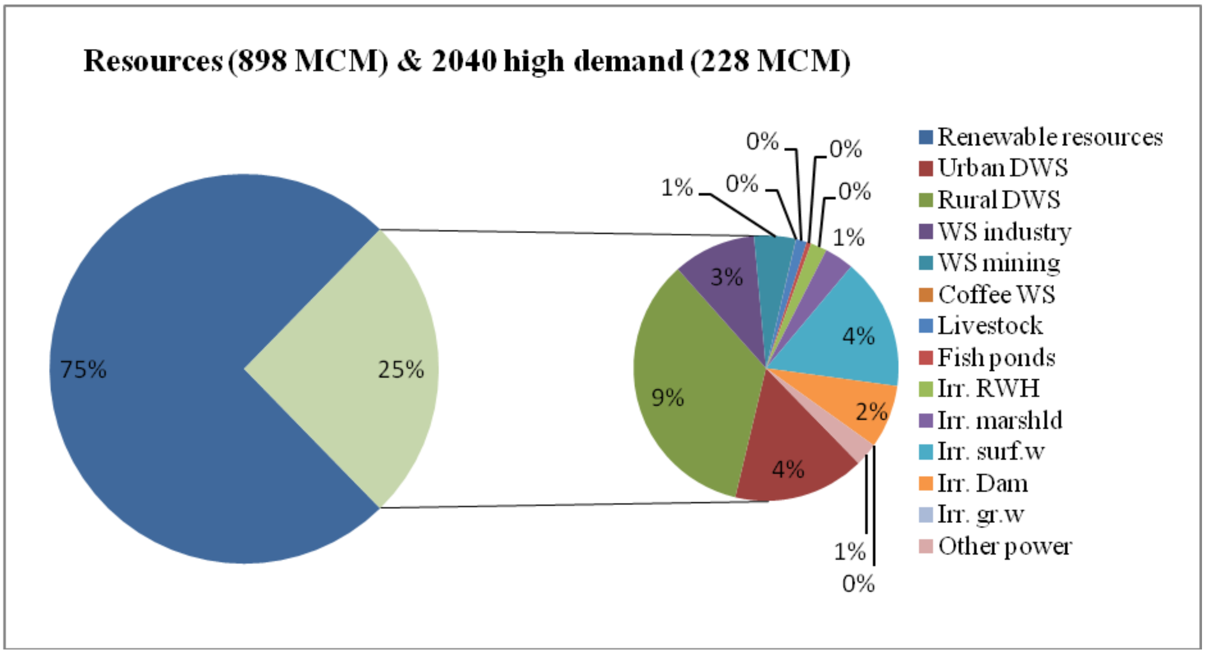
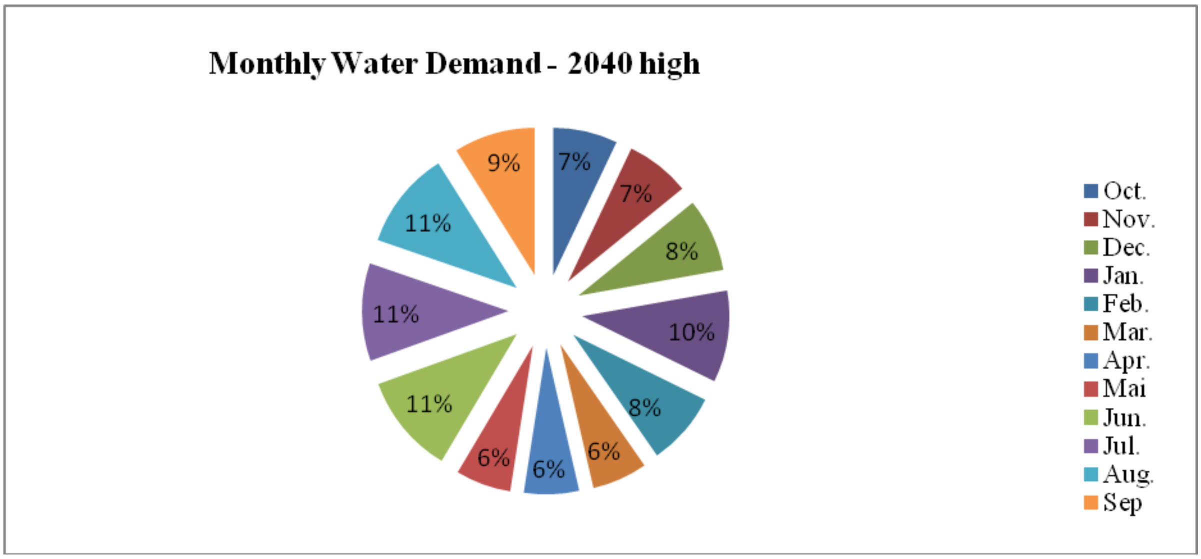


Table 20: Monthly demand distribution for CKIV 2040 - high demand scenario



For the period up to 2040, annual demand increases to about 25% of the average renewable resources (this was 35% for the unadjusted water balance in section 1.7.2.1). The principal consumptive demand categories remain rural water supply, urban water supply, irrigation from Lake Kivu, industries, mining, irrigation from dam sites and other power.

The distribution of demand during the year is somewhat uneven with an approximate factor 2 between dry and wet season months

Further issues on water resources and their use are related to flooding, pollution, erosion and appropriate land use aiming for economic, social and environmental sustainability.

Details on water use and demand under extreme conditions and exploitation risks as obtained from the District Survey, are discussed in section 3.3.5.1. of the CKIV Catchment Master Plan presented in appendix 01CKIV.

1.7.3.2 ADJUSTED DEMAND AND WATER BALANCE FOR CRUS

Details of the demand analysis for the CRUS catchment are given in paragraph 3.3.3. of the Catchment Master Plan for the Rusizi catchment (appendix 02CRUS).

From paragraph 1.7.2.2 it is evident that the water balance of the catchment does not impose adjustment of the different demand categories. However, when considering the concentration of demand almost exclusively in the Rubyiro tributary which generates but a third of the catchments resources, there may be need to adjust demand for a viable long term water balance. Nevertheless, the review of demand did not reveal any need to reduce demand for any category other than the irrigation sector as follows:

- irrigation by means of rainwater harvesting ponds: based on an increased estimate of the number of filling cycles of the ponds demand per pond is increased from 1 000 to 2 000 m^3/year (10 filling cycles of a 200 m^3 pond).
- irrigation by means of marshland development: due to the unavailability of resources beyond the currently developed 445 ha, no further extension of the irrigation infrastructure is foreseen. When the currently developed command area can be irrigated from the Rusizi River supplies, further development upstream in the Bugarama plain is possible from the Rubyiro River resources. The irrigated area remains standing at the current command area of 445 ha. The potential irrigation area identified in the RIMP (4,075 ha) cannot be developed for lack of available water resources.
- irrigation from surface water sources: it seems that the lower section of the Bugarama plain can be irrigated from the Rusizi River by means of an upstream intake with gravity flow which can replace the limited resources of the Rubyiro River. The RIMP report does not mention any potential for this type of irrigation yet it is suggested to irrigate about 555 ha through this method for a water demand tentatively estimated at 10,000 m^3/ha. This development is only possible when provided from the surplus resources of the CKIV catchment (a de facto catchment transfer of 6 MCM by means of natural lake/river flow) and when a suitable rice variety can be identified that supports the less ideal water quality of the Rusizi water.
- irrigation with surface water storage reservoirs: this irrigation method is expensive in investment cost (dam development and irrigation command area) and an effort has been made to assess the viability of the different sites identified in the RIMP. The only identified dam site has been found to provide a negligible storage volume for a dam of 24 m high. This opportunity has been judged expensive and of little interest. No storage reservoirs are foreseen during the lifetime of the Master Plan.

The adjusted water balance for the CRUS catchment is presented in the table below.

Table 21: Adjusted water balance CRUS 2012 - 2020 - 2030 - 2040.

volume data in '000 m³	annual total	oct	nov	dec	jan	feb	mar	apr	may	jun	jul	aug	sep
$Rs_{5\%}$	785,627	59,189	80,191	95,900	53,534	51,018	62,242	110,416	103,210	48,591	29,330	48,891	43,115
$Rs_{35\%}$	459,635	29,794	39,700	45,539	44,455	36,725	53,036	61,698	53,676	32,766	22,267	17,641	22,338
$Rs_{50\%}$	379,596	25,524	34,947	39,539	30,975	32,244	38,875	45,122	47,330	28,500	20,045	16,279	20,217
$Rs_{65\%}$	335,702	22,201	29,933	37,421	23,399	27,965	32,954	41,388	41,352	26,120	18,102	15,828	19,038
$Rs_{95\%}$	205,632	17,448	15,743	20,720	17,698	20,678	17,588	16,719	29,014	17,607	10,808	11,050	10,558
$gr.w._{50\%}$	269,036	21,609	22,330	23,410	23,050	23,770	23,410	25,211	29,173	25,211	18,008	15,847	18,008
Dem 2012	7,134	518	518	518	522	518	521	521	521	745	745	745	741
Surpl @ $_{95\%}$	198,498	16,930	15,225	20,201	17,176	20,160	17,067	16,198	28,493	16,862	10,063	10,305	9,817
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%
Dem 2020-low	17,985	1,192	1,192	1,423	1,906	1,423	954	954	962	2,129	2,103	2,103	1,645
Surpl @ $_{95\%}$	187,648	16,257	14,552	19,297	15,792	19,255	16,634	15,765	28,052	15,479	8,705	8,948	8,913
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%
Dem 2020-med	18,685	1,250	1,250	1,481	1,965	1,481	1,012	1,012	1,021	2,187	2,161	2,161	1,704
Surpl @ $_{95\%}$	186,947	16,198	14,493	19,238	15,733	19,197	16,576	15,707	27,993	15,420	8,647	8,889	8,854
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%
Dem 2020-high	19,179	1,291	1,291	1,522	2,006	1,522	1,053	1,053	1,062	2,228	2,202	2,202	1,745
Surpl @ $_{95\%}$	186,454	16,157	14,452	19,197	15,692	19,156	16,535	15,666	27,952	15,379	8,606	8,848	8,813
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%
Dem 2030-low	24,561	1,741	1,741	1,972	2,476	1,972	1,493	1,493	1,512	2,698	2,633	2,633	2,195
Surpl @ $_{95\%}$	181,071	15,707	14,002	18,747	15,222	18,706	16,095	15,226	27,502	14,909	8,175	8,417	8,363
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%
Dem 2030-med	26,872	1,934	1,934	2,165	2,668	2,165	1,686	1,686	1,704	2,891	2,826	2,826	2,387
Surpl @ $_{95\%}$	178,761	15,515	13,810	18,555	15,030	18,513	15,902	15,033	27,310	14,716	7,982	8,225	8,171
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%
Dem 2030-high	28,722	2,088	2,088	2,319	2,823	2,319	1,840	1,840	1,859	3,045	2,980	2,980	2,542
Surpl @ $_{95\%}$	176,911	15,360	13,655	18,400	14,876	18,359	15,748	14,879	27,155	14,562	7,828	8,070	8,016
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%
Dem 2040-low	31,915	2,350	2,350	2,582	3,126	2,582	2,082	2,082	2,121	3,349	3,244	3,244	2,804
Surpl @ $_{95\%}$	173,718	15,098	13,393	18,138	14,572	18,097	15,506	14,637	26,893	14,259	7,564	7,806	7,754
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%
Dem 2040-med	38,199	2,874	2,874	3,105	3,650	3,105	2,606	2,606	2,645	3,872	3,768	3,768	3,328
Surpl @ $_{95\%}$	167,434	14,574	12,869	17,614	14,048	17,573	14,983	14,113	26,369	13,735	7,040	7,283	7,230
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%
Dem 2040-high	43,766	3,338	3,338	3,569	4,114	3,569	3,070	3,070	3,109	4,336	4,231	4,231	3,792
Surpl @ $_{95\%}$	161,867	14,110	12,406	17,151	13,585	17,109	14,519	13,649	25,905	13,271	6,576	6,819	6,766
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%

In comparison with the unadjusted water balance presented in section 1.7.2.2, the stress conditions that appeared during the months of April and the dry season of the 'one in twenty year dry year', have not completely vanished. At the scale of the level 1 catchment, the renewable resources seem however sufficient to cater for the projected demand over the next thirty year or so as just the environmental demand is somewhat affected during this rather extreme situation.

The graphs below highlight the importance of the different demand categories and the fraction consumptive demand over the average renewable resources, as well as the distribution of this demand during the months of the year for the maximum development condition for 2014. Intermediate graphs for 2012, 2020, and 2030 are presented in the CRUS Catchment Master Plan presented in appendix 02CRUS.

Table 22: Resources and demand pie chart graph for CRUS 2040 - high demand scenario

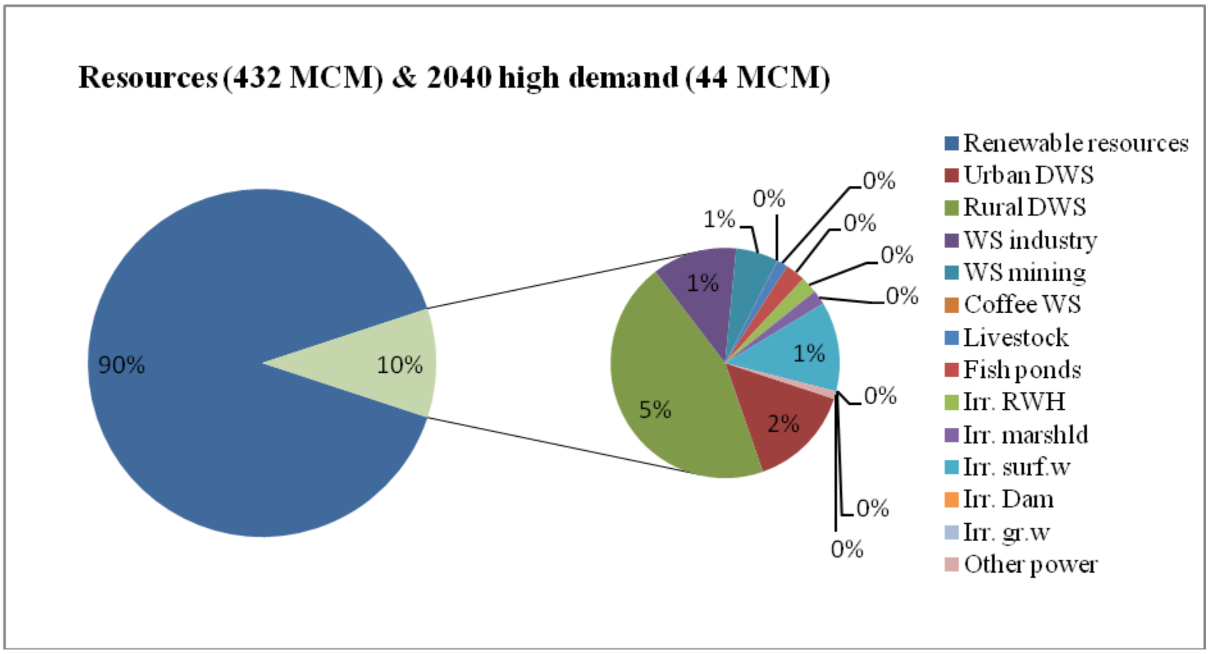
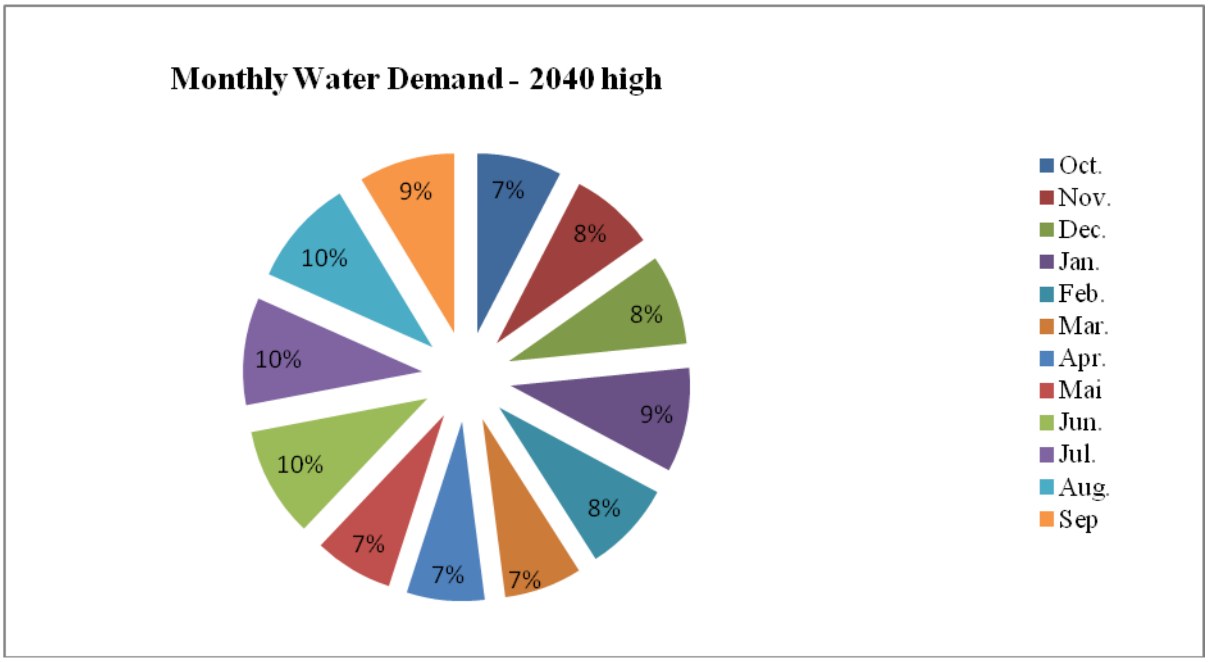


Table 23: Monthly demand distribution for CRUS 2040 - high demand scenario



For the period up to 2040, annual demand increases to about 10 % of the average renewable resources (this was identical for the unadjusted water balance in section 1.7.2.2). The principal consumptive demand categories are rural water supply, urban water supply, surface water irrigation from Rusizi River and industries. Minor demand categories are mining, fish ponds, marshland irrigation and irrigation from rain water harvesting.

The distribution of demand during the year is rather constant which is related to the predominance of demand from drinking water supply over the irrigation sector's demand.

Further issues on water resources and their use are related to flooding, pollution, erosion and appropriate land use aiming for economic, social and environmental sustainability.

Details on water use and demand under extreme conditions and exploitation risks as obtained from the District Survey, are discussed in section 3.3.5.1. of the CRUS Catchment Master Plan presented in appendix 02CRUS.

1.7.3.3 ADJUSTED DEMAND AND WATER BALANCE FOR NNYU

Details of the demand analysis for the NNYU catchment are given in paragraph 3.3.3. of the Catchment Master Plan for the Upper Nyabarongo catchment (appendix 03NNYU).

From paragraph 1.7.2.3 it is clear that the water balance of the catchment does not impose adjustment of the different demand categories. Consequently, all demand for potable water supply, sanitation, industries, mining, livestock, fisheries, hydropower, non consumptive and other energy demand was reviewed and thereupon maintained as is. Notwithstanding the abundance of resources, there are a number of adjustments in the irrigation sector deemed necessary as follows:

- irrigation by means of rainwater harvesting ponds: based on an increased estimate of the number of filling cycles of the ponds demand per pond is increased from 1 000 to 2 000 m^3/year (10 filling cycles of a 200 m^3 pond).
- irrigation by means of marshland development: because of the interesting performance and reduced investment and operational costs of this method, the full development potential as identified in the RIMP has been maintained. Considering the important area to be developed for this irrigation method (almost 23.000 ha), the implementation schedule is set to a third of the area per planning period (2012 - 2020, 2020 - 2030 and 2030 - 2040) which is somewhat accelerated from the initial regime presented in section 1.7.2.3. The total area to be developed by 2040 and the per hectare water demand for this method (2 000 m^3/ha/yr) have not been changed.
- irrigation from surface water sources: this irrigation method is expensive in investment and exploitation costs; the latter especially when irrigating land at higher elevation level from the water source level. For this reason, the 6,755 ha foreseen in the RIMP report have been separated in 4 altitude classes and only the lower 2 altitude classes (0-25 and 25-50 m command area elevation level above source level) for a total of 2,200 ha command area, have been considered for development during the lifetime of the Master Plan. The per hectare water demand for this method (6 000 m^3/ha/yr) has not been changed. Adjusted demand from this use category has consequently been reduced to a third of the demand from the potential irrigation areas identified in the RIMP or from 38 MCM/year to 13 MCM/year.
- irrigation with surface water storage reservoirs: this irrigation method is rather expensive in investment cost for both dam and state of the art irrigation command area development. An effort has been made to assess the viability of the different sites identified in the RIMP. Out of 26 identified sites 7 have been found sufficiently interesting in terms of site configuration and storage volume. The corresponding command area is 2,048 ha (out of 6,772 ha for 26 sites). With this select and more

practical number of dams to be constructed and an improved estimate of the retained water quantities, the projected demand has dropped from 44 to 31 MCM/year for the 2040 time horizon. Details on the endorsed reservoir sites are provided in the Upper Nyabarongo catchment Master Plan in appendix 03NNYU.

- Irrigation from groundwater: this irrigation method is similarly susceptible to thwart viable exploitation due to high energy costs (for pumping). The presumably viable command area has been estimated at about a quarter of the area proposed in the RIMP (9,955 ha). Water demand at the 2040 time horizon has been reduced from 60 to 15 MCM/annum. Details are provided in the Upper Nyabarongo catchment Master Plan in appendix 03NNYU.

The resulting adjusted water balance for the NNYU catchment is presented in the next table:

Table 24: Adjusted water balance NNYU 2012 - 2020 - 2030 - 2040.

volume data in '000 m^3	annual total	oct	nov	dec	jan	feb	mar	apr	may	jun	jul	aug	sep
$Rs_{5\%}$	1,858,415	138,436	136,591	143,245	163,932	178,526	183,368	185,509	206,542	142,537	123,629	122,377	133,725
$Rs_{35\%}$	1,397,023	98,741	124,979	119,083	112,942	116,062	125,847	143,764	141,071	118,539	101,229	99,054	95,711
$Rs_{50\%}$	1,202,282	93,734	100,109	99,927	96,617	97,539	107,570	126,569	129,294	101,163	87,014	78,548	84,198
$Rs_{65\%}$	1,060,332	84,857	88,299	89,847	82,106	82,537	86,997	117,140	119,050	81,118	74,991	74,612	78,779
$Rs_{95\%}$	884,495	66,953	72,108	72,734	72,187	74,505	72,843	90,663	93,948	76,374	64,894	64,219	63,066
gr.w.$_{50\%}$	977,616	74,002	79,700	80,392	79,787	82,349	80,512	100,208	103,840	84,415	71,726	70,980	69,706
Dem 2012	31,329	2,534	2,534	2,556	2,614	2,556	2,506	2,506	2,513	2,771	2,763	2,763	2,713
Surpl @ $_{95\%}$	853,167	64,419	69,574	70,179	69,573	71,949	70,337	88,156	91,435	73,603	62,132	61,456	60,353
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%
Dem 2020-low	83,388	5,018	5,018	5,663	7,069	5,663	4,318	4,318	4,375	10,891	10,785	10,785	9,485
Surpl @ $_{95\%}$	801,108	61,935	67,090	67,072	65,118	68,842	68,525	86,345	89,573	65,483	54,110	53,434	53,581
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%
Dem 2020-med	86,624	5,288	5,288	5,932	7,339	5,932	4,588	4,588	4,645	11,161	11,054	11,054	9,755
Surpl @ $_{95\%}$	797,872	61,665	66,821	66,802	64,848	68,573	68,255	86,075	89,304	65,213	53,840	53,165	53,311
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%
Dem 2020-high	88,892	5,477	5,477	6,121	7,528	6,121	4,777	4,777	4,834	11,350	11,243	11,243	9,944
Surpl @ $_{95\%}$	795,603	61,476	66,632	66,613	64,659	68,383	68,066	85,886	89,115	65,024	53,651	52,976	53,122
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%
Dem 2030-low	150,771	8,444	8,444	10,007	13,366	10,007	6,767	6,767	6,882	21,011	20,712	20,712	17,652
Surpl @ $_{95\%}$	733,724	58,509	63,665	62,727	58,821	64,498	66,076	83,895	87,067	55,364	44,182	43,507	45,414
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%
Dem 2030-med	161,331	9,324	9,324	10,887	14,246	10,887	7,647	7,647	7,762	21,891	21,592	21,592	18,532
Surpl @ $_{95\%}$	723,164	57,629	62,785	61,847	57,941	63,618	65,196	83,015	86,187	54,484	43,302	42,627	44,534
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%
Dem 2030-high	169,788	10,028	10,028	11,592	14,950	11,592	8,352	8,352	8,467	22,595	22,297	22,297	19,237
Surpl @ $_{95\%}$	714,707	56,925	62,080	61,143	57,236	62,913	64,491	82,311	85,482	53,779	42,597	41,922	43,829
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%
Dem 2040-low	222,735	12,226	12,226	14,707	20,130	14,707	9,517	9,517	9,746	31,598	31,093	31,093	26,174
Surpl @ $_{95\%}$	661,760	54,727	59,883	58,027	52,056	59,798	63,326	81,146	84,202	44,776	33,801	33,126	36,892
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%
Dem 2040-med	251,459	14,619	14,619	17,101	22,524	17,101	11,911	11,911	12,140	33,992	33,487	33,487	28,568
Surpl @ $_{95\%}$	633,036	52,334	57,489	55,634	49,662	57,404	60,932	78,752	81,809	42,383	31,407	30,732	34,498
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%
Dem 2040-high	276,906	16,740	16,740	19,221	24,645	19,221	14,031	14,031	14,260	36,112	35,607	35,607	30,689
Surpl @ $_{95\%}$	607,589	50,213	55,368	53,513	47,542	55,284	58,812	76,631	79,688	40,262	29,287	28,612	32,377
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%

In comparison with the unadjusted water balance discussed in section 1.7.2.3, which showed negligible stress during the dry season for the 2040 horizon, in the dry month of July, these stress signals have now completely vanished and the catchment's own demands including environmental flow requirements are met under any scenario up till the end of the master plan time horizon.

The graphs below highlight the importance of the different demand categories and the fraction consumptive demand over the average renewable resources, as well as the distribution of this demand during the months of the year for the maximum development condition for 2014. Intermediate graphs for 2012, 2020, and 2030 are presented in the NNYU Catchment Master Plan presented in appendix 03NNYU.

Table 25: Resources and demand pie chart graph for NNYU 2040 - high demand scenario

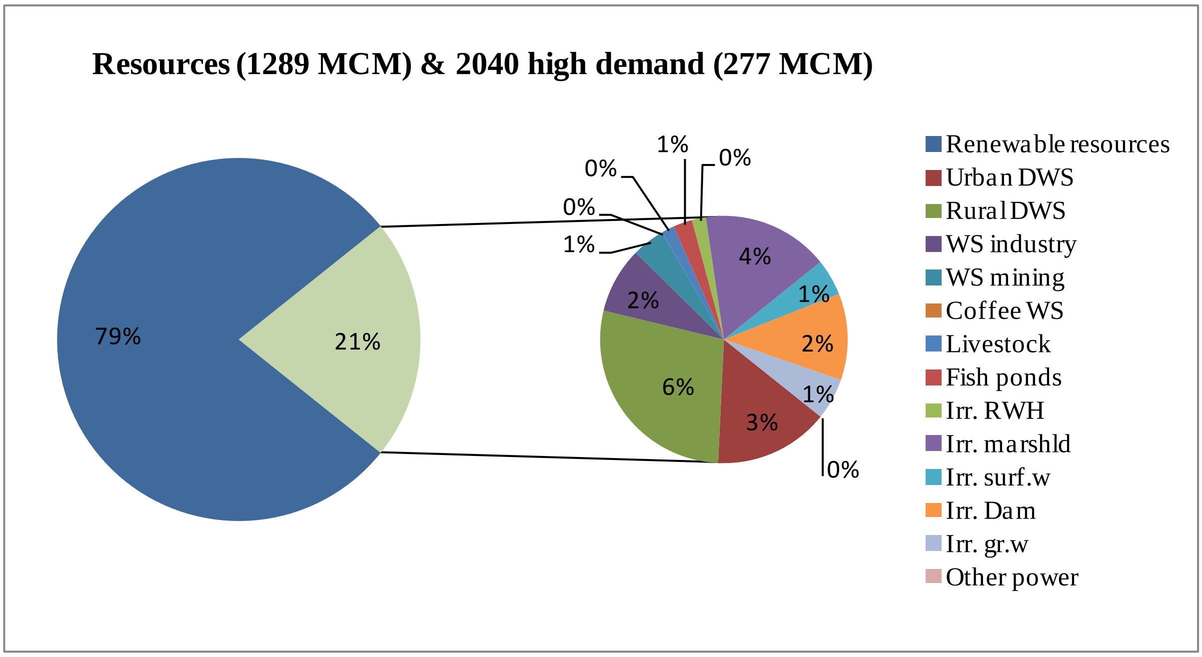
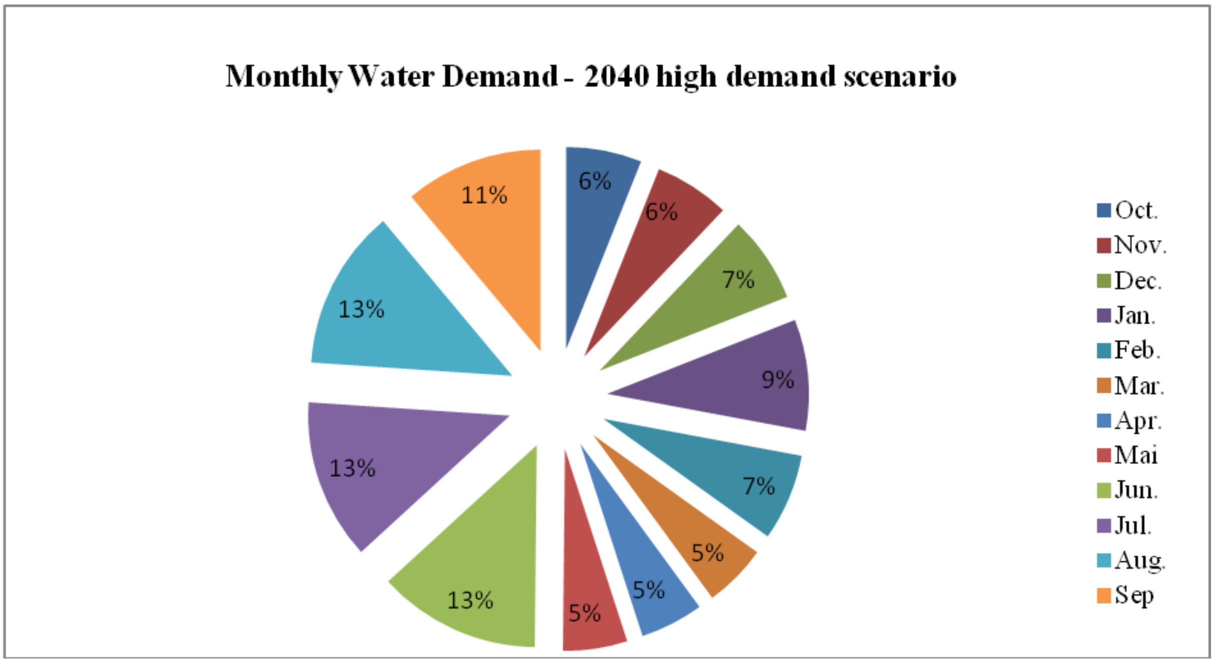


Table 26: Monthly demand distribution for NNYU 2040 - high demand scenario



For the period up to 2040, annual demand increases to about 25% of the average renewable resources (this was 28% for the unadjusted water balance in section 1.7.2.3). The principal consumptive demand categories are rural water supply, irrigation in marshlands, irrigation from dams and urban water supply.

The distribution of demand during the year is significantly skewed with about half the overall demand realized during the four dry season months.

Further issues on water resources and their use are related to flooding, pollution, erosion and appropriate land use aiming for economic, social and environmental sustainability.

Details on water use and demand under extreme conditions and exploitation risks as obtained from the District Survey, are discussed in section 3.3.5.1. of the NNYU Catchment Master Plan presented in appendix 03NNYU.

1.7.3.4 ADJUSTED DEMAND AND WATER BALANCE FOR NMUK

Details of the demand analysis for the NMUK catchment are given in paragraph 3.3.3. of the Catchment Master Plan for the Mukungwa catchment (appendix 04NMUK).

From paragraph 1.7.2.4 it is clear that the water balance of the catchment does not impose adjustment of the different demand categories. Consequently, all demand for potable water supply, sanitation, industries, mining, livestock, fisheries, hydropower, non consumptive and other energy demand was reviewed and thereupon maintained as is. Notwithstanding the abundance of resources, there are a number of adjustments in the irrigation sector deemed necessary as follows:

- irrigation by means of rainwater harvesting ponds: based on an increased estimate of the number of filling cycles of the ponds, the demand per pond is increased from 1,000 to 2,000 m³/year (10 filling cycles of a 200 m³ pond).

- irrigation by means of marshland development: because of the interesting performance and reduced investment and operational costs of this method, the full development potential as identified in the RIMP has been put forward for equal development during the first and second stage of the Master Plan, the period prior to 2020 and the period from 2021 - 2030. The per hectare water demand for this method (2,000 m^3/ha/yr) has not been changed. The annual and monthly demand for 2020 has been increased to 50% of the full potential and from 2030 onwards up to 2040 the full potential is assumed (initially foreseen for 2040). The 2030-2040 water demand has not been changed.
- irrigation with surface water storage reservoirs: this irrigation method is mostly rather expensive in investment cost (dam development and irrigation command area) and an effort has been made to assess the viability of the sole site identified in the RIMP. The site appears interesting but surely not ideal. The site is considered for implementation during the 2030-2040 investment period which results in a demand of 2.425 MCM per annum as against 1.866 MCM per annum for the unadjusted version.

The adjusted water balance for the NMUK catchment is presented in the table below.

Table 27: Adjusted water balance NMUK 2012 - 2020 - 2030 - 2040.

volume data in '000 m³	annual total	oct	nov	dec	jan	feb	mar	apr	may	jun	jul	aug	sep
Rs$_{5\%}$	1,518,572	131,749	164,627	178,394	98,713	100,871	110,822	157,046	146,911	127,432	104,583	92,474	104,951
Rs$_{35\%}$	886,599	68,467	87,657	69,652	57,517	62,176	63,545	95,396	105,610	88,052	63,913	59,728	64,887
Rs$_{50\%}$	766,459	62,255	70,863	62,308	55,621	58,885	59,070	77,944	95,686	66,335	49,251	51,673	56,569
Rs$_{65\%}$	678,644	55,832	58,885	55,174	48,804	54,016	55,621	67,546	81,603	55,042	47,408	47,777	50,936
Rs$_{95\%}$	511,148	34,826	48,303	47,172	42,223	41,775	34,431	52,252	57,174	43,065	39,301	36,116	34,510
gr.w.$_{50\%}$	627,665	45,453	56,196	53,717	50,412	49,585	45,453	64,461	66,113	53,717	49,585	47,519	45,453
Dem 2012	25,590	2,132	2,132	2,132	2,134	2,132	2,131	2,131	2,132	2,134	2,134	2,134	2,132
Surpl @ $_{95\%}$	485,558	32,694	46,171	45,040	40,089	39,643	32,300	50,121	55,042	40,931	37,167	33,982	32,378
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%
Dem 2020-low	50,887	3,837	3,837	3,837	3,865	3,837	3,823	3,823	3,837	5,099	5,011	5,011	5,071
Surpl @ $_{95\%}$	460,261	30,989	44,467	43,335	38,358	37,939	30,608	48,429	53,338	37,966	34,290	31,105	29,439
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%
Dem 2020-med	53,666	4,068	4,068	4,068	4,096	4,068	4,055	4,055	4,069	5,331	5,243	5,243	5,303
Surpl @ $_{95\%}$	457,482	30,758	44,235	43,103	38,126	37,707	30,376	48,197	53,106	37,735	34,058	30,873	29,207
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%
Dem 2020-high	55,600	4,230	4,230	4,230	4,258	4,230	4,216	4,216	4,230	5,492	5,404	5,404	5,464
Surpl @ $_{95\%}$	455,548	30,596	44,074	42,942	37,965	37,546	30,215	48,036	52,945	37,573	33,897	30,712	29,046
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%
Dem 2030-low	79,125	5,794	5,794	5,794	5,846	5,794	5,769	5,769	5,795	8,315	8,096	8,096	8,263
Surpl @ $_{95\%}$	432,023	29,031	42,509	41,377	36,376	35,981	28,662	46,483	51,380	34,750	31,205	28,020	26,247
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%
Dem 2030-med	88,074	6,540	6,540	6,540	6,592	6,540	6,514	6,514	6,540	9,060	8,841	8,841	9,008
Surpl @ $_{95\%}$	423,075	28,286	41,763	40,631	35,631	35,235	27,917	45,738	50,634	34,005	30,459	27,274	25,502
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%
Dem 2030-high	95,239	7,137	7,137	7,137	7,189	7,137	7,112	7,112	7,137	9,658	9,439	9,439	9,606
Surpl @ $_{95\%}$	415,909	27,689	41,166	40,034	35,034	34,638	27,319	45,140	50,037	33,408	29,862	26,677	24,904
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%
Dem 2040-low	108,253	8,130	8,130	8,231	8,535	8,231	7,978	7,978	8,029	11,003	10,653	10,653	10,699
Surpl @ $_{95\%}$	402,896	26,696	40,173	38,941	33,688	33,544	26,453	44,274	49,145	32,062	28,648	25,462	23,811
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%
Dem 2040-med	132,592	10,158	10,158	10,259	10,563	10,259	10,007	10,007	10,057	13,032	12,682	12,682	12,728
Surpl @ $_{95\%}$	378,556	24,668	38,145	36,912	31,659	31,516	24,424	42,245	47,117	30,033	26,619	23,434	21,782
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%
Dem 2040-high	154,154	11,955	11,955	12,056	12,360	12,056	11,803	11,803	11,854	14,829	14,478	14,478	14,525
Surpl @ $_{95\%}$	356,994	22,871	36,348	35,115	29,862	29,719	22,628	40,449	45,320	28,236	24,822	21,637	19,985
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%

In comparison with the unadjusted water balance discussed in section 1.7.2.4, there is a slight increase of demand for the 2020, 2030 and 2040 time horizons which is due to the acceleration of the marshland development but there are no signs of stress conditions. At the scale of the level 1 catchment, the renewable resources are sufficient to cater for the projected demand over the next thirty years.

The graphs below highlight the importance of the different demand categories and the fraction consumptive demand over the average renewable resources, as well as the distribution of this demand during the months of the year for the maximum development condition for 2014. Intermediate graphs for 2012, 2020, and 2030 are presented in the NMUK Catchment Master Plan presented in appendix 04NMUK.

Table 28: Resources and demand pie chart graph for NMUK 2040 - high demand scenario

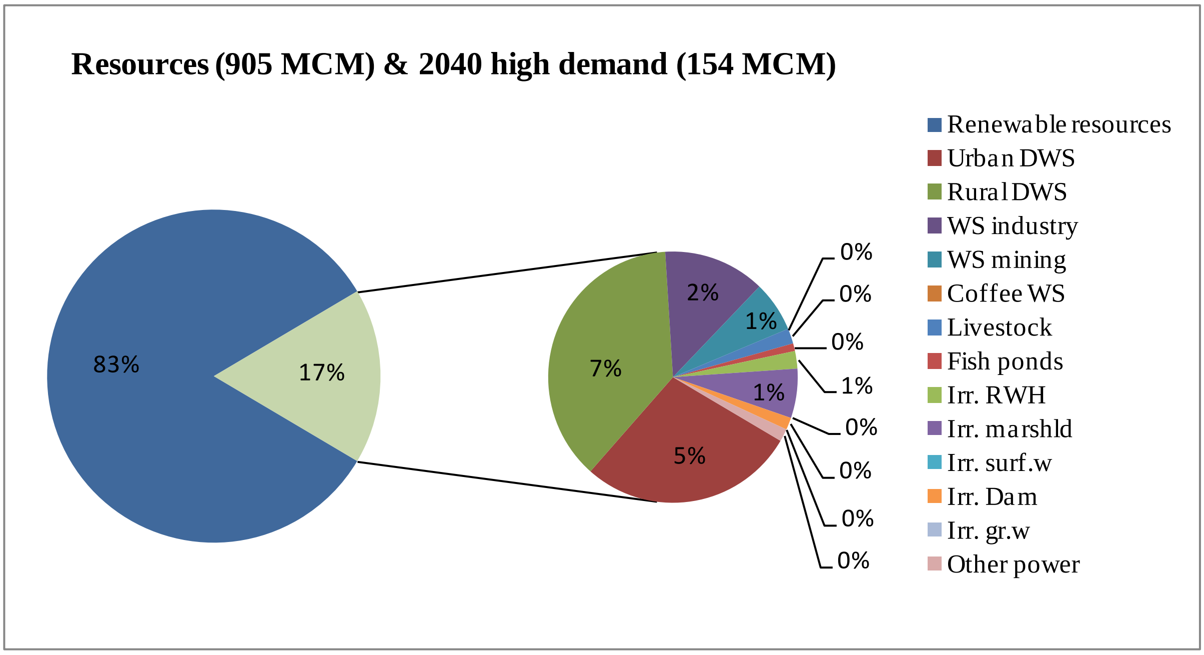
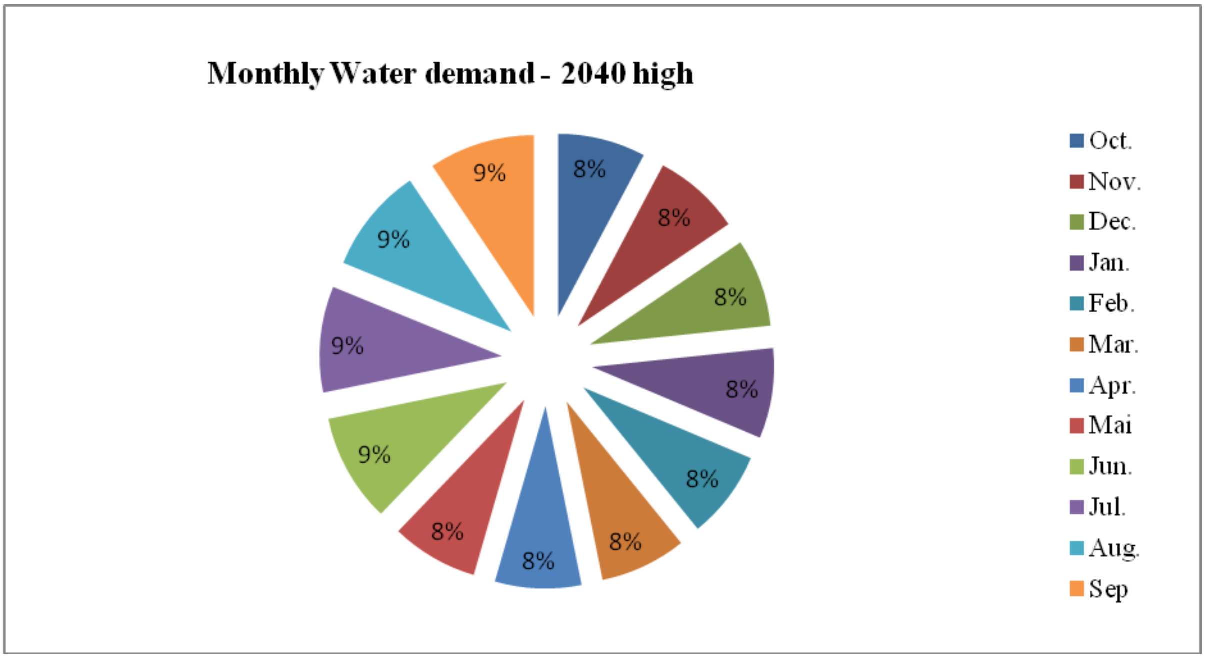


Table 29: Monthly demand distribution for NMUK 2040 - high demand scenario



For the period up to 2040, annual demand increases to about 17% of the average renewable resources (this was identical for the unadjusted water balance in section 1.7.2.4). The principal consumptive demand categories remain rural water supply, urban water supply, industrial demand, mining and mainly marshland development.

The distribution of demand during the year is rather constant which is related to the predominance of demand from drinking water supply over the irrigation sector's demand.

Further issues on water resources and their use are related to high costs of potable water installations especially for the lava region, flooding, pollution and appropriate land use aiming for economic, social and environmental sustainability.

Details on water use and demand under extreme conditions and exploitation risks as obtained from the District Survey, are discussed in section 3.3.5.1. of the NMUK Catchment Master Plan presented in appendix 04NMUK.

1.7.3.5 ADJUSTED DEMAND AND WATER BALANCE FOR NNYL

Details of the demand analysis for the NNYL catchment are given in paragraph 3.3.3. of the Catchment Master Plan for the Lower Nyabarongo catchment (appendix 05NNYL).

From paragraph 1.7.2.5 it is clear that the water balance of the catchment does impose adjustment of the different demand categories. Nevertheless, the review of the different demand categories did not reveal any good reason to reduce demand for any category other than the irrigation sector. For the latter the following changes are proposed:

- irrigation by means of rainwater harvesting ponds: based on an increased estimate of the number of filling cycles of the ponds demand per pond is increased from 1,000 to 2,000 m^3/year (10 filling cycles of a 200 m^3 pond).
- irrigation by means of marshland development: because of the interesting performance and reduced investment and operational costs of this method, the full development potential as identified in the RIMP has been maintained but the implementation has been accelerated slightly (2030 planning period). The per hectare water demand for this method (2,000 m^3/ha/yr) has been left unaltered.
- irrigation from surface water sources: this irrigation method is expensive in investment and exploitation costs. Due to the lack of available resources for this type of irrigation, the command area as indicated in the RIMP (12,245 ha) has been reduced to 5,000 ha of which 2,000 ha at a level of max 25 m along the Muhazi Lake and 3,000 ha at a level of max 50 m along the Nyabarongo river. This development is assumed completed by 2030. The per hectare water demand for this method (7,000 m^3/ha/yr for the central region) has not been changed. Adjusted demand from this use category has consequently been reduced to 35 MCM/year.
- irrigation with surface water storage reservoirs: this irrigation method is very expensive in investment cost (dam development and irrigation command area) and an effort has been made to assess the viability of the different sites identified in the RIMP. Out of 30 identified sites 12 have been judged as sufficiently interesting in terms of site configuration and storage volume. Their total storage capacity is about 36 MCM. There is also a cost effective and simple method to use Lake Muhazi as water reservoir for irrigation. A storage of about 16 MCM can be made available which permits to irrigate an additional command area of 3,600 ha along Lake Muhazi at a level between 25 and 50 m above lake level. Details are provided in the Lower Nyabarongo Catchment Master Plan in appendix 05NNYL.
- irrigation demand from groundwater: this irrigation method is also susceptible to bring high exploitation costs for pumping. The area viable for exploitation has been estimated at about 25% of the area identified in the RIMP (15,550 ha). Water demand

from this reduced command area (~3,900 ha) is estimated at 27 MCM/year which is proportionally implemented over the period from 2012 - 2040.

The adjusted water balance for the NNYL catchment is presented in the table below.

Table 30: Adjusted water balance NNYL 2012 - 2020 - 2030 - 2040.

volume data in '000 m^3	annual total	oct	nov	dec	jan	feb	mar	apr	may	jun	jul	aug	sep
$Rs_{5\%}$	1,326,684	94,382	116,797	129,692	112,083	119,469	116,557	163,914	156,350	99,833	78,173	64,834	74,599
$Rs_{35\%}$	929,046	62,576	84,225	73,718	68,738	73,252	87,327	117,368	117,145	73,290	59,153	54,749	57,504
$Rs_{50\%}$	848,870	58,585	75,168	72,133	62,985	69,387	72,348	101,115	107,112	69,155	53,382	52,050	55,450
$Rs_{65\%}$	786,114	57,373	71,344	66,814	57,528	63,222	64,380	95,325	96,483	64,215	51,009	46,721	51,700
$Rs_{95\%}$	633,802	45,188	54,583	52,307	49,586	51,934	53,577	75,826	75,628	48,402	42,429	40,508	43,833
$gr.w._{50\%}$	544,628	41,858	50,561	48,452	45,932	48,107	48,593	49,287	48,593	45,816	39,303	37,523	40,603
Dem 2012	55,216	4,361	4,361	4,361	4,813	4,361	3,927	3,927	4,363	5,306	5,292	5,292	4,854
Surpl @ $_{95\%}$	578,585	40,827	50,222	47,946	44,774	47,573	49,649	71,899	71,265	43,096	37,138	35,217	38,979
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%
Dem 2020-low	161,950	11,056	11,056	11,056	15,761	11,056	6,397	6,397	11,060	20,761	20,648	20,648	16,056
Surpl @ $_{95\%}$	471,851	34,132	43,527	41,251	33,825	40,878	47,180	69,429	64,569	27,641	21,782	19,860	27,777
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%
Dem 2020-med	166,822	11,462	11,462	11,462	16,167	11,462	6,803	6,803	11,466	21,167	21,054	21,054	16,462
Surpl @ $_{95\%}$	466,980	33,726	43,122	40,845	33,419	40,472	46,774	69,023	64,163	27,235	21,376	19,454	27,371
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%
Dem 2020-high	170,169	11,741	11,741	11,741	16,446	11,741	7,082	7,082	11,745	21,446	21,333	21,333	16,741
Surpl @ $_{95\%}$	463,633	33,447	42,843	40,566	33,140	40,193	46,495	68,744	63,884	26,956	21,097	19,175	27,093
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%
Dem 2030-low	291,723	19,352	19,352	19,352	29,260	19,352	9,567	9,567	19,356	39,260	38,976	38,976	29,352
Surpl @ $_{95\%}$	342,079	25,836	35,231	32,955	20,327	32,582	44,010	66,259	56,272	9,142	3,454	1,532	14,481
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%
Dem 2030-med	307,049	20,629	20,629	20,629	30,537	20,629	10,844	10,844	20,634	40,537	40,253	40,253	30,629
Surpl @ $_{95\%}$	326,753	24,558	33,954	31,677	19,050	31,304	42,732	64,982	54,995	7,865	2,176	255	13,204
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%
Dem 2030-high	319,322	21,652	21,652	21,652	31,560	21,652	11,867	11,867	21,656	41,560	41,276	41,276	31,652
Surpl @ $_{95\%}$	314,480	23,536	32,931	30,655	18,027	30,282	41,710	63,959	53,972	6,842	1,154	0	12,181
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=65%	>=95%
Dem 2040-low	409,210	26,830	26,830	26,830	40,522	26,830	13,460	13,460	26,834	55,554	55,100	55,100	41,862
Surpl @ $_{95\%}$	224,592	18,358	27,753	25,477	9,064	25,104	40,117	62,366	48,795	0	0	0	1,971
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=65%	>=35%	>=5%	>=95%
Dem 2040-med	450,897	30,304	30,304	30,304	43,996	30,304	16,934	16,934	30,308	59,028	58,574	58,574	45,336
Surpl @ $_{95\%}$	182,904	14,884	24,280	22,003	5,590	21,630	36,643	58,892	45,321	0	0	0	0
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=65%	>=35%	>=5%	>=65%
Dem 2040-high	487,828	33,381	33,381	33,381	47,074	33,381	20,011	20,011	33,385	62,106	61,652	61,652	48,413
Surpl @ $_{95\%}$	145,974	11,807	21,202	18,926	2,513	18,553	33,565	55,815	42,243	0	0	0	0
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=65%	>=5%	>=5%	>=65%

In comparison with the unadjusted water balance discussed in section 1.7.2.1, the stress conditions do not seem to have been solved to a definite extent:

- the 2020 unadjusted balance did not show any sign of stress and, notwithstanding a slight increase in demand (due to the acceleration of development opportunities), this condition is preserved for the adjusted water balance. Please note that there is already significant storage capacity created in the catchment (about 10 MCM spread over different locations; see Nyabarongo Catchment Master Plan in appendix 05NNYL for details).

- the 2030 unadjusted balance showed a little bit of stress which compromised the environmental flow criterion. The annual demand of the adjusted water balance has been slightly reduced (by some 7 MCM/annum) but the stress remains mostly unaltered. When considering that the catchment contains about 24 MCM of storage from artificial reservoirs and a potential 16 MCM management storage from Lake Muhazi, the monthly dry season surplus that can be released from these reservoirs can be close to 7 MCM/month which leaves meaningful (3 m^3/s), though formally insufficient, flow available for sustaining minimum hydro-ecological requirements during the dry season.
- with resources insufficient even for the once in twenty years wet year, the 2040 unadjusted balance was evidently not sustainable. For the adjusted balance, annual demand has been reduced by 120 MCM or some 20% of demand. The dry season situation is improved but remains precarious especially for the high demand scenario (insufficiency of resources even for the once in three year wet year). The additional storage capacity from artificial reservoirs and the management storage from Lake Muhazi stand at 52 MCM which means that a monthly surplus of about 10 MCM/month is available. A better use of this surplus storage volume can be made when it is released when most required, especially during the months of July and August. Indicatively, the 'once in three year dry year' resources plus the targeted distribution of the storage allow to supply for the 2040 demand exclusive of environmental demand. In 'better' hydrological years there is some environmental flow. In years with lesser flow, part of the demand should be satisfied from reuse (easily achievable in irrigation), temporary overexploitation of groundwater resources, temporary suspension of demand, or transfer from Mukungwa and upper Nyabarongo catchments.

In conclusion, at the scale of the level 1 catchment, the catchment's own renewable resources are just sufficient to cater for the projected demand over the next thirty year or so.

The graphs below highlight the importance of the different demand categories and the fraction consumptive demand over the average renewable resources, as well as the distribution of this demand during the months of the year for the maximum development condition for 2014. Intermediate graphs for 2012, 2020, and 2030 are presented in the NNYL Catchment Master Plan presented in appendix 05NNYL.

Table 31: Resources and demand pie chart graph for NNYL 2040 - high demand scenario

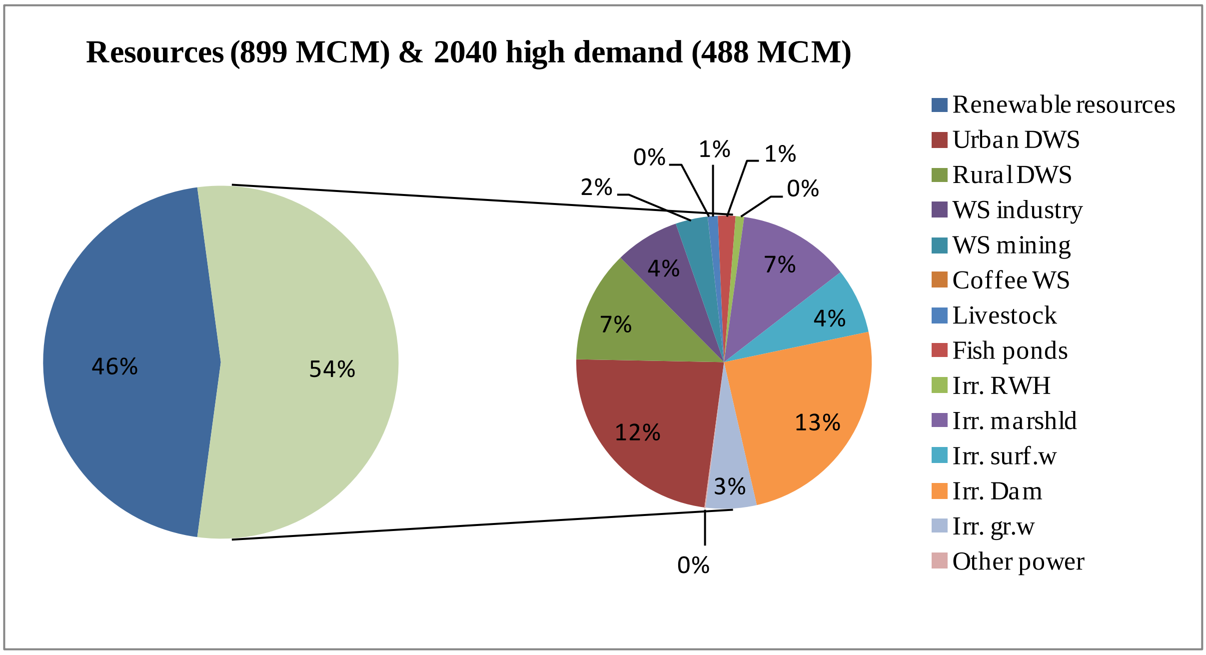
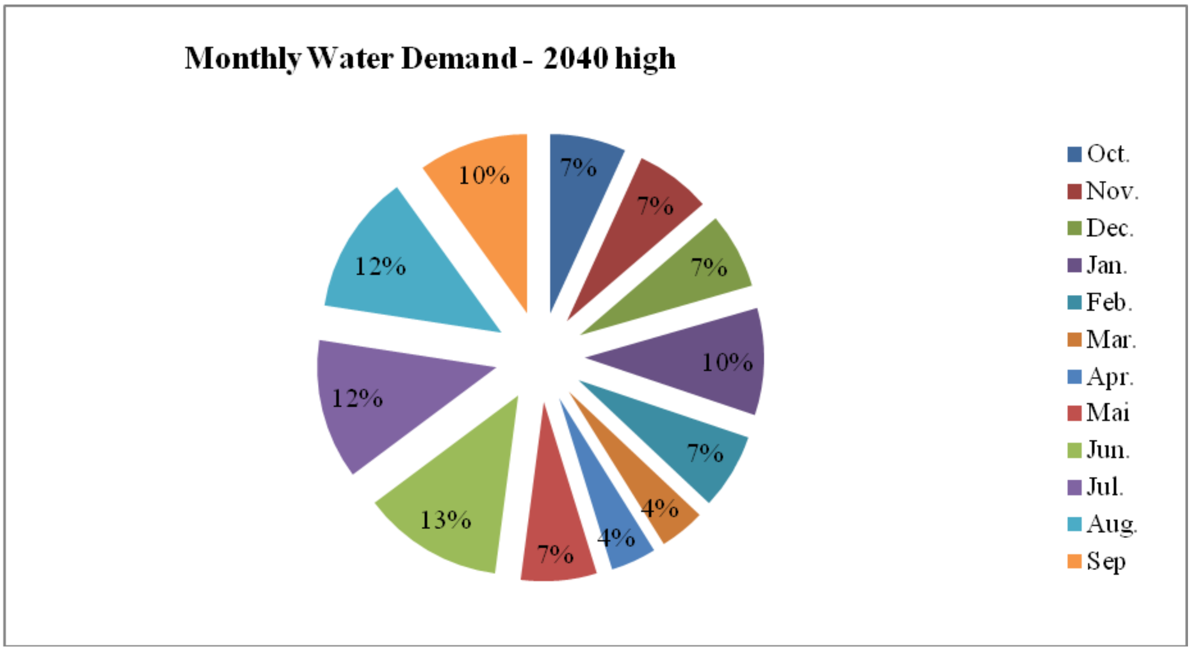


Table 32: Monthly demand distribution for NNYL 2040 - high demand scenario



For the period up to 2040, annual demand increases to about 54 % of the average renewable resources (this was 68% for the unadjusted water balance in section 1.7.2.5). The principal consumptive demand categories remain irrigation from dam, urban and rural water supply, irrigation from surface water, marshland and industries.

The distribution of demand during the year is significantly skewed with almost half the overall demand realized during the four dry season months.

This catchment soon requires state of the art water management procedures that is based on both resources and water use monitoring and strict rules for resources development and exploitation. A water use permit system and a decentralized management entity under the auspices of the RNRA, will be mandatory to materialize this.

Further issues on water resources and their use are related to the high cost of development for rural drinking water supply, flooding, pollution, erosion and appropriate land use aiming for economic, social and environmental sustainability.

Details on water use and demand under extreme conditions and exploitation risks as obtained from the District Survey, are discussed in section 1.7.2.5 of the NNYL Catchment Master Plan presented in appendix 05NNYL.

1.7.3.6 Adjusted demand and water balance for NAKN

Details of the demand analysis for the NAKN catchment are given in paragraph 3.3.3. of the Catchment Master Plan for the Akanyaru catchment (appendix 06NAKN).

From paragraph 1.7.2.6 it is evident that the water balance of the catchment requires adjustment of the different demand categories. Notwithstanding this prerequisite, the review of the different demand categories did not reveal any good reason to reduce demand for any category other than the irrigation sector. For the latter the following changes are proposed

- irrigation by means of rainwater harvesting ponds: based on an increased estimate of the number of filling cycles of the ponds demand per pond is increased from 1,000 to 2,000 m³/year (10 filling cycles of a 200 m³ pond).
- irrigation by means of marshland development: notwithstanding the interesting performance and reduced investment and operational costs of this method, the full development potential as identified in the RIMP cannot be implemented because of insufficiency of available dry season resources by 2040. In order to correct the unadjusted water balance, the potential irrigation area of 59,000 ha will be curtailed to about 45,000 ha which reduces demand from about 120 MCM/year to 90 MCM/year. Part of the developed area will run into supply difficulties about once every four years whence the dry season production should not be engaged or supply should be topped up from groundwater resources.
- irrigation from surface water sources: this irrigation method is expensive in investment and exploitation costs; the latter especially when irrigating land at higher level from the water source level. Due to the unavailability of dry season water resources and giving preference to the marshland development (see previous bullet) no developments are scheduled for this category. The water demand for a single existing project (along Lake Cyohoha) has however been accounted for over the entire Master Plan time period. The entire potential irrigation area identified in the RIMP of 26,000 ha cannot be developed and the 195 MCM/year demand is reduced to 0.34 MCM/year.
- irrigation with surface water storage reservoirs: this irrigation method is expensive in investment cost (dam development and irrigation command area) yet it allows to carry over resources from the wet season to the dry season which reduces the vulnerability of the Akanyaru peat marshland for irreversible settling. The seemingly most interesting dam sites identified in the RIMP and by LWH project have been scheduled

for gradual implementation over the entire Master Plan period (2012-2040). A total of 14 projects have been endorsed for a total storage capacity of about 47 MCM with an estimated demand of 80 MCM/year. A schematic map of the reservoir sites and further details are provided in the Akanyaru catchment Master Plan report in appendix 06NAKN.

- irrigation demand from groundwater: this irrigation method is also susceptible to bring high exploitation costs for pumping. The area viable for exploitation has been estimated at about 25% of the area identified in the RIMP (2,380 ha). Water demand from this reduced command area is estimated at 4 MCM/year which can be implemented prior 2020.

Waste water treatment from urban and industrial water supply may provide a surplus which has so far been ignored

The adjusted water balance for the NAKN catchment is presented in the table below.

Table 33: Adjusted water balance NAKN 2012 - 2020 - 2030 - 2040.

volume data in '000 m³	annual total	oct	nov	dec	jan	feb	mar	apr	may	jun	jul	aug	sep
$Rs_{5\%}$	1,248,658	74,172	109,085	128,465	89,581	118,511	113,420	167,240	170,708	79,532	61,315	68,819	67,810
$Rs_{35\%}$	866,158	59,890	77,863	73,058	73,575	68,228	80,707	111,251	112,898	64,086	50,843	42,392	51,367
$Rs_{50\%}$	774,661	54,490	68,652	69,979	67,758	62,281	70,365	96,823	100,495	54,783	43,937	39,988	45,110
$Rs_{65\%}$	706,238	51,682	62,774	65,558	59,873	58,473	64,345	86,703	89,091	49,217	38,868	39,093	40,562
$Rs_{95\%}$	430,507	32,783	33,200	34,551	39,433	32,230	50,611	63,623	46,054	32,720	22,384	21,414	21,503
$gr.w._{50\%}$	531,701	36,569	38,563	39,893	51,861	49,866	56,515	63,623	47,872	45,212	36,569	33,244	31,914
Dem 2012	51,041	3,803	3,803	3,803	5,123	3,803	2,494	2,494	3,804	5,824	5,793	5,793	4,504
Surpl @ $_{95\%}$	379,466	28,980	29,397	30,748	34,309	28,427	48,118	61,129	42,250	26,896	16,591	15,621	16,999
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%
Dem 2020-low	148,461	7,642	7,642	7,642	10,964	7,642	4,471	4,471	7,643	23,464	23,369	23,369	20,142
Surpl @ $_{95\%}$	282,046	25,142	25,558	26,910	28,469	24,588	46,140	59,152	38,411	9,256	0	0	1,361
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=65%	>=65%	>=95%
Dem 2020-med	151,534	7,898	7,898	7,898	11,220	7,898	4,727	4,727	7,900	23,720	23,626	23,626	20,398
Surpl @ $_{95\%}$	278,973	24,886	25,302	26,654	28,212	24,332	45,884	58,896	38,155	9,000	0	0	1,105
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=65%	>=65%	>=95%
Dem 2020-high	153,676	8,076	8,076	8,076	11,399	8,076	4,906	4,906	8,078	23,899	23,804	23,804	20,576
Surpl @ $_{95\%}$	276,831	24,707	25,124	26,475	28,034	24,153	45,706	58,717	37,976	8,821	0	0	926
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=65%	>=65%	>=95%
Dem 2030-low	237,981	11,487	11,487	11,487	16,491	11,487	6,783	6,783	11,489	38,991	38,755	38,755	33,987
Surpl @ $_{95\%}$	192,526	21,297	21,713	23,065	22,941	20,743	43,828	56,840	34,565	0	0	0	0
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=65%	>=65%	>=65%	>=65%
Dem 2030-med	247,907	12,314	12,314	12,314	17,318	12,314	7,610	7,610	12,316	39,818	39,582	39,582	34,814
Surpl @ $_{95\%}$	182,600	20,469	20,886	22,237	22,114	19,916	43,001	56,013	33,738	0	0	0	0
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=65%	>=50%	>=50%	>=65%
Dem 2030-high	255,856	12,976	12,976	12,976	17,981	12,976	8,273	8,273	12,978	40,481	40,245	40,245	35,476
Surpl @ $_{95\%}$	174,651	19,807	20,224	21,575	21,452	19,253	42,339	55,350	33,076	0	0	0	0
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=65%	>=50%	>=35%	>=65%
Dem 2040-low	298,497	16,134	16,134	16,134	23,359	16,134	9,505	9,505	16,136	45,859	45,481	45,481	38,634
Surpl @ $_{95\%}$	132,010	16,649	17,066	18,417	16,073	16,096	41,107	54,118	29,918	0	0	0	0
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=65%	>=35%	>=5%	>=65%
Dem 2040-med	325,496	18,384	18,384	18,384	25,609	18,384	11,755	11,755	18,386	48,109	47,731	47,731	40,884
Surpl @ $_{95\%}$	105,011	14,400	14,816	16,168	13,823	13,846	38,857	51,868	27,668	0	0	0	0
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=65%	>=35%	>=5%	>=50%
Dem 2040-high	349,414	20,377	20,377	20,377	27,603	20,377	13,748	13,748	20,379	50,103	49,725	49,725	42,877
Surpl @ $_{95\%}$	81,093	12,406	12,823	14,174	11,830	11,853	36,864	49,875	25,675	0	0	0	0
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=50%	>=35%	>=5%	>=50%

In comparison with the unadjusted water balance discussed in section 1.7.2.1, the stress conditions do not seem to have been entirely solved:

- for the 2020 adjusted balance we observe an increase of annual water demand by some 12 MCM which is related to the early implementation of admissible commercial water use (irrigation activities). The dry season surplus during the once in twenty year dry year is zero and the frequency of demand not being met is in-between once every three years and once every twenty years. When considering that storage capacity to the amount of 13 MCM is programmed for construction and that this will allow for an extra flow of some 3 MCM per month over the three driest months, the 95 % reliability minimum monthly flow can be raised from 21.5 to 24.5 MCM which is just ahead of the dry season monthly demand (23.4 to 23.8 MCM/month depending on the scenario). The water balance is tight but in manageable equilibrium for the 2020 situation.

- for the 2030 adjusted balance the annual adjusted demand has been reduced by some 31 MCM which is related to the non implementation of a number of irrigation activities (especially irrigation from surface water). The storage capacity programmed for implementation stands at close to 30 MCM which allows for surplus dry season resources of some 6 MCM/month; not enough to guarantee sufficient resources for the once in twenty year dry conditions but enough to make sure that marshland irrigation can be successful during the dry season for most years (4 MCM/month better than the once in three year dry conditions; possibly once in 5 to 10 years).
- for the 2040 adjusted balance the demand has been reduced by a very substantial 190 MCM as compared with the unadjusted version. In comparison with the 2030 situation there is some additional demand that mostly comes from the non irrigation categories and stands for an additional 7 to 8 MCM/month during the dry season. The total storage of 47 MCM will allow for a monthly surplus of 8 to 10 MCM/month which brings the frequency of dry season stress rather approximately to a 'once in three' to 'once in five' year event.

Note that less water-efficient irrigation methods (surface irrigation) allow for dry season water reuse and are thus beneficial for practical water management with a stretched water balance.

Note also that the wet season 'yellows' that show up from 2030 onwards, all occur under the 95% reliability or once in twenty year dry conditions with surpluses that are insufficient for the rather arbitrary environmental flow requirement; hence, this is not really problematic.

In conclusion, the limited (Rwandan) renewable resources of the catchment are stretched but manageable. It is important to monitor the resources and demand situation as it evolves during the lifetime of the Master Plan and to adjust the plan when needed.

The vulnerable spot of the entire catchment is the dry season water table of the Akanyaru marshland which should be maintained at higher levels in order to prevent irreversible settling which may even bring a lowering of the Cyohoha south Lake water table with possibly grave and unpredictable consequences.

A further risk factor is the early sedimentation of the numerous surface storage reservoirs. The construction of this series of 14 reservoirs which is essential for sustainable water management in the catchment should be accompanied with effective erosion protection measures[8]. It is understood that Minagri has experience with the containment of reservoir sedimentation.

The graphs below highlight the importance of the different demand categories and the fraction consumptive demand over the average renewable resources, as well as the distribution of this demand during the months of the year for the maximum development condition for 2014. Intermediate graphs for 2012, 2020, and 2030 are presented in the CKIV Catchment Master Plan presented in appendix 01CKIV.

[8] The examination of the catchment water balances has not considered sediment deposition in the live storage capacity of the surface water storage reservoirs.

Table 34: Resources and demand pie chart graph for NAKN 2040 - high demand scenario

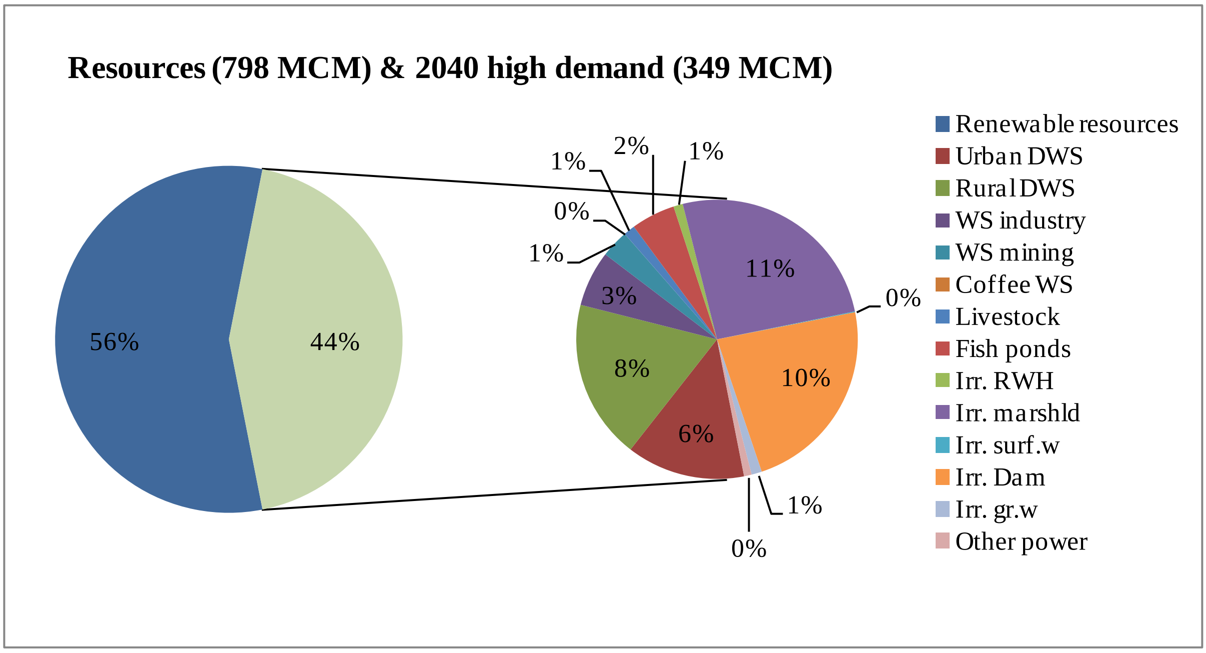
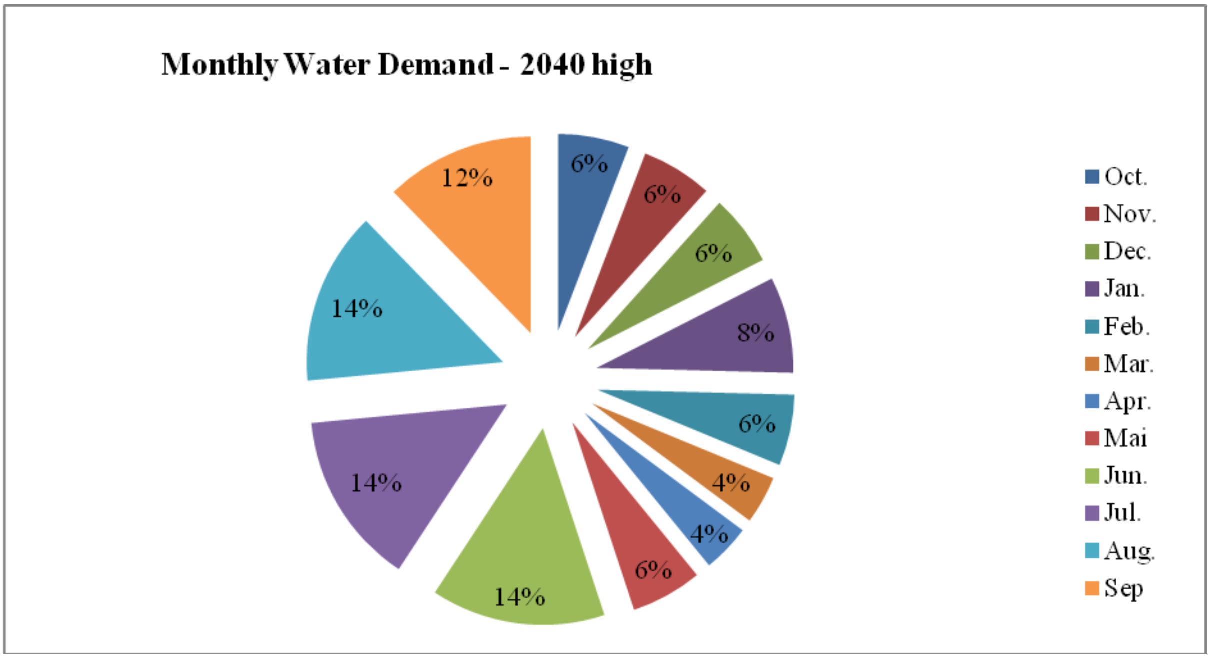


Table 35: Monthly demand distribution for NAKN 2040 - high demand scenario



For the period up to 2040, annual demand increases to about 44 % of the average renewable resources (this was 68% for the unadjusted water balance in section 1.7.2.6).

The principal consumptive demand categories are rural water supply, urban water supply, irrigation from dam sites and marshland irrigation. Demand for industries, mining and fishponds is not very important in terms of consumptive use but is likely to yield very significant revenue per cubic meter.

The distribution of demand during the year is rather uneven with more than half the demand realized during the four dry season months (June - September).

Further issues on water resources and their use are related to drought in some selected tributaries, flooding, pollution, erosion and appropriate land use aiming for economic, social and environmental sustainability. The vulnerability of the peat-based Akanyaru marshland is specifically important and a reasonably high water table should be guaranteed at all time.

Details on water use and demand under extreme conditions and exploitation risks as obtained from the District Survey, are discussed in section 3.3.5.1. of the NAKN Catchment Master Plan presented in appendix 06NAKN.

1.7.3.7 ADJUSTED DEMAND AND WATER BALANCE FOR NAKU

Details of the demand analysis for the NAKU catchment are given in paragraph 3.3.3. of the Catchment Master Plan for the Upper Akagera catchment (appendix 07NAKU).

From paragraph 1.7.2.7 it is clear that the water balance of the catchment is not sustainable and requires a reduction of demand. Nonetheless, demand for potable water supply, sanitation, industries, mining, livestock, fisheries, hydropower, non consumptive and other energy demand was reviewed and thereupon maintained as is. A number of changes is however proposed for the irrigation sector as follows:

- irrigation by means of rainwater harvesting ponds: based on an increased estimate of the number of filling cycles of the ponds demand per pond is increased from 1,000 to 2,000 m^3/year (10 filling cycles of a 200 m^3 pond).
- irrigation by means of marshland development: because of the interesting performance and reduced investment and operational costs of this method, the full development potential as identified in the RIMP has been put forward for development during the first and second stages of the Master Plan (2012-2020 and 2020-2030) The per hectare water demand for this method remains at 2,000 m^3/ha/yr.
- irrigation from surface water sources: this irrigation method is expensive in investment and exploitation costs; the latter especially when irrigating land at higher level from the water source level. For this reason, for the limited resources of this catchment and for the not so convincing soil suitability of the areas identified in the RIMP, the 55,000 ha foreseen in the RIMP report has reconsidered. The area identified has been separated in 4 'lift classes' from which only the lowest lift class (0-25 m lift from source level) is retained for irrigation development for a total command area of 11,500 ha plus 1969 ha already implemented. The per hectare water demand for this method (7,000 m^3/ha/yr) has not been changed. This resulted in a reduction of water demand from 407 MCM/year to 94 MCM/year.
- irrigation with surface water storage reservoirs: this irrigation method is expensive in investment cost (dam development and irrigation command area) and an effort has been made to assess the viability of the different sites identified in the RIMP and from the LWH report. Out of 20 identified sites 11 have been found sufficiently interesting in terms of site configuration and storage volume. The water demand from this irrigation method was initially based on command area (assuming that storage was sufficient) and the runoff in the catchment. The update of the demand (which

comprises multipurpose use) has given a similar result (from 47.4 MCM/year to 49.5 MCM/year).

The upper Akagera catchment requires a dry season transfer of 82 MCM for 2040 once in twenty year dry conditions which can be provided by upper Nyabarongo and Mukungwa catchments under the same (dry) conditions.

The adjusted water balance for the NAKU catchment is presented in the table below.

Table 36: Adjusted water balance NAKU 2012 - 2020 - 2030 - 2040.

volume data in '000 m³	annual total	oct	nov	dec	jan	feb	mar	apr	may	jun	jul	aug	sep
$Rs_{5\%}$	673,170	48,331	57,528	60,128	56,777	57,305	61,020	63,323	67,324	61,353	53,412	41,207	45,463
$Rs_{35\%}$	531,383	39,194	45,497	49,594	46,844	45,537	47,169	52,143	54,762	51,294	35,623	30,154	33,573
$Rs_{50\%}$	502,501	35,147	43,340	46,852	44,265	44,003	44,342	51,118	53,228	48,053	33,576	27,096	31,481
$Rs_{65\%}$	478,721	32,941	40,081	44,896	42,082	42,116	42,754	50,314	52,144	45,871	30,856	25,153	29,512
$Rs_{95\%}$	350,708	26,089	31,449	28,983	32,004	35,245	33,536	36,804	41,338	27,453	21,543	16,322	19,941
$gr.w._{50\%}$	351,095	26,118	31,484	29,015	32,039	35,284	33,573	36,845	41,384	27,484	21,567	16,340	19,963
Dem 2012	39,841	2,940	2,940	2,940	3,890	2,940	2,936	2,000	2,942	4,103	4,061	4,061	4,089
Surpl @ $_{95\%}$	310,867	23,149	28,509	26,043	28,114	32,305	30,600	34,804	38,397	23,351	17,483	12,261	15,853
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%
Dem 2020-low	145,989	8,074	8,074	8,074	12,926	8,074	7,988	3,316	8,076	20,426	20,357	20,357	20,246
Surpl @ $_{95\%}$	204,719	18,015	23,375	20,909	19,077	27,171	25,548	33,488	33,262	7,027	1,186	0	0
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=65%	>=65%
Dem 2020-med	148,462	8,280	8,280	8,280	13,132	8,280	8,194	3,522	8,282	20,632	20,563	20,563	20,452
Surpl @ $_{95\%}$	202,246	17,809	23,169	20,703	18,871	26,965	25,342	33,282	33,056	6,821	980	0	0
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=65%	>=65%
Dem 2020-high	150,174	8,423	8,423	8,423	13,275	8,423	8,336	3,664	8,425	20,775	20,706	20,706	20,595
Surpl @ $_{95\%}$	200,534	17,666	23,026	20,560	18,729	26,822	25,199	33,140	32,914	6,678	838	0	0
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=65%	>=65%
Dem 2030-low	243,734	13,373	13,373	13,373	21,862	13,373	13,197	5,066	13,374	34,362	34,190	34,190	34,003
Surpl @ $_{95\%}$	106,974	12,717	18,077	15,610	10,141	21,873	20,339	31,738	27,964	0	0	0	0
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=65%	>=35%	>=5%	>=5%
Dem 2030-med	251,622	14,030	14,030	14,030	22,520	14,030	13,854	5,723	14,032	35,020	34,847	34,847	34,661
Surpl @ $_{95\%}$	99,086	12,059	17,419	14,953	9,484	21,215	19,682	31,081	27,307	0	0	0	0
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=65%	>=35%	>=5%	>=5%
Dem 2030-high	257,939	14,556	14,556	14,556	23,046	14,556	14,380	6,249	14,558	35,546	35,373	35,373	35,187
Surpl @ $_{95\%}$	92,769	11,533	16,893	14,427	8,958	20,689	19,155	30,555	26,780	0	0	0	0
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=65%	>=35%	>=5%	>=5%
Dem 2040-low	285,647	16,507	16,507	16,507	26,214	16,507	16,151	7,161	16,508	38,714	38,438	38,438	37,996
Surpl @ $_{95\%}$	65,061	9,583	14,943	12,476	5,790	18,739	17,385	29,643	24,830	0	0	0	0
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=65%	>=5%	>=5%	>=5%
Dem 2040-med	307,102	18,294	18,294	18,294	28,002	18,294	17,939	8,949	18,296	40,502	40,226	40,226	39,784
Surpl @ $_{95\%}$	43,606	7,795	13,155	10,688	4,002	16,951	15,597	27,855	23,042	0	0	0	0
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=65%	>=5%	>=5%	>=5%
Dem 2040-high	326,109	19,878	19,878	19,878	29,586	19,878	19,523	10,533	19,880	42,086	41,810	41,810	41,368
Surpl @ $_{95\%}$	24,599	6,211	11,571	9,105	2,418	15,367	14,013	26,271	21,458	0	0	0	0
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=65%	>=5%	<5%	>=5%

In comparison with the unadjusted water balance discussed in section 1.7.2.7 which proved completely unmanageable by 2040, the stress conditions seem to have been 'reduced' except for the dry season months:

- for the 2020 adjusted scenario we observe a slight decrease of annual water demand by some 10 MCM to about 150 MCM/year, but the dry season demand shows a slight increase and the stress conditions persist during exceptionally dry years whence environmental flow requirements may not be honored.
- for the 2030 adjusted scenario the annual water demand has decreased by 80 MCM to about 250 - 260 MCM/year. The dry season demand exceeds the renewable resources except for the wettest years, there is need for either local storage carry over from wet season to dry season or a transfer from upstream catchments. The wet season situation is fully under control.
- for the 2040 scenario the adjusted water balance demand has been reduced by 330 MCM to about 325 MCM/year which is slightly less than the twenty year dry year renewable resources. The wet season situation is very manageable but the dry season reveals absolute lack of resources with the dry season monthly demand exceeding even the two in three years wet conditions renewable resources.

Notwithstanding these observations the adjusted water balance is manageable because of the provision of surface water storage capacity within the catchment (26 MCM capacity by 2040) and an inter-basin transfer from the upstream catchments of at least 82 MCM (minimum for the once in twenty year dry conditions; less would be needed for 'normal' years).

In conclusion, the adjusted water balance table corroborates the notion that the proposed water demand scenarios are tight but can be handled successfully. This requires comprehensive monitoring of actual water use and renewable resources.

The graphs below highlight the importance of the different demand categories and the fraction consumptive demand over the average renewable resources, as well as the distribution of this demand during the months of the year for the maximum development condition for 2014. Intermediate graphs for 2012, 2020, and 2030 are presented in the NAKU Catchment Master Plan presented in appendix 07NAKU.

Table 37: Resources and demand pie chart graph for NAKU 2040 - high demand scenario

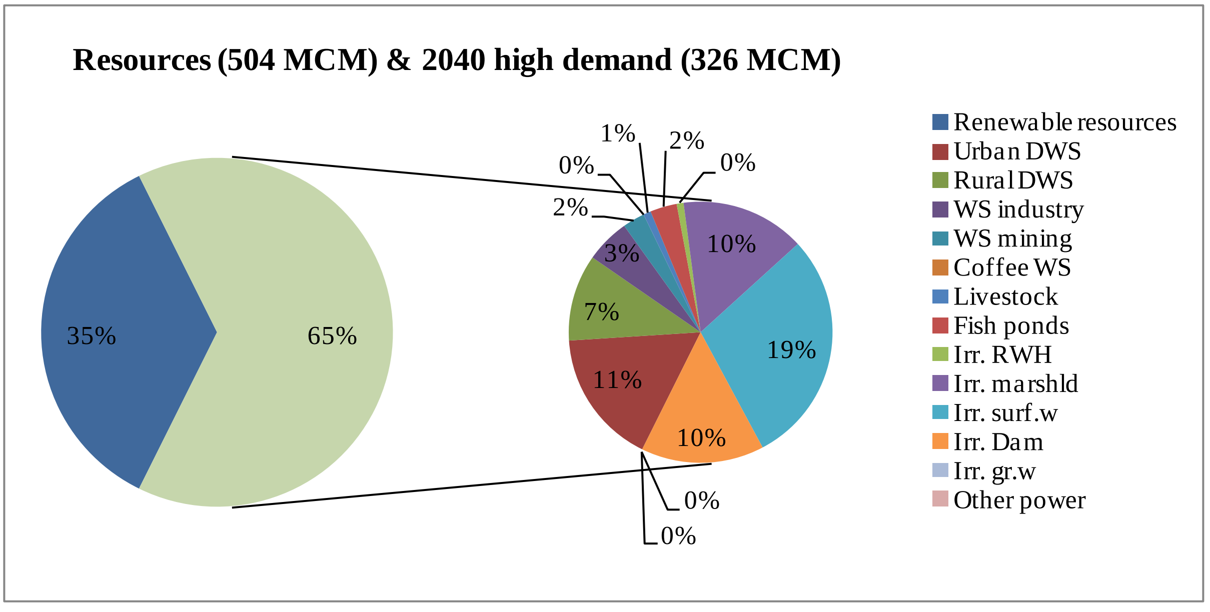
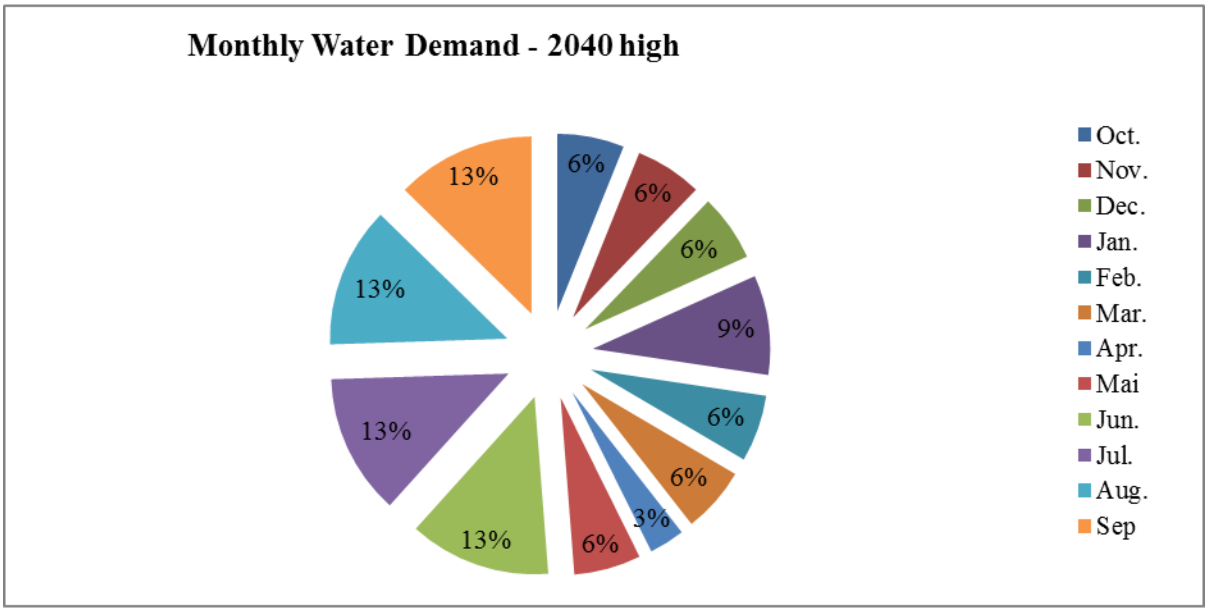


Table 38: Monthly demand distribution for NAKU 2040 - high demand scenario



For the period up to 2040, annual demand increases to about 65% of the average renewable resources (this was a completely unrealistic 130% for the unadjusted water balance in section 1.7.2.7). Notwithstanding the very substantial reduction of irrigation sector demand, the principal consumptive demand categories are irrigation (surface water, marshland and dam sites), urban and rural water supply and industries and mining.

The distribution of demand during the year is concentrated on the dry season which requires half the annual demand during its four months duration.

It is clear that this catchment requires state of the art resources and demand management especially as regards the irrigation developments which should be closely monitored. Considering the limited availability of water resources it is of utmost importance to select the best suitable land and aim for rational water use. Beyond the requirements of the primary use category (water to sustain livelihood), the highest return per cubic meter of water should be considered (if not rule). This generally means that the irrigation sector is the lowest priority user but within this sector there should be differentiation in priority between perennial crops (fruit trees, etc.) and seasonal crops, and between investment level costs (localized irrigation versus surface irrigation. Even when the irrigation sector may be the prime sector to endure the fluctuations of water availability, this doesn't mean that other sectors should not respond to temporarily reduced resources availability.

Further issues on water resources and their use are related to flooding, pollution, erosion and appropriate land use aiming for economic, social and environmental sustainability.

Details on water use and demand under extreme conditions and exploitation risks as obtained from the District Survey, are discussed in section 3.3.5.1. of the NAKU Catchment Master Plan presented in appendix 07NAKU.

1.7.3.8 ADJUSTED DEMAND AND WATER BALANCE FOR NAKL

Details of the demand analysis for the NAKL catchment are given in paragraph 3.3.3. of the Catchment Master Plan for the Lower Akagera catchment (appendix 08NAKL).

The unadjusted water balance for this catchment as presented in paragraph 1.7.2.8 clearly indicated that there is need for demand to be reduced in order to maintain a sustainable exploitation in case of full development by 2040. This reduction is specifically sought in the irrigation sector. Due to the important difference between the 2012 census data (~30 % above the projections based on the 2002 census data), the water demand from rural water supply has been revised upward. The changes from the unadjusted demand projections are as follows:

- rural drinking water supply has been increased by 31% for every time horizon and demand scenario of the Master Plan to account for the difference between the 2012 census data and the population projection data (from 2002 census) for this catchment. Due to the marginal demand from other categories this correction wasn't applied elsewhere.
- irrigation by means of rainwater harvesting ponds: based on an increased estimate of the number of filling cycles of the ponds demand per pond is increased from 1,000 to 2,000 m³/year (10 filling cycles of a 200 m³ pond).
- irrigation by means of marshland development: because of the interesting performance and reduced investment and operational costs of this method, the full development potential as identified in the RIMP (33,355 ha) has been allowed for with an annual demand of 2,500 m³/ha. The implementation schedule has been put forward a little bit in order to make optimum use of available resources. (2020 - 2030 - 2040 assumed implementation status is: 10,600 - 25,600 - 33,355 ha). The dry season water availability in the command areas of the Kamiramugezi and Karangaza rivers may be limited.
- irrigation from surface water sources: this irrigation method is expensive in investment and exploitation costs; the latter especially when irrigating land at higher level from the water source level. For this reason, the 33,000 + ha foreseen in the RIMP report has been separated in 4 altitude classes and only the lower 2 altitude classes (0-25 and 25-50 m lift from source level) for a total of 18,000 ha command area, have been considered for gradual development during the lifetime of the Master Plan. The per hectare water demand for this method (8,000 m³/ha/yr) has not been changed. Adjusted demand from this use category has consequently been reduced to 55 % of the initial demand (from 263 MCM/year to 144 MCM/year).
- irrigation with surface water storage reservoirs: this irrigation method is expensive in investment cost (dam development and irrigation command area and an effort has been made to assess the viability of the different sites identified in the RIMP. Eight out of 10 identified sites have been found sufficiently interesting in terms of site configuration and storage volume. A total storage volume of 21 MCM is supported but any further storage volume up to about 115 MCM for the total catchment will be effective and beneficial to the regulation and increased use of water resources. The water demand from this irrigation method progresses from 2, via 21 and 38 to 48 MCM/yr for 2012, 2020, 2030 and 2040 time horizon. This was initially set at 12 MCM/yr.
- irrigation demand from groundwater: this irrigation method is also susceptible to bring high exploitation costs for pumping. The area viable for exploitation has been

estimated at about 50 60 % of the area identified in the RIMP (8,548 ha). Water demand from this reduced command area (~5,000 ha) is estimated at 40 MCM/year which is gradually implemented over the period from 2012 - 2040.

The lower Akagera catchment requires a dry season transfer of 43 MCM for 2040 once in twenty year dry conditions which can be provided by upper Nyabarongo and Mukungwa catchments under the same conditions along with the transfer to the upper Akagera catchment's transfer of 82 MCM.

The adjusted water balance for the NAKL catchment is presented in the table below.

Table 39: Adjusted water balance NAKL 2012 - 2020 - 2030 - 2040.

volume data in '000 m³	annual total	oct	nov	dec	jan	feb	mar	apr	may	jun	jul	aug	sep
$Rs_{5\%}$	1,285,266	73,080	82,640	97,397	98,981	105,763	115,277	136,037	142,848	134,544	114,129	106,544	78,026
$Rs_{35\%}$	964,603	59,628	65,017	72,784	78,192	78,205	90,840	102,955	107,707	96,775	82,500	68,334	61,665
$Rs_{50\%}$	874,040	56,391	60,588	69,081	71,164	71,196	76,402	91,208	97,439	86,018	75,166	62,834	56,553
$Rs_{65\%}$	814,376	52,479	57,393	61,835	64,558	69,924	71,661	84,199	92,047	79,178	70,200	60,077	50,823
$Rs_{95\%}$	593,775	35,191	40,411	42,008	50,423	56,371	56,287	59,817	68,756	58,442	48,887	40,876	36,306
$gr.w._{50\%}$	536,000	31,767	36,479	37,921	45,517	50,886	50,810	53,997	62,066	52,756	44,130	36,899	32,773
Dem 2012	22,454	1,605	1,605	1,605	2,050	1,605	1,602	1,165	1,606	2,425	2,384	2,384	2,418
Surpl @ $_{95\%}$	571,321	33,586	38,805	40,403	48,373	54,766	54,684	58,652	67,150	56,018	46,503	38,492	33,888
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%
Dem 2020-low	128,576	6,864	6,864	6,864	11,852	6,864	6,783	1,959	6,864	18,477	18,436	18,436	18,313
Surpl @ $_{95\%}$	465,199	28,327	33,547	35,144	38,571	49,507	49,504	57,858	61,891	39,965	30,451	22,440	17,993
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%
Dem 2020-med	129,905	6,975	6,975	6,975	11,963	6,975	6,893	2,069	6,975	18,588	18,547	18,547	18,424
Surpl @ $_{95\%}$	463,870	28,217	33,436	35,034	38,460	49,396	49,393	57,748	61,781	39,855	30,340	22,329	17,882
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%
Dem 2020-high	130,758	7,046	7,046	7,046	12,034	7,046	6,965	2,141	7,046	18,659	18,618	18,618	18,495
Surpl @ $_{95\%}$	463,017	28,145	33,365	34,962	38,389	49,325	49,322	57,677	61,709	39,783	30,269	22,258	17,811
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%
Dem 2030-low	260,630	13,036	13,036	13,036	23,219	13,036	12,872	3,017	13,036	39,219	39,116	39,116	38,891
Surpl @ $_{95\%}$	333,145	22,156	27,375	28,973	27,204	43,335	43,414	56,800	55,720	19,223	9,771	1,760	0
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=65%
Dem 2030-med	264,886	13,390	13,390	13,390	23,574	13,390	13,227	3,372	13,391	39,574	39,471	39,471	39,246
Surpl @ $_{95\%}$	328,889	21,801	27,020	28,618	26,849	42,981	43,060	56,445	55,365	18,869	9,416	1,405	0
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=65%
Dem 2030-high	268,160	13,663	13,663	13,663	23,847	13,663	13,500	3,645	13,664	39,847	39,744	39,744	39,519
Surpl @ $_{95\%}$	325,615	21,528	26,747	28,345	26,576	42,708	42,787	56,172	55,092	18,596	9,143	1,132	0
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=65%
Dem 2040-low	370,418	18,955	18,955	18,955	34,093	18,955	18,628	4,146	18,956	54,940	54,775	54,775	54,284
Surpl @ $_{95\%}$	223,357	16,236	21,455	23,053	16,330	37,416	37,659	55,671	49,800	3,503	0	0	0
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=65%	>=65%	>=50%
Dem 2040-med	381,470	19,876	19,876	19,876	35,014	19,876	19,549	5,067	19,877	55,861	55,696	55,696	55,205
Surpl @ $_{95\%}$	212,305	15,315	20,534	22,132	15,409	36,495	36,738	54,750	48,879	2,582	0	0	0
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=65%	>=65%	>=50%
Dem 2040-high	391,178	20,685	20,685	20,685	35,823	20,685	20,358	5,876	20,686	56,670	56,505	56,505	56,014
Surpl @ $_{95\%}$	202,597	14,506	19,725	21,323	14,600	35,686	35,929	53,941	48,070	1,773	0	0	0
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=65%	>=65%	>=50%

In comparison with the unadjusted water balance discussed in section 1.7.2.8, the stress conditions do not seem to have been solved:

- current situation without any stress identified; some demand assumptions were adjusted.
- for the 2020 adjusted balance the demand is higher by some 15 MCM/year to about 130 MCM/year. This is related to the somewhat accelerated implementation of development opportunities (irrigation) The environmental flow requirement is a little bit comprised at the end of the dry season under a once in twenty year dry condition. No major issue however.
- for the 2030 adjusted scenario the annual water demand is higher by some 25 MCM/year to about 270 MCM/year and for the same reason as above. There is significant impact on the environmental flow which is however in practice not the case because of storage facilities and transfer of resources from upper catchments.
- for the 2040 scenario the adjusted water balance demand is lower by some 85 MCM/year which is due to the more realistic development levels of especially hill side and borehole irrigation. The impact on the environmental flow is less extreme in the balance but remains evident. In practice the balance will be fitting due to storage reservoirs and interbasin transfers.

In conclusion: while the table still highlights stress conditions, the additional measures, transfer and carrying over of resources from the wet to the dry season, assure a sustainable and manageable water balance up to 2040 under the high growth scenario.

The graphs below highlight the importance of the different demand categories and the fraction consumptive demand over the average renewable resources, as well as the distribution of this demand during the months of the year for the maximum development condition for 2014. Intermediate graphs for 2012, 2020, and 2030 are presented in the NNAKL Catchment Master Plan presented in appendix 08NAKL.

Table 40: Resources and demand pie chart graph for NAKL 2040 - high demand scenario

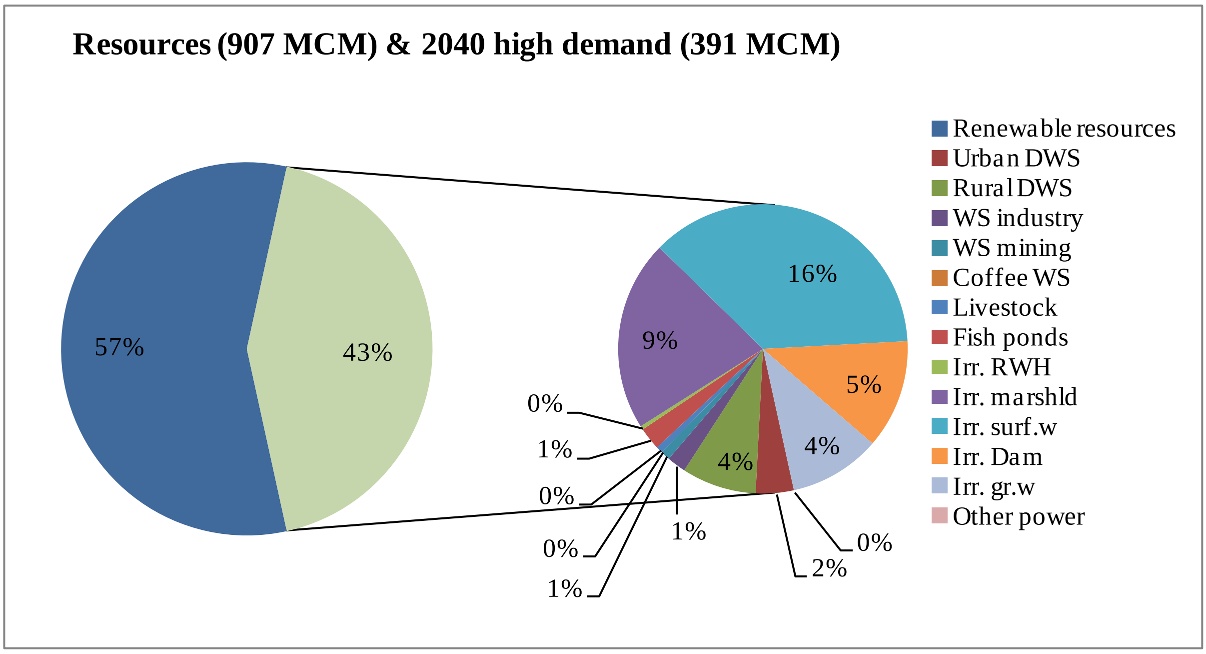
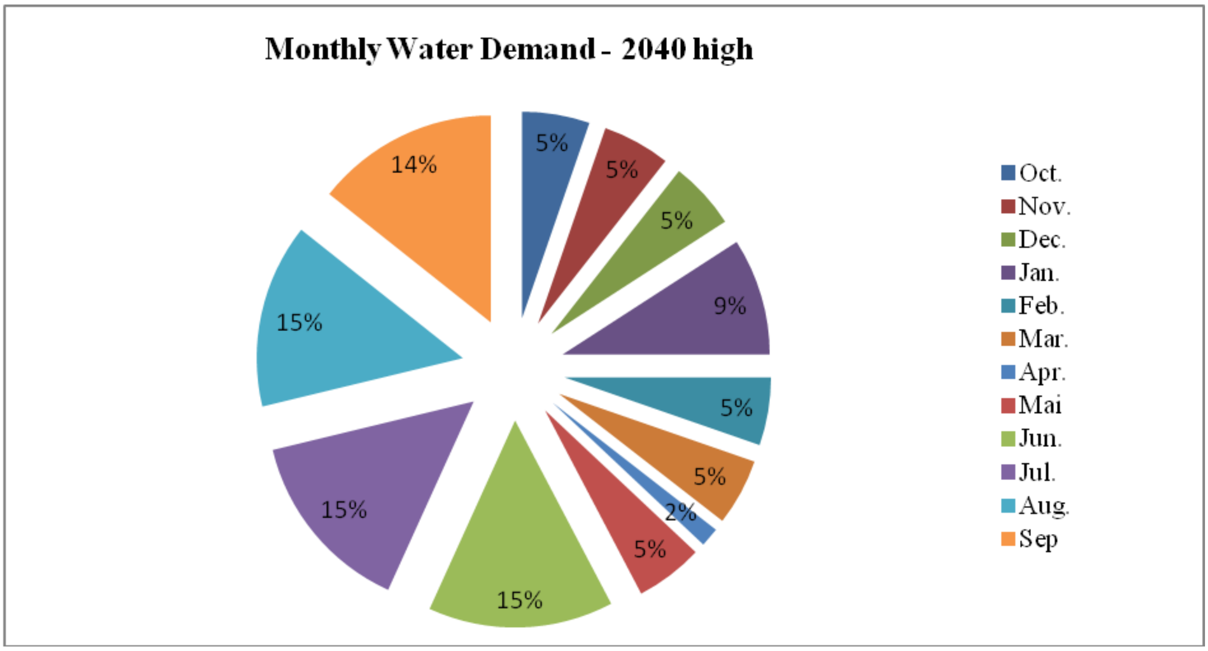


Table 41: Monthly demand distribution for NAKL 2040 - high demand scenario



For the period up to 2040, annual demand increases to about 43 % of the average renewable resources (this was 53 % for the unadjusted water balance in section 1.7.2.1).

The principal consumptive demand categories are irrigation (surface water, marshland and dam sites), with additional demand for rural and urban water supply. industries and mining. Water demand for industries, mining, livestock and fisheries is not very important but contributes significantly to revenue generation.

More than half the annual demand is registered during the four wet season months when resources availability is at its lowest.

State of the art water management procedures will be required sooner or later in order to control implementation of water resources development works and their exploitation. The access to groundwater resources (a very reliable source of supply) should be incorporated in these management procedures and preferably allocated to primary use categories (notably drinking water supply).

Further issues on water resources and their use are related to flooding, pollution and appropriate land use aiming for economic, social and environmental sustainability.

Details on water use and demand under extreme conditions and exploitation risks as obtained from the District Survey, are discussed in section 3.3.5.1. of the NAKL Catchment Master Plan presented in appendix 08NAKL.

1.7.3.9 ADJUSTED DEMAND AND WATER BALANCE FOR NMUV

Details of the demand analysis for the NMUV catchment are given in paragraph 3.3.3. of the Catchment Master Plan for the Muvumba catchment (appendix 09NMUV).

From the unadjusted water balance presented in paragraph 1.7.2.9 it is absolutely clear that the water balance of the catchment requires a substantial downward revision of demand.

Although the bulk of water demand comes from the irrigation sector, it is also proposed that the demand from industries be limited to the 2040 medium demand scenario (on the premise that water intensive industries be referred to other catchments with richer water availability). The changes of water demand in the irrigation sector are as follows:

- irrigation by means of rainwater harvesting ponds: based on an increased estimate of the number of filling cycles of the ponds demand per pond is increased from 1,000 to 2,000 m^3/year (10 filling cycles of a 200 m^3 pond).
- irrigation by means of marshland development: because of the interesting performance and reduced investment and operational costs of this method, the full development potential as identified in the RIMP has been put forward for development during the first and second stages of the Master Plan, the period prior to 2020 and between 2020 and 2030. The per hectare water demand for this method has been adjusted to 2,500 m^3/ha/yr). In order to support the water requirements during the second stage of the Master Plan a series of 4 reservoirs is proposed with a combined storage capacity of 34 MCM (or more).
- irrigation from surface water sources: this irrigation method is expensive in investment and exploitation costs; the latter especially when irrigating land at higher level from the water source level. Considering the imminent water stress in this catchment, no extension of this irrigation method is foreseen but the currently developed 400 ha can be maintained. The potential irrigation area foreseen in the RIMP was more than 10,000 ha but available water resources are deemed largely insufficient.
- irrigation with surface water storage reservoirs: this irrigation method is expensive in investment cost (dam development and irrigation command area and an effort has been made to assess the viability of the different sites identified in the RIMP and from the LWH report. All the 9 identified sites have been judged as sufficiently interesting in terms of site configuration and storage volume. Four of these sites are required to support the marshland irrigation and their water requirements are considered declared under that category. The water demand from 5 further sites to be implemented during the 2030 - 2040 planning period has been estimated at some 26 MCM.

The adjusted water balance for the NMUV catchment is presented in the table below.

Table 42: Adjusted water balance NMUV 2012 - 2020 - 2030 - 2040.

volume data in '000 m³	annual total	oct	nov	dec	jan	feb	mar	apr	may	jun	jul	aug	sep
$Rs_{5\%}$	290,071	22,974	34,164	26,179	18,623	20,148	20,605	36,243	36,165	20,772	18,006	17,761	18,433
$Rs_{35\%}$	198,480	16,342	17,065	16,883	15,839	15,739	16,398	18,235	18,018	16,420	15,951	15,683	15,907
$Rs_{50\%}$	185,593	15,314	16,080	15,957	14,706	14,901	15,337	17,124	16,990	15,169	14,694	14,666	14,655
$Rs_{65\%}$	172,744	14,287	15,169	14,923	14,007	13,656	14,169	16,063	15,962	14,141	13,403	13,400	13,564
$Rs_{95\%}$	108,685	8,662	11,025	10,689	8,358	6,390	7,572	13,716	13,684	8,423	5,602	6,246	8,320
$gr.w._{50\%}$	110,376	8,797	11,196	10,855	8,488	6,490	7,690	13,929	13,896	8,554	5,689	6,343	8,449
Dem 2012	22,908	1,383	1,383	1,383	1,745	1,383	1,379	1,024	1,383	2,976	2,952	2,952	2,969
Surpl @ $_{95\%}$	85,777	7,279	9,642	9,306	6,613	5,008	6,193	12,692	12,301	5,447	2,650	3,294	5,351
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%
Dem 2020-low	59,521	2,124	2,124	2,124	2,545	2,124	2,092	1,737	2,125	10,670	10,625	10,625	10,605
Surpl @ $_{95\%}$	49,165	6,537	8,900	8,564	5,813	4,266	5,480	11,979	11,559	0	0	0	0
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=65%	>=65%	>=65%	>=65%
Dem 2020-med	60,815	2,232	2,232	2,232	2,652	2,232	2,200	1,845	2,232	10,777	10,733	10,733	10,712
Surpl @ $_{95\%}$	47,871	6,430	8,793	8,456	5,706	4,158	5,372	11,871	11,451	0	0	0	0
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=65%	>=65%	>=65%	>=65%
Dem 2020-high	61,721	2,308	2,308	2,308	2,728	2,308	2,275	1,920	2,308	10,853	10,809	10,809	10,788
Surpl @ $_{95\%}$	46,965	6,354	8,717	8,381	5,630	4,082	5,296	11,795	11,376	0	0	0	0
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=65%	>=65%	>=65%	>=65%
Dem 2030-low	104,217	3,136	3,136	3,136	3,621	3,136	3,071	2,716	3,136	19,870	19,759	19,759	19,740
Surpl @ $_{95\%}$	4,468	5,526	7,889	7,553	4,737	3,254	4,501	11,000	10,547	0	0	0	0
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=5%	<5%	<5%	<5%
Dem 2030-med	108,434	3,488	3,488	3,488	3,973	3,488	3,423	3,068	3,488	20,221	20,110	20,110	20,091
Surpl @ $_{95\%}$	252	5,174	7,537	7,201	4,385	2,903	4,149	10,648	10,196	0	0	0	0
Reliab.%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=5%	<5%	<5%	<5%
Dem 2030-high	110,522	3,662	3,662	3,662	4,147	3,662	3,597	3,242	3,662	20,395	20,284	20,284	20,265
Surpl @ $_{95\%}$	0	5,000	7,363	7,027	4,211	2,729	3,975	10,474	10,022	0	0	0	0
Reliab.%	>=65%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=5%	<5%	<5%	<5%
Dem 2040-low	142,255	5,782	5,782	5,782	7,872	5,782	5,717	3,757	5,782	24,121	23,943	23,943	23,991
Surpl @ $_{95\%}$	0	2,880	5,243	4,907	486	608	1,855	9,959	7,901	0	0	0	0
Reliab.%	>=65%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	>=95%	<5%	<5%	<5%	<5%
Dem 2040-med	153,724	6,738	6,738	6,738	8,828	6,738	6,673	4,713	6,738	25,077	24,899	24,899	24,947
Surpl @ $_{95\%}$	0	1,924	4,287	3,951	0	0	899	9,003	6,946	0	0	0	0
Reliab.%	>=65%	>=95%	>=95%	>=95%	>=65%	>=65%	>=95%	>=95%	>=95%	<5%	<5%	<5%	<5%
Dem 2040-high	160,724	7,321	7,321	7,321	9,411	7,321	7,256	5,296	7,321	25,660	25,482	25,482	25,530
Surpl @ $_{95\%}$	0	1,341	3,704	3,368	0	0	316	8,420	6,362	0	0	0	0
Reliab.%	>=65%	>=95%	>=95%	>=95%	>=65%	>=65%	>=95%	>=95%	>=95%	<5%	<5%	<5%	<5%

In comparison with the unadjusted water balance discussed in section 1.7.2.9, the stress conditions do not seem to have been 'solved' at all:

- for the 2020 adjusted scenario we observe a slight increase of annual water demand by some 10 %, from about 55 MCM to about 60 MCM, from which the results an extension of the 0 surplus during all four months of the dry season and a deficit positioned between the once in twenty years and once in three years dry conditions;
- for the 2030 adjusted scenario the annual water demand is essentially identical between the two water balances yet, the supply reliability has apparently worsened as a twice in three years deficit situation for the unadjusted water balance now appears for 19 out of 20 years (adjusted water balance).

- for the 2040 scenario the adjusted water balance demand has been reduced by 50 to 60 MCM (depending on the low, medium or high scenario) but this scenario still shows a persistent deficit during the entire dry season for 19 out of 20 years.

Notwithstanding these observations the adjusted water balance is manageable because there is in inter-seasonal storage of about 35 MCM (1 MCM existing, 34 MCM new capacity to be implemented during 2020 - 2030) planned for the 2030 time horizon and about 43 MCM for the 2040 time horizon. This storage permits to carry over surplus capacity from the wet season to the dry season and provide sufficient resources for successful irrigation campaigns.

It can be read from the adjusted water balance table (Table 42 on preceding page) that the storage capacity of about 35 MCM foreseen for the 2030 time horizon, will be filled even during the once in twenty years dry year (surplus values at 95% dry conditions from the month of October up to May).

This is not the case for the 2040 time horizon when 43 MCM[9] of storage capacity has to be filled from surplus supply during the preceding wet season. Based on the substantial increase of renewable resources for the 65 % dry conditions, it can be deducted that seasonal carry over will partly fail once every ten years or so. For these circumstances, proper allocation procedures should be established which consider social, economic and environmental criteria to manage the scarcity.

In conclusion, the adjusted water balance table corroborates the notion that the proposed water demand scenarios are tight but can be handled successfully. This requires comprehensive monitoring of actual water use and renewable resources. If significant deviations from the plan occur, this catchment development plan needs to be adjusted.

The graphs below highlight the importance of the different demand categories and the fraction consumptive demand over the average renewable resources, as well as the distribution of this demand during the months of the year for the maximum development condition for 2014. Intermediate graphs for 2012, 2020, and 2030 are presented in the NMUV Catchment Master Plan presented in appendix 09NMUV.

[9] This assessment does not consider sediment deposition in the live storage capacity of the different reservoirs.

Table 43: Resources and demand pie chart graph for NMUV 2040 - high demand scenario

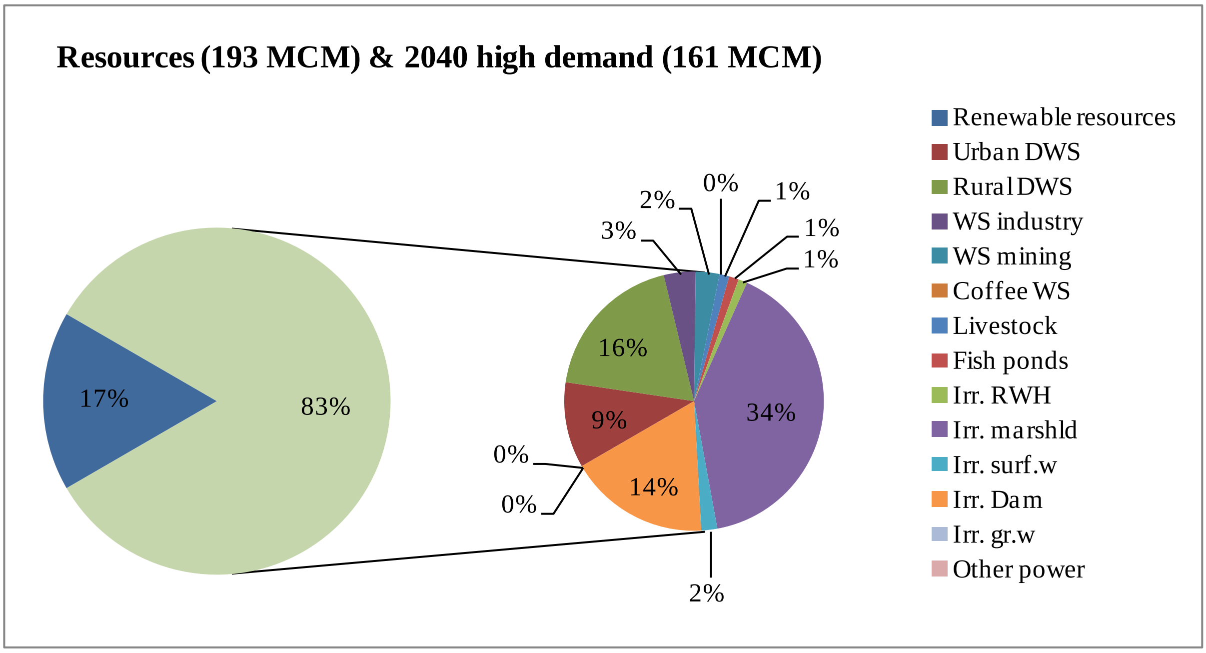
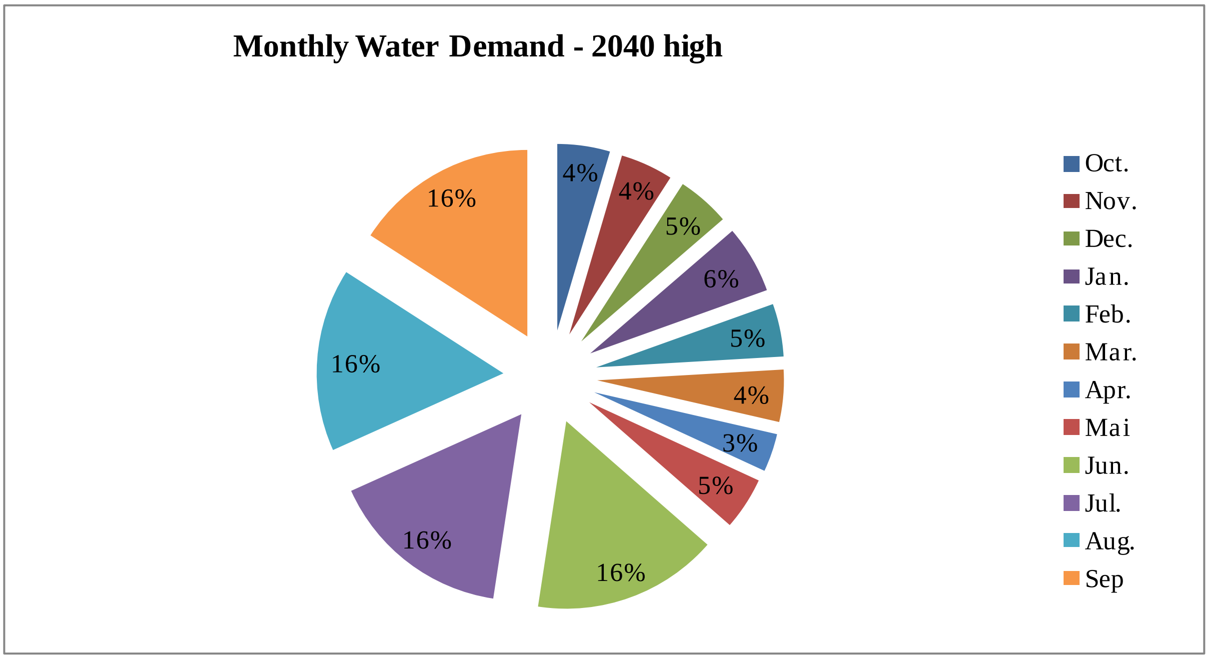


Table 44: Monthly demand distribution for NMUV 2040 - high demand scenario



For the period up to 2040, annual demand increases to about 83% of the average renewable resources (this was 112% for the unadjusted water balance in section 1.7.2.9). The principal consumptive demand categories are again irrigation (mainly marshland and dam irrigation, no long term resources for river supply), rural and urban water supply, with some complementary demand from industries, mining, livestock and fish ponds.

The water use is massively concentrated during the four dry season months.

With a targeted water use of 83% of the average annual renewable resources, the practical impossibility to provide for supplementary resources by means of inter basin transfer and notwithstanding development of important surface water storage capacity and possible flow from Uganda, it should be expected that partial deficits are encountered with a rather high frequency (once every two years or even more often).

These deficits may only fractionally be supported by non irrigation sector use hence the bulk of the deficits must be borne by the irrigation sector. This catchment requires state of the art resources and demand management especially as regards the irrigation developments which should be closely monitored. Considering the limited availability of water resources it of utmost importance to select the best suitable land and aim for rational irrigation development (not necessarily highest standard) and water use (not necessarily highest water efficiency). Beyond the requirements of the primary use category (water to sustain livelihood), the highest return per cubic meter of water should dominate. This generally means that the irrigation sector is the lowest priority user but within this sector there should be differentiation in priority between perennial crops (fruit trees, ...) and seasonal crops, and between investment level costs (localized irrigation versus surface irrigation. Even when the irrigation sector may be the prime sector to endure the fluctuations of water availability, this doesn't mean that other sectors should not respond to temporarily reduced resources availability.

Apart from the water scarcity in the entire north eastern part of the catchment, further issues on water resources and their use are related to flooding, pollution and appropriate land use aiming for economic, social and environmental sustainability.

Details on water use and demand under extreme conditions and exploitation risks as obtained from the District Survey, are discussed in section 3.3.5.1. of the NMUV Catchment Master Plan presented in appendix 09NMUV.

1.7.3.10 SUMMARY AND OVERVIEW OF ADJUSTED DEMAND AND WATER BALANCES

In the preceding paragraphs the particular relevance and adequacy of the different demand categories have been reviewed, and the availability of the renewable resources of the different catchments has been verified. For the catchments where resources are ultimately expected to be insufficient for full development, a number of measures has been proposed ranging from reduction of demand, intra annual regulation of resources (creation of surface water storage capacity), and transfer of additional resources from other catchments. A further option is the reuse of used water (if needed after treatment) which may ultimately become important when the sanitation of urban water use pushes off and it is recommended to be implemented in the irrigation sector. At the level of detail of this national study it is not very realistic to rely on this technique but it should be taken up when more precise catchment Master Plans are developed; this latter action is highly recommended.

The results of the review and verification of the water resources and their use in the nine catchment can be summarized as follows:

1. Lake Kivu catchment:
    - surplus water balance up to 2040 and beyond
    - land and water resources protection mandatory
    - development of surface water storage facilities (4 sites endorsed)
    - development of rural and urban water supply

- o surface water irrigation from lake Kivu if water quality issue can be solved
- o micro scale hydropower potential

2. Rusizi catchment
   - o surplus water balance up to 2040 and beyond but imminent deficit in Rubyiro tributary (CRUS_1)
   - o land and water resources protection mandatory
   - o development of rural and urban water supply
   - o surface water irrigation from Rusizi river if water quality issue can be solved
   - o micro and medium scale hydropower potential
3. Upper Nyabarongo catchment
   - o surplus water balance up to 2040 and beyond
   - o land and water resources protection mandatory
   - o development of surface water storage facilities (7 sites endorsed)
   - o development of rural and urban water supply
   - o marshland irrigation (23,000 ha)
   - o micro scale hydropower potential
4. Mukungwa catchment
   - o surplus water balance up to 2040 and beyond
   - o land and water resources protection mandatory
   - o development of rural and urban water supply
   - o micro scale hydropower potential
5. Lower Nyabarongo catchment
   - o tense equilibrium water balance up to 2040 (but no need for transfer)
   - o land and water resources protection mandatory
   - o superior water management essential
   - o development of surface water storage facilities (12 sites endorsed plus development of Muhazi Lake as reservoir)
   - o development of urban and rural water supply
   - o marshland irrigation (30,000 ha)
   - o river and lake irrigation (5,000 ha)
   - o groundwater irrigation (4,000 ha)
   - o micro scale hydropower potential
6. Akanyaru catchment
   - o tense equilibrium water balance up to 2040 (transfer not possible)
   - o land and water resources protection mandatory with i) Akanyaru river vulnerable and ii) drought prone tributaries in shallow granite deposits
   - o superior water management essential
   - o development of surface water storage facilities (14 sites endorsed)
   - o development of rural and urban water supply
   - o marshland irrigation (45,000 ha limit on potential of 59,000 ha)
   - o river and lake irrigation further <u>development to be discontinued</u>
   - o micro scale hydropower potential
7. Upper Akagera catchment
   - o deficit equilibrium water balance by 2040 (up to 82 MCM transfer by 2040)
   - o land and water resources protection mandatory
   - o superior water management essential
   - o development of surface water storage facilities (11 sites endorsed)

- development of urban and rural water supply
- marshland irrigation (25,000 ha limit on potential of 36,000 ha)
- river and lake irrigation (11,500 ha limit on potential of 55,000 ha)
- medium scale hydropower potential (Rusumo falls)

8. Lower Akagera catchment
   - deficit equilibrium water balance by 2040 (up to 43 MCM transfer by 2040)
   - land and water resources protection mandatory
   - superior water management essential
   - development of surface water storage facilities (8 sites endorsed)
   - development of rural and urban water supply
   - marshland irrigation (33,000 ha with likely recurrent deficits for Kamiramugezi and Karangaza rivers)
   - river and lake irrigation (18,000 ha suitable from potential of 33,000 ha)
   - groundwater irrigation (5,000 ha)

9. Muvumba catchment
   - extremely tense equilibrium water balance by 2040 (transfer not possible)
   - land and water resources protection mandatory
   - superior water management essential
   - development of surface water storage facilities (9 sites endorsed for maximum storage capacity development)
   - development of rural and urban water supply
   - marshland irrigation (26,000 ha supplied by 4 strategic reservoirs with recurrent deficits)
   - river and lake irrigation <u>further development to be stopped</u>
   - micro scale hydropower potential

The review of the catchment water balances for the period from 2012 up to 2040 permits to prepare annual flow schedules. These schedules are presented in the diagrams on the next pages for the medium demand scenario of 2012 and the highest growth (maximum demand) scenarios for 2020, 2030 and 2040 assuming average resources conditions (Figure 9 up to Figure 12). Each schedule presents the Congo basin on the left and the Nile basin on the right.

A brief explanation of the parameters presented in the flow schedule is as follows:

- arrows indicate flow direction and the arrow width refers to the magnitude of flow.
- 'inflow' is the uncommitted annual volume in MCM that enters the catchment from upstream
- 'flow' is the annual volume in MCM that is generated within the catchment on Rwandan territory
- 'use' is the annual volume in MCM that is spent within the catchment
- 'balance' is the volume in MCM of changed ground or surface water resources; this value is typically zero for an annual flow schedule but would be positive or negative for monthly flow schedules
- 'transfer' is the volume in MCM that is specifically transferred from a surplus catchment to a deficit catchment in order to sustain the water demand of the deficit catchment
- 'outflow' is the uncommitted volume in MCM that leaves the catchment downstream

All volume are counted for the time step of the schedule; in this case a single year.

Within an international context, the flow schedules based on average resources conditions and medium (1012) and high (later years) demand, indicate a moderate reduction of annual outflow for the Congo basin from 1,295 MCM to 1,064 MCM (82 % remaining). For the Nile basin the reduction is stronger from 5,077 MCM to 3,442 MCM (68 % remaining).

Similar schedules can be prepared for non average resources conditions; the 5%, 35%, 50%, 65% and 95% resources reliability conditions. Especially for the dryer resources conditions, the impact from Rwandan use on the outflow will be stronger.

As already hinted while discussing the 'Balance', the annual flow schedules could be further split to represent the monthly situation. The monthly flow schedules could then be compared with the actual situation provided that the level of monitoring of resources and their use is sufficient. Such practice is extremely helpful for adequate water management which will soon be required for especially the lower Nyabarongo, Akanyaru, upper and lower Akagera, and Muvumba rivers.

A sample of the monthly flow schedule for the high demand situation during the month of August for the 2040 situation is presented in Figure 13. All catchment balances are negative which implies that the catchment resources content (natural and artificial surface water storage and groundwater storage) are being depleted. The catchment balances are estimated from marshland (lowering of groundwater table) and surface water reservoir depletion only. Further depletion from general groundwater reserves has not been accounted for.

Figure 9: Annual flow schedule for nine catchments - medium demand situation 2012

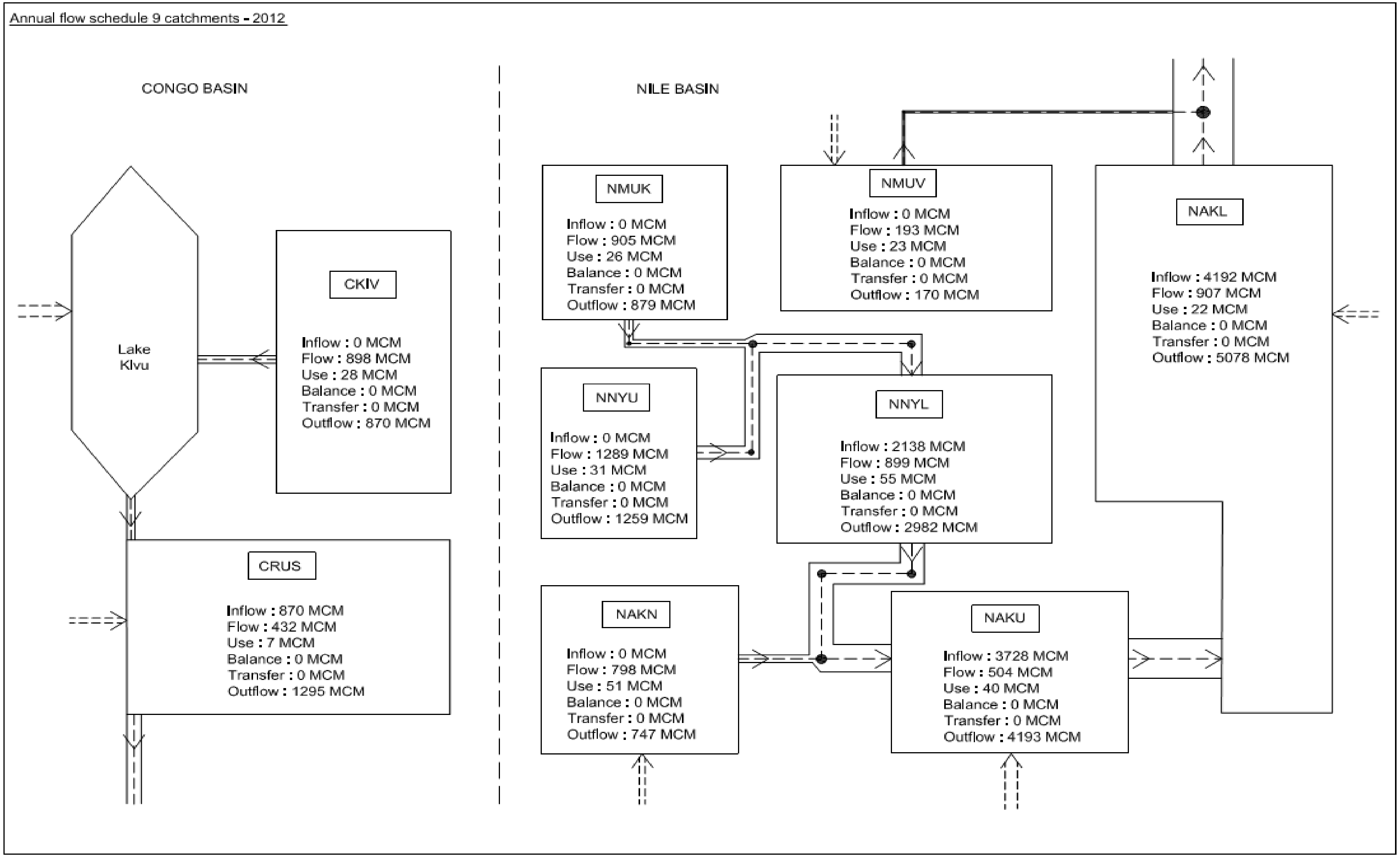


Figure 10: Annual flow schedule for nine catchments - high demand situation 2020

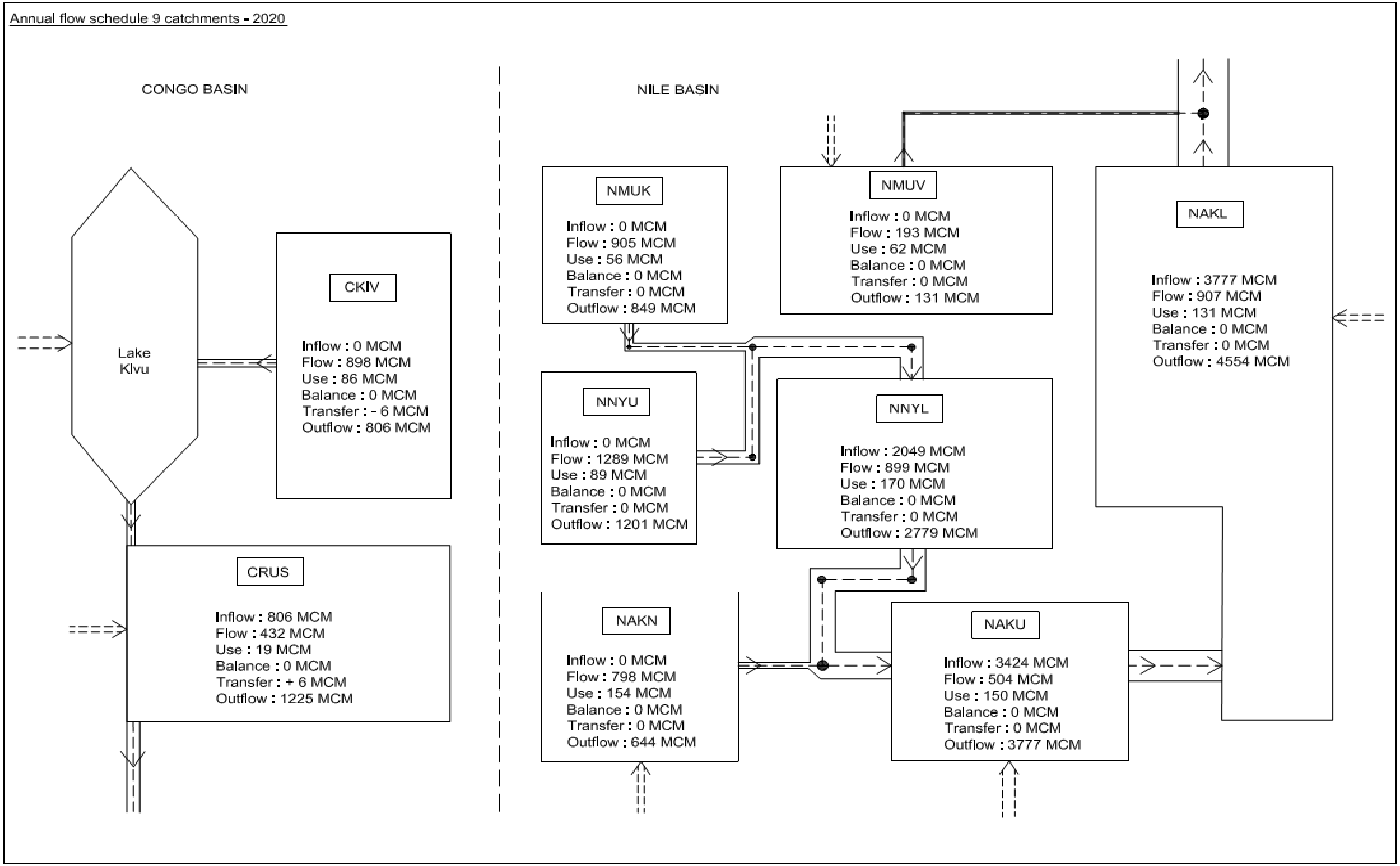


Figure 11: Annual flow schedule for nine catchments - high demand situation 2030

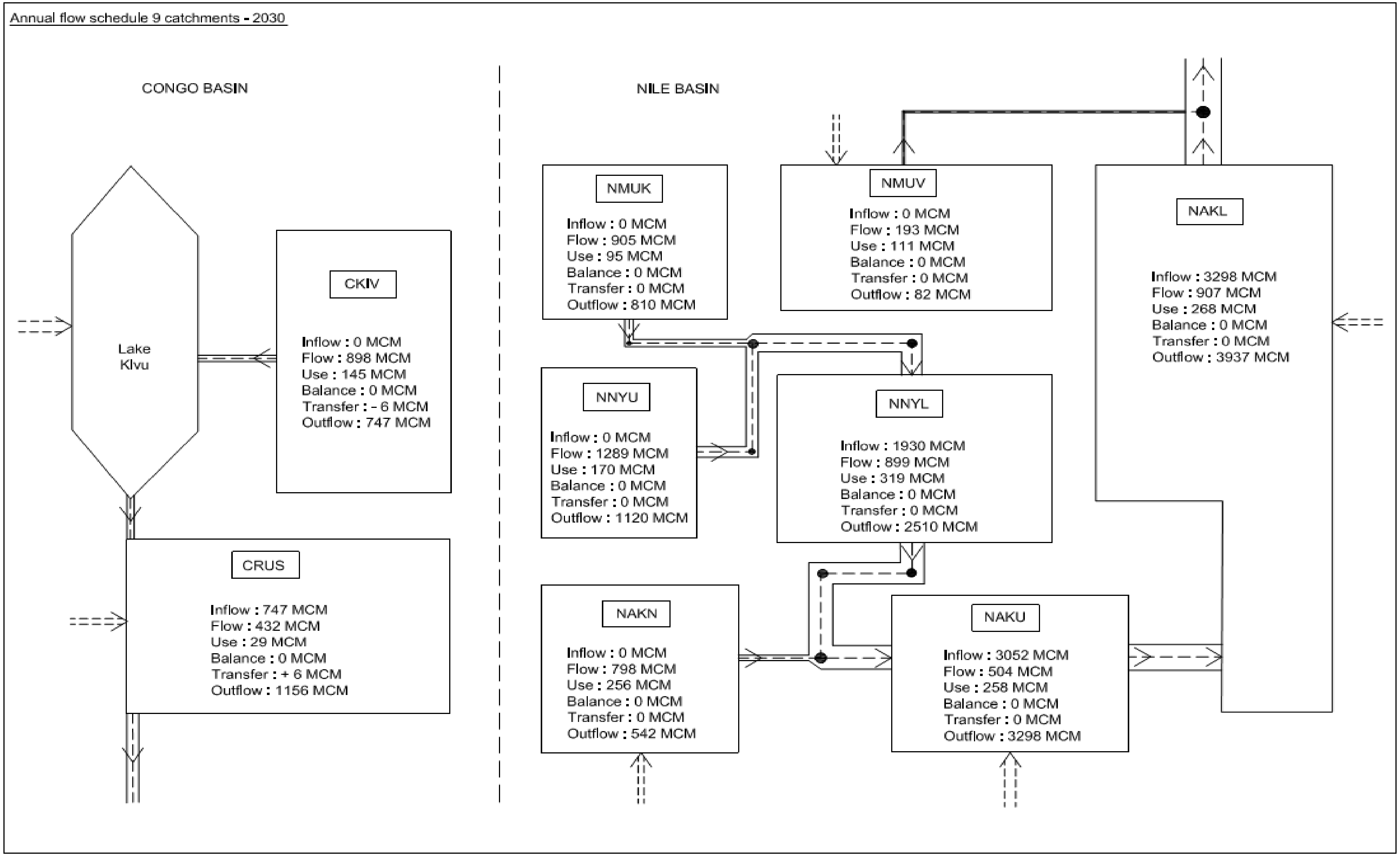


Figure 12: Annual flow schedule for nine catchments - high demand situation 2040

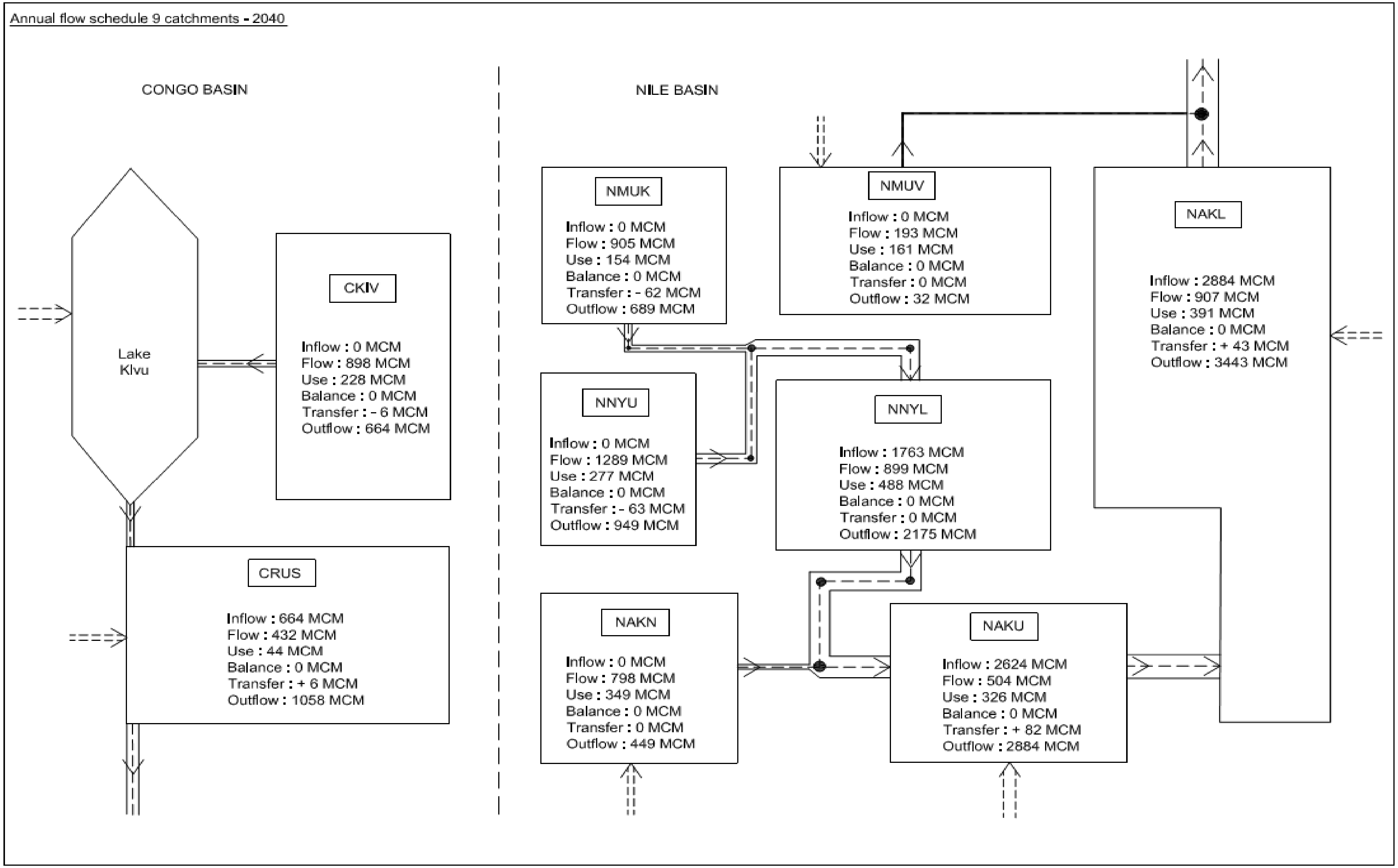
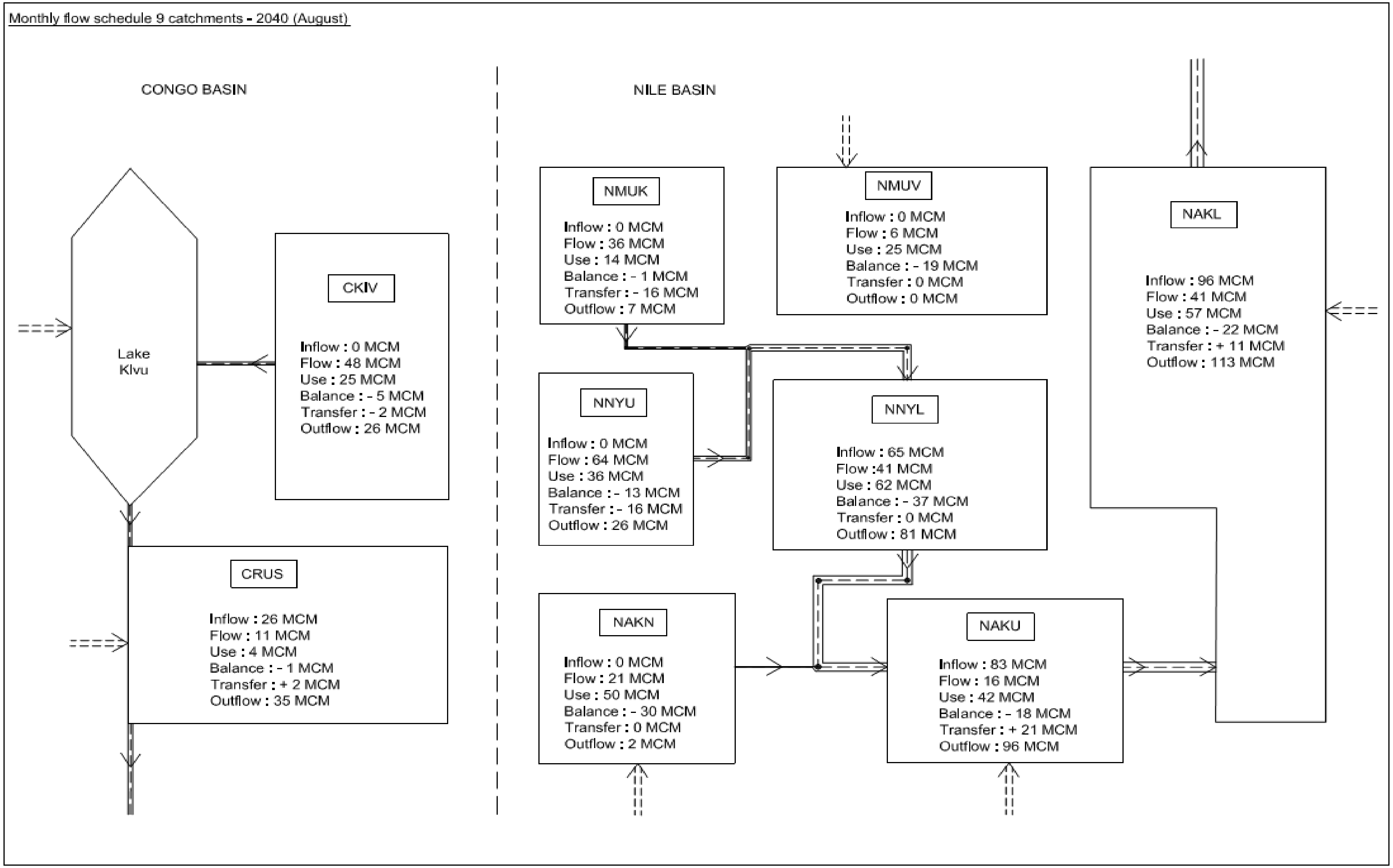


Figure 13: Monthly flow schedule for nine catchments - high demand situation August 2040



1.8 WATER RESOURCES DEVELOPMENT PROGRAM

The detailed Master Plan investment program for the medium growth scenario for each catchment is presented in the corresponding Catchment Master Plan in the nine appendixes. This investment program is presented as a table with the investment costs for the different demand categories over three investment periods running from 2014 - 2020, 2021 - 2030 and 2031 - 2040.

The table for each catchment contains estimates for investment costs mostly as they may incur to the government of Rwanda and based on the medium demand scenario. Thus costs for drinking water supply and sanitation, industries, and monitoring are presented. Costs for irrigation development have also been included although it is very questionable whether such costs should be borne by government. In general all water resources development costs for commercial ventures (hence including irrigation) should be borne by the private sector with government or its representative as regulator and controller. The costs for such private investments are not included in the investment tables.

The assumptions and calculations for the investment cost estimates for the different demand categories are presented in annex C2_6. The procedure for the estimation of investment costs per catchment is explained as follows:

- all investment need is based on a volume of water to be produced per annum; this is expressed in TCM/yr (Thousand Cubic Meter per year). The volume is derived from the difference between the projected demand at the start and at the end of the planning period. Where needed, the total volume is partitioned according to the different demand locations in order to obtain a daily production capacity which is needed for the assessment of the unit costs. For instance the production volume of urban water supply for the CKIV catchment is partitioned between Rubavu, Karongi, Rusizi and 9 emerging centers.
- the unit cost is the investment cost per cubic meter produced during the lifetime of the investment (mostly averaged to 20 years, sometimes 10 or 15 years for the entire investment comprising civil works and electromechanical equipment as may be the case) expressed in RWF per cubic meter. The level of the investment cost per cubic meter depends on the production capacity required. For instance, the cost of supply for an installation with a capacity of 10,000 m^3/day is estimated at 177 rwf/m^3 against 219 rwf/m^2 for an installation with a capacity of 2,000 m^3/day. The rwanda franc is assumed constant for its average 2013 value over the entire investment period.
- the investment finally expressed in MRWF (million Rwandan Franc) is the result of the unit cost multiplied with the cubic meter volume produced during the lifetime of the investment. For instance the expansion of water supply for Karongi for 661 TCM/yr at a unit investment cost of 219 rwf/m^3 requires 2,895 Mrwf (count 661,000 m^3/yr * 219 rwf/m^3 * 20 year / 1,000,000).

Details of the investment costs per catchment for the medium growth scenario are presented in catchment Master Plan documents. Summary tables for the low, medium and high growth scenarios are presented here below.

The estimated investment cost for water resources development works for the medium growth scenario are about 2.5 thousand billion RWF (~2.8 billion Euro) for the period up to 2020, with 2.7 and 5 thousand billion RWF for the following decades of 2021-2030 and 2031-2040.

The difference in investment between the different growth scenarios is not that important (a maximum 18% difference between medium and low growth scenario for 2040, the difference between medium and high growth is then just 13%). This can be explained by the fact that i) differentiation of population growth between the growth scenarios is less than the population increase over the entire planning period of more than 25 years and ii) irrigation and other investments are development opportunities that may be developed irrespective of population growth.

It further strikes that the difference between the first two planning periods is modest whereas the investment over the third planning period is much higher. This can be explained by the circumstance that the last planning period comprises reinvestment costs for the development actions of the first planning period after 20 years.

Table 45: Summary of government related investment costs - low growth scenario (in MRWF)

investment period / demand category	2014-2020	2021-2030	2031-2040
Total urban WS and sanitation	269.304	461.298	1.068.462
Total rural WS and sanitation	874.680	552.365	1.253.283
Total WS for irrigation	946.650	1.139.693	1.489.843
Other investments	262.248	113.230	268.789
Grand total	**2.299.157**	**2.382.246**	**4.069.116**

Table 46: Summary of government related investment costs - medium growth scenario (in MRWF)

investment period / demand category	2014-2020	2021-2030	2031-2040
Total urban WS and sanitation	305.590	544.002	1.329.237
Total rural WS and sanitation	962.782	722.382	1.563.626
Total WS for irrigation	977.871	1.321.180	1.640.081
Other investments	230.803	133.388	433.318
Grand total	**2.477.046**	**2.720.953**	**4.966.263**

Table 47: Summary of government related investment costs - high growth scenario (in MRWF)

investment period / demand category	2014-2020	2021-2030	2031-2040
Total urban WS and sanitation	303.757	591.644	1.511.084
Total rural WS and sanitation	1.041.108	821.427	1.863.306
Total WS for irrigation	977.871	1.321.180	1.640.081
Other investments	257.192	213.777	578.270
Grand total	**2.579.928**	**2.948.028**	**5.592.741**

A more detailed overview of investment costs per catchment per demand category and per planning period for the medium growth scenario is presented on the next table.

The vertical axis presents the investment cost in units of million RWF where 100,000 thus represents 100 billion RWF.

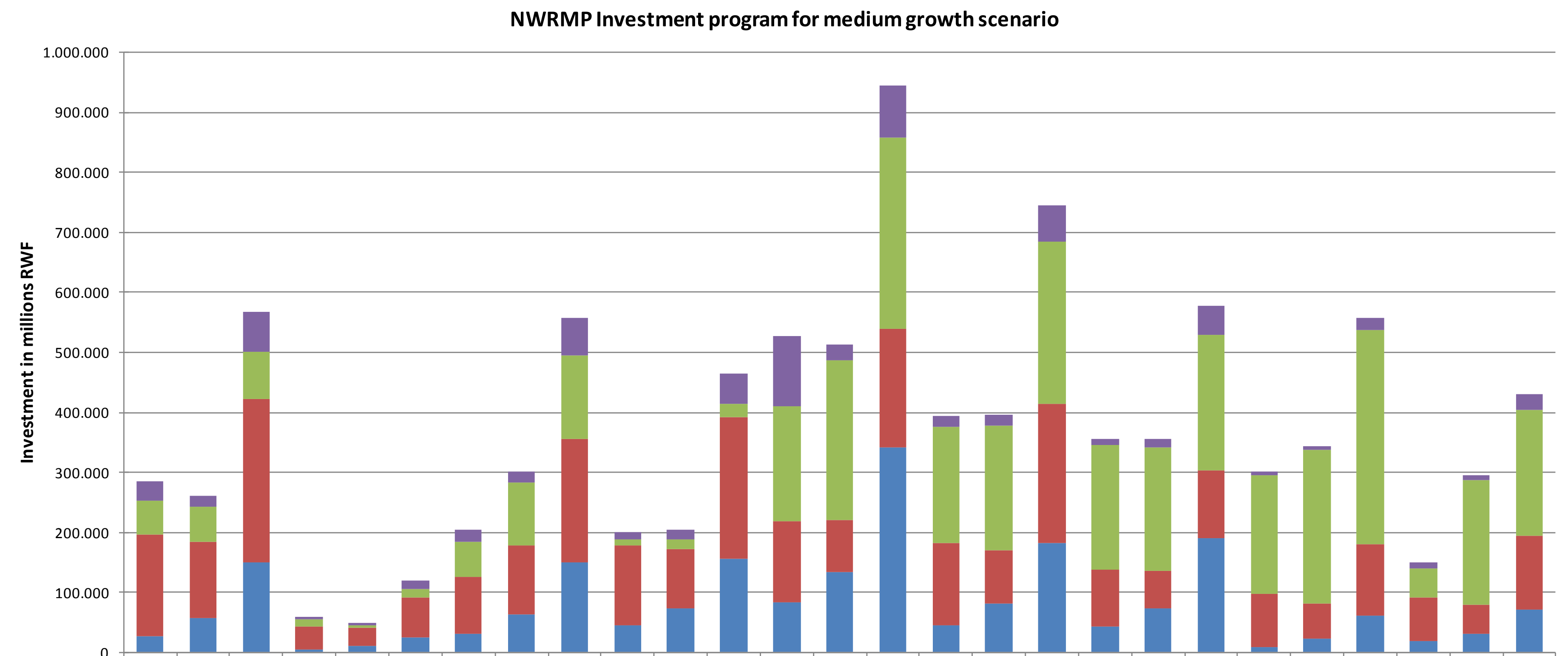
The horizontal axis contains five lines: the first line indicates the catchment (CKIV, CRUS, etc.) with the 1, 2, and 3 postfix representing the investment period of 2014-2020, 2021-2030 and 2031-2040 respectively.

The remaining lines of the vertical axis indicate the demand category and the number value of the estimated investment (in MRWF) for the water demand category, for the specified catchment and investment period. 'WS&S-urban' and 'WS&S-rural' lines stand for investments in the water supply and sanitation sector in urban and rural areas. 'Irrigation' line stands for the investment in the irrigation sector (rainwater harvesting, marshland, surface irrigation, dam and groundwater). The 'other' line stands for other investment groups in as far as government would be called upon to realize these investments; it mostly relates to water and sanitation for industrial parks, monitoring, and miscellaneous activities like research activities, special investigations, protection works, etc.

When considering that most investments for the 2014-2020 investment period come to the term of their investment lifetime during the last decade of 2030-2040 and require reinvestment, the following conclusions can be drawn:

- investment for rural water supply is a large or even the largest investment component for all catchments. When accounting for the reinvestment during the last planning period there is however a gradual decline in 'new' investment. This is related to still outstanding water related MDG investments for the current planning period (the difference between demand and use). It should also be considered that most of the population increase will be absorbed by urban or emerging urban areas with a likely more or less stationary population count in the rural areas.
- investment for urban water supply and sanitation is relatively timid during the current planning period (except for NNYL which provides most of the water supply for Kigali town), but it increases vigorously in all catchments for reasons of population increase and migration from rural areas, as well as for the reinvestment of the current investments by 2030.
- Especially in the central and eastern catchments, the irrigation sector is a significant investment target. With the exception of the Muvumba catchment, the level of investment tends to remain fairly constant over the three planning periods. When considering the reinvestment of the current planning period investments by 2030, this implies that most development in this sector is programmed to be completed in the next 15 to 20 years or so. It remains very questionable whether the Rwandan government should spearhead this level of investment across all irrigation types.
- other investments are quite modest for most catchments with the exception of the lower Nyabarongo. This is probably related to the number of industrial parks in this catchment and the presence of the city of Kigali. It is emphasized that the investment for miscellaneous activities, though not very cost intensive, is important for the attainment of adequate water management in the different catchments and the protection of land and water resources.

Table 48: Overview of investment costs per catchment per demand category and per planning period for the medium growth scenario



	CKIV 1	CKIV 2	CKIV 3	CRUS 1	CRUS 2	CRUS 3	NNYU 1	NNYU 2	NNYU 3	NMUK 1	NMUK 2	NMUK 3
Other	32.092	19.774	65.238	5.191	4.755	14.713	21.061	19.475	62.986	12.778	16.553	49.682
Irrigation	56.768	56.757	80.279	11.953	3.258	13.433	58.014	103.384	139.850	8.723	15.006	23.252
WS&S-rural	168.923	127.970	270.578	38.407	31.385	66.713	94.841	114.963	206.474	133.244	99.680	235.384
WS&S-urban	26.426	57.205	150.858	3.873	9.813	25.218	30.367	63.797	148.985	45.496	72.546	156.209

	NNYL 1	NNYL 2	NNYL 3	NAKN 1	NAKN 2	NAKN 3	NAKU 1	NAKU 2	NAKU 3	NAKL 1	NAKL 2	NAKL 3	NMUV 1	NMUV 2	NMUV 3
Other	116.582	26.659	85.725	17.737	18.114	60.130	10.311	14.550	48.198	5.213	5.636	20.458	9.838	7.873	26.187
Irrigation	191.582	265.986	318.876	194.996	207.258	270.110	208.131	205.670	226.813	198.653	255.976	357.373	49.053	207.884	210.095
WS&S-rural	134.821	87.849	197.634	137.329	90.640	231.987	94.765	61.511	112.477	87.972	59.374	119.488	72.481	49.011	122.890
WS&S-urban	84.225	133.502	342.009	44.366	80.387	183.090	42.592	73.956	190.852	9.195	22.487	60.159	19.050	30.308	71.858

The last paragraph in this chapter in the National Water Resources Master Plan is dedicated to the discussion of issues, conclusions and recommendations.

1.9 ISSUES, CONCLUSIONS AND RECOMMENDATIONS

The nine Catchment Master Plans each present a chapter (chapter 4) with the main observations and conclusions a well as a series of necessary development actions and recommendations. These observations along with the recommended actions are succinctly presented below for each catchment.

The last sections presents an action plan at national level

1.9.1 OBSERVATIONS AND RECOMMENDED ACTIONS FOR THE CKIV CATCHMENT

The main observations and conclusions on the CKIV catchment are:

- predominance of good, deeply weathered soils with high infiltration rates in narrow valleys with steep gradients. There is significant erosion which is related to land use.
- high rainfall with a relatively short dry season.
- overall significant surface flow generated from numerous small catchments each with small base flow (~ less than 1 m^3/s except for Sebeya River).
- significant groundwater reserves yet difficult to access.
- population to increase from 1.4 million to 3.2 million, urban population scheduled to grow tenfold from one hundred thousand to a million.
- very difficult accessibility; opportunity in Lake Kivu navigation.
- the current level of water use is very low (registered use less than 1% of renewable resources; current demand estimated at 4%).
- the adjusted water balance for the Lake Kivu catchment up to 2040 indicates that all essential demand and presumably viable commercial ventures can be developed without restrictions or compromising environmental flow requirements.
- even with the very low use level, there are already (minor) conflict over water use in the catchment.

Necessary developments and recommendations are:

- Water supply services in the rural domain is still insufficient for reasons of planning, investment, exploitation and repair, resources decline or inadequate service solutions. The development of a catchment based water supply plan is highly recommended (and so far initiated by EWSA for Eastern Area, Akanyaru and upper Nyabarongo).
- Water supply services in the urban domain seems mostly satisfactory yet there is insufficient planning (EWSA service is responsive but not yet proactive). The water supply planning for urban areas should be integrated in the catchment based plan specified above.
- Urban sanitation is a growth sector aiming at 50% of urban water supply being centrally collected and treated by 2040. Currently there is no central treatment.

- Water requirements for industry, mining, coffee washing stations, livestock and non hydro-power power plants should be integrated in the catchment based plan specified above (under rural demand). Any opportunity in these domains should be pursued making sure they are operated in a socially and environmentally sustainable manner.
- water supply for livestock can be viably generated from rainwater harvesting and is in that format ideally suited to complement the 'one cow - one family' concept. It is recommended that Minagri / RARDA investigates this option and promotes it.
- rain fed agriculture shall remain the mainstay of the catchment's agricultural production. The protection of the catchment's land resources is a huge priority. Appropriate land-use (when needed by readjustment of land use), erosion protection by radical and bunch terraces and other protective measures must remain the focus for the future of the catchment
- water supply from irrigation ponds is endorsed; additional training of farmers in the use of the ponds may improve productivity from these facilities.
- being relatively cheap and effective, water supply in marchlands is endorsed for the full identified area of just over 4,000 ha in the catchment.
- irrigation from Lake Kivu. The command area in the Irrigation master plan has been reduced for command at an elevation higher than 25 m above the lake. A further issue is the doubtful water quality of the Lake Kivu water for purposes of irrigation (alkaline and slightly saline). There is nevertheless a reservation of 4,000 ha to be irrigated from Kivu Lake.
- irrigation from dams. With the narrow and steeply inclined valleys, it is difficult to find good dam sites. Four dam sites have been judged sufficiently interesting for further study and their water demand is considered in the master plan.
- Small hydropower is of interest for the catchment but the scope for larger plants (>= 1 MW) is limited because of the less significant flow generated from the small catchments.
- the stunning scenic beauty of the catchment is an asset for eco tourism.

In order to manage the catchment adequately from its current condition with hardly any use to the 2040 situation whence about 25 % of the renewable resources may be mobilized for primary use and a number of commercial ventures, a number of miscellaneous measures is proposed that are valid for all catchments:

- monitoring of rainfall resource and general climate data
- monitoring of surface water resource quantity and quality
- monitoring of groundwater resource quantity and quality.
- monitoring of users' interventions in the natural hydrological cycle.
- the development and use of a dedicated water management information system (Water MIS, see chapter 2 in this report).
- the formulation and introduction of a permit system for water use interventions. Details are provided in chapter 2.4.2 (the water permit procedure as part of the Water MIS) and in appendix 10.
- the installation of a decentralized catchment water management office reliant on the RNRA-IWRM. Details are provided in chapter 0

These points will be further discussed in paragraph 1.9.10. A necessary measure that is specific to the Lake Kivu catchment is as follows:

- The cause of the excessive erosion from the Sebeya river catchment needs to be investigated and adequate corrective measures implemented shortly.

1.9.2 OBSERVATIONS AND RECOMMENDED ACTIONS FOR THE CRUS CATCHMENT

The main observations and conclusions on the CRUS catchment are:

- predominance of good, deeply weathered soils with high infiltration rates in narrow valleys with steep gradients. There is significant erosion which is related to land use; artisanal mining and agriculture are the main culprits.
- high rainfall with a relatively short dry season.
- overall significant surface flow generated from two main tributaries Rubyiro (comprising Gishoma basin) and Ruhwa rivers.
- significant groundwater reserves that are however difficult to access.
- population to double over the lifetime of the masterplan from 350,000 to 700,000; the urban population is scheduled to grow almost tenfold from 20,000 to 175,000.
- the catchment is isolated by its remoteness from the center of Kigali. Accessibility of the catchment is very difficult especially as regards the eastern area on the fringes of the Nyungwe forest. Positive points are the navigation on Lake Kivu (Rusizi) and the accessibility of Bujumbura and Lake Tanganyika.
- the current level of water use is very low (registered use is not even 0,5% of renewable resources and the current demand estimated at less than 2%).
- the examination for the adjusted water balance of the Rusizi catchment up to 2040 indicates that most of the demand is located in the Rubyiro catchment which generates about a third of the available resources. While the catchment wide water balance does not reveal any stress, there are already significant limitations in the Rubyiro catchment especially as regards irrigation development. Catchment wide all essential demand (primary use) and presumably viable commercial ventures can be developed with the exception of dry season irrigation in the Bugarama valley.
- even with the very low use level, there are already (minor) conflicts over water use in the catchment.

Necessary developments and recommendations are:

- Water supply services in the rural domain is still insufficient for reasons of planning, investment, exploitation and repair, resources decline or inadequate service solutions. The development of a catchment based water supply plan is highly recommended (similar to CKIV catchment).
- Water supply services in the urban domain seems mostly satisfactory and there are only two minor urban centers (Rusizi which is located on the boundary with CKIV catchment and Bugarama) so overall demand is limited even when growth may be significant over time. The water supply planning for urban areas should be integrated in the catchment based plan specified above.

- Urban sanitation is a growth sector aiming at 50% of urban water supply being centrally collected and treated by 2040. Currently there is no central treatment.
- Water requirements for industry, mining, coffee washing stations, livestock and non hydro-power power plants should be integrated in the catchment based plan specified above (under rural demand). The exploitation of peat in the Gishoma valley does not require any water (on the contrary) yet this exploitation reduces agricultural use and excludes the development of an interesting site for surface water storage for the Bugarama rice production. This exploitation is granted under a long term concession issued after an EIA investigation. This operation should also be integrated in the catchment based water management plan.
- water supply for livestock can be viably generated from rainwater harvesting and is in that format ideally suited to complement the 'one cow - one family' concept. It is recommended that Minagri / RARDA investigates this option and promotes it.
- rain fed agriculture shall remain the mainstay of the catchment's agricultural production. The protection of the catchment's land resources is a huge priority. Appropriate land-use (when needed by readjustment of land use), erosion protection by radical and bunch terraces and other protective measures must remain the focus for the future of the catchment.
- water supply from irrigation ponds is endorsed; additional training of farmers in the use of the ponds may boost their feasibility.
- being relatively cheap and effective, water supply in marchlands is endorsed yet dry season surface water resources from Rubyiro are insufficient to sustain much development. Provided that the Bugarama rice irrigation scheme can be irrigated with Rusizi water (see next point), the Rubyiro river can be used for non rice production upstream in the valley for about 450 ha.
- It is recommended to investigate the practicability of using Rusizi water for rice production for about 550 ha in the lower Bugarama valley (or any larger area that can be reached by gravity intake from the Rusizi). The Rusizi river water quality may prove unsuitable due to high alkalinity level (soil and or plant nutrition issues) which would block this option.
- there are no viable dam sites identified in the catchment area. A viable site in the upper reach of the Rubyiro river would be very valuable for flow regulation and sustaining dry season flow for irrigation in the Bugarama valley.
- In addition to the larger projects on the Rusizi river (international cooperation), there are some interesting sites for micro hydropower in the range of 50 to 500 kW installed capacity. Their development should be taken up by the private investors.

In order to manage the catchment adequately from its current condition with hardly any use to the 2040 situation whence about 10 % of the renewable resources may be mobilized for primary use and a number of commercial ventures (especially in the Rubyiro basin CRUS_1), a number of miscellaneous measures is proposed. These points are common for all catchments where watermanagement improvement is mandatory:

- monitoring of rainfall resource and general climate data
- monitoring of surface water resource quantity and quality
- monitoring of groundwater resource quantity and quality.

- monitoring of users' interventions in the natural hydrological cycle.
- the development and use of a dedicated water management information system (Water MIS, see chapter 2 in this report).
- the formulation and introduction of a permit system for water use interventions. Details are provided in chapter 2.4.2.
- the installation of a decentralized catchment water management office reliant on the RNRA-IWRM. Details are provided in chapter 0

1.9.3 OBSERVATIONS AND RECOMMENDED ACTIONS FOR THE NNYU CATCHMENT

The main observations and conclusions on the NMUK catchment are:

- predominance of good, deeply weathered soils with relatively high infiltration rates. There is significant erosion which is mainly due to agriculture and mining activities.
- high rainfall with a relatively short dry season.
- overall significant surface flow generated from a number of larger tributaries and the upper Nyabarongo river.
- very significant groundwater reserves that are however mostly difficult to access.
- population to increase from 1.5 million to 3.3 million, urban population scheduled to grow about sevenfold from one hundred and sixty thousand to almost 1.2 million.
- difficult accessibility outside of the main roads (3 axes: Muhanga - Nyabihu; Muhanga - Karongi and Huye - Nyamasheke).
- the current level of water use is very low (registered use less than one percent of renewable resources; current demand estimated at less than three percent).
- the adjusted water balance for the Upper Nyabarongo catchment up to 2040 indicates that all essential demand and presumably viable commercial ventures can be developed without restrictions or compromising environmental flow requirements. The Upper Nyabarongo, together with the Mukungwa catchment constitute the water tower for Rwanda.

Necessary developments and recommendations are:

- Water supply services in the rural domain is still insufficient for reasons of planning, investment, exploitation and repair, resources decline or inadequate service solutions. The development of a catchment based water supply plan is highly recommended and so far initiated by EWSA for this catchment (ongoing).
- Water supply services in the urban domain seems mostly satisfactory for the principal urban centers of the catchment (Muhanga, Ruhango, Nyanza and Nyamagabe) but there is a list of twenty emerging urban areas with generally insufficient supply which are not registered with EWSA as emerging urban centers. The water supply planning for urban areas should be integrated in the catchment based water supply plan specified above.
- Urban sanitation is a growth sector aiming at 50% of urban water supply being centrally collected and treated by 2040. Currently there is no central treatment.

- Water requirements for industry, mining, coffee washing stations, livestock and non hydro-power power plants should be integrated in the catchment based plan specified above (under rural water supply).
- water supply for livestock can be viably generated from rainwater harvesting. It is recommended that Minagri / RARDA investigates this option and promotes it.
- notwithstanding substantial investments in the irrigation sector, rain fed agriculture shall remain the mainstay of the catchment's agricultural production. The protection of the catchment's land resources and sustainable land use are huge priorities.
- although irrigation ponds are likely to have more impact on farmer's household in dryer areas (central and east), water supply from irrigation ponds is endorsed. Further research and additional training of farmers in the use of the ponds may raise the profitability.
- being relatively cheap and effective, water supply in marchlands is endorsed for the full identified area of almost 23,000 ha in the catchment.
- irrigation of hillsides from surface water has been curtailed as compared with the areas proposed in the RIMP (Rwanda Irrigation Master Plan) mainly with respect to excessive lift required. Where land and water resources are available and the required skills have been acquired by farmers and cooperatives, an area of about 2,200 ha may be profitably exploited.
- irrigation from dams. A number of 7 out of 26 dam sites have been found to be most interesting from a hydrological perspective. Further to the irrigation of command area, these reservoirs have a positive effect on sustaining dry season flow especially when irrigation infrastructure and operation rules are not directed at the highest possible water efficiency. After further study, each site should be optimized for the highest possible storage capacity that can be efficiently exploited for irrigation and other purposes (hydropower, fish production, ...).
- There is scope for the development of irrigation command area from groundwater. It is suggested that groundwater is first and foremost allocated to drinking water supply. Irrigation of alluvial plains from alluvial aquifers may proof effective and sustainable and can be developed for motorized and human powered pumping equipment. It is estimated that about 2,500 ha may be developed in this catchment.
- There is substantial scope for the development of small hydropower in the catchment. A number of sites have been developed recently (Rukarara river) and further (smaller) sites are available.

In order to manage the catchment adequately from its current condition with hardly any use to the 2040 situation whence about 21 % of the renewable resources may be mobilized for primary use and commercial ventures, a number of miscellaneous measures is proposed. These points are identical for all catchments:

- monitoring of rainfall resource and general climate data
- monitoring of surface water resource quantity and quality
- monitoring of groundwater resource quantity and quality.
- monitoring of users' interventions in the natural hydrological cycle.
- the development and use of a dedicated water management information system (Water MIS, see chapter 2 in this report).

- the formulation and introduction of a permit system for water use interventions. Details are provided in chapter 2.4.2.
- the installation of a decentralized catchment water management office reliant on the RNRA-IWRM. Details are provided in chapter 0

1.9.4 OBSERVATIONS AND RECOMMENDED ACTIONS FOR THE NMUK CATCHMENT

The main observations and conclusions on the NMUK catchment are:

- predominance of good, deeply weathered soils with high infiltration rates. The western part of the catchment presents partly steeply inclined highland on volcanic soils while the eastern part shows the common configuration of narrow valleys with steep gradients in a dendritic pattern. Especially in the eastern part of the catchment erosion is significant which is due to agriculture and mining activities.
- high rainfall with a relatively short dry season.
- overall significant surface flow generated from the eastern valleys starting with the Rugezi marshland. The western volcanic highlands present few permanent surface water channels.
- significant groundwater reserves yet difficult to access when not released from natural springs
- population to increase from 1.3 million to 2.8 million, urban population scheduled to grow about fivefold from two hundred and fifty thousand to 1.2 million.
- difficult accessibility outside of the main roads (axe - Kigali - Musanze - Rubavu)
- the current level of water use is very low (registered use less than half a percent of renewable resources; current demand estimated at about 3 percent).
- the adjusted water balance for the Mukungwa catchment up to 2040 indicates that all essential demand and presumably viable commercial ventures can be developed without restrictions or compromising environmental flow requirements. The Mukungwa, together with the Upper Nyabarongo catchment constitute the water tower for Rwanda.

Necessary developments and recommendations are:

- Water supply services in the rural domain is still insufficient for reasons of planning, investment, exploitation and repair, resources decline or inadequate service solutions. The development of a catchment based water supply plan is highly recommended.
- Water supply services in the urban domain seems rather satisfactory for Musanze town but there is a list of emerging urban areas with lacking supply that are not registered with EWSA as emerging urban centers. The water supply planning for urban areas should be integrated in the catchment based water supply plan specified above.
- Urban sanitation is a growth sector aiming at 50% of urban water supply being centrally collected and treated by 2040. Currently there is no central treatment.
- Water requirements for industry, mining, coffee washing stations, livestock and non hydro-power power plants should be integrated in the catchment based plan specified

above (under rural demand). Any opportunity in these domains should be pursued making sure they are operated in a socially and environmentally sustainable manner.

- water supply for livestock can be viably generated from rainwater harvesting. It is recommended that Minagri / RARDA investigates this option and promotes it.
- rain fed agriculture shall remain the mainstay of the catchment's agricultural production. Appropriate land use and the protection of the catchment's land resources are essential.
- although irrigation ponds are likely to have more impact on farmer's household in dryer areas (central and east), water supply from irrigation ponds is endorsed. Further research and additional training of farmers in the use of the ponds may raise their profitability.
- being relatively cheap and effective, water supply in marchlands is endorsed for the full identified area of almost 5,000 ha in the catchment.
- irrigation from dams. With the extreme infiltration rates in the west and the narrow and steeply inclined valleys, it is difficult to find good dam sites and rainfall is abundant throughout the catchment. A single dam site has been identified which has been tentatively considered for implementation by 2040.
- Small hydropower is of interest for the catchment and a number of larger capacity plants is operational on the Mukungwa and upstream main waters for a combined capacity of 28 MW). The Giciye river has potential for development of further hydropower production sites along with smaller rivers.
- the scenic beauty of the catchment, the volcano park and its wildlife are invaluable assets for (eco-) tourism.

In order to manage the catchment adequately from its current condition with hardly any use to the 2040 situation whence about 17% of the renewable resources may be mobilized for primary use and commercial ventures, a number of miscellaneous measures is proposed. These points are essentially identical for all catchments; brief discussion is presented in paragraph 1.9.10:

- monitoring of rainfall resource and general climate data
- monitoring of surface water resource quantity and quality
- monitoring of groundwater resource quantity and quality.
- monitoring of users' interventions in the natural hydrological cycle.
- the development and use of a dedicated water management information system (Water MIS, see chapter 2 in this report).
- the formulation and introduction of a permit system for water use interventions. Details are provided in chapter 2.4.2
- the installation of a decentralized catchment water management office reliant on the RNRA-IWRM. Details are provided in chapter 0

1.9.5 OBSERVATIONS AND RECOMMENDED ACTIONS FOR THE NNYL CATCHMENT

The main observations and conclusions on the NNYL catchment are:

- predominance of good, deeply weathered soils with rather high infiltration rates in narrow valleys with steep gradients. There is significant erosion which is related to land use in particular agriculture and mining. Main pollution sources are the city of Kigali and mining activities. The Nyabarongo River is a wide wetland with a very flat gradient.
- medium to high rainfall with a relatively short dry season in the west and low to medium rainfall with more pronounced dry seasons in the east (Nyabugogo tributary).
- major inflow from the upper Nyabarongo and Mukungwa catchments.
- significant surface flow generated from the Base, Mambu and Nyubugogo rivers with a number of smaller tributaries that join the Nyabarongo or Nyabugogo rivers.
- significant groundwater reserves that are relatively easy to abstract from the alluvial aquifer of the Nyabarongo floodplain and from mainland aquifers in the north and east of the catchment.
- population to increase from 2.3 million to 4.7 million, urban population including the city of Kigali scheduled to grow from nine hundred thousand to over 3 million.
- difficult accessibility outside of the main roads (axe - Kigali - Musanze - Ruhango - Gicumbi - Rwamagana).
- the current level of water use is very low (registered use slightly over two percent of renewable resources; current demand estimated at about six percent).
- the adjusted water balance for the lower Nyabarongo catchment up to 2040 indicates that all essential demand and presumably viable commercial ventures can be developed with occasional restrictions and reducing allocations for environmental requirements during less abundant hydrological years. The resources surpluses of upper Nyabarongo and Mukungwa catchment make this water management possible as these surplus flows sustain minimum environmental flow conditions in the Nyabarongo valley.

Necessary developments and recommendations are:

- Water supply services in the rural domain is still insufficient for reasons of planning, investment, exploitation and repair, resources decline or inadequate service solutions. The development of a catchment based water supply plan is highly recommended.
- Water supply services in the urban domain seems rather satisfactory for most of Kigali and the other urban centers of the catchment. The district survey allowed to make a list of emerging urban areas with insufficient supply that need to upgrade to an 'urban' water supply status. The water supply planning for urban areas should be integrated in the catchment based water supply plan specified above.
- Urban sanitation is a growth sector aiming at 50% of urban water supply being centrally collected and treated by 2040. Currently there is a public waste water collection and treatment facility in one of the suburbs of Kigali.
- Water requirements for industry, mining, coffee washing stations, livestock and non hydro-power power plants should be integrated in the catchment based plan specified above (under rural demand).

- water supply for livestock can be viably generated from rainwater harvesting. It is recommended that Minagri / RARDA investigates this option and promotes it.
- rain fed agriculture shall remain the mainstay of the catchment's agricultural production. Sustainable land use and the protection of the catchment's land resources are vital.
- with respect to the irrigation sector, all apparently viable developments are supported provided that water resources can be made available. For each irrigation mode the recommendations are specified below.
- water supply from irrigation ponds is endorsed. Further research and additional training of farmers in the use of the ponds may raise the profitability at the family level.
- being relatively cheap and effective as an irrigation method and with the catchment's own resources being sufficient, water supply for marchland irrigation is endorsed for the full identified area of some 30,000 ha in the catchment.
- irrigation of hillsides from surface water has been curtailed as compared with the areas proposed in the RIMP (Rwanda Irrigation Master Plan) mainly with respect to excessive lift required. Where land and water resources are available and the required skills have been acquired by farmers and cooperatives, an area of about 5,000 ha may be profitable exploited along the Nyabarongo river (3,000 ha) and around Lake Muhazi (2,000 ha). The command area around Lake Muhazi can be extended (from 2,000 ha to 5,600 ha) provided that the lake is used as a storage reservoir. This requires the outlet structure to be redesigned and reconstructed. The current dam and outlet structure are dangerous because of i) badly repaired piping leading to dam collapse, and ii) insufficient spillway capacity leading to dam overtopping and catastrophic breach.
- irrigation from dams. All irrigation demand supported by surface water storage facilities (comprising Lake Muhazi) is endorsed. The regulation volume that may effectively be generated in this catchment is about 36 MCM or 52 MCM when including Lake Muhazi. The construction and exploitation of surface reservoirs helps to sustain a minimum dry season flow even with substantial water use.
- irrigation from groundwater. Groundwater is a prime resource in the sense that it typically carries no sediment and its availability is more dependable than surface water. It should therefore firstly be allocated to primary uses (drinking water supply) and only when surpluses remain to irrigation. We suggest to develop about 4,000 ha of irrigation command area with supply from groundwater.
- Small hydropower is of interest for the catchment and a number of interesting sites is under study on the Base River and other tributaries.

In order to manage the catchment adequately from its current condition with a few percentages of the renewable resources being used to the 2040 situation whence about 54 % of its resources may be mobilized for primary use and commercial ventures, a number of miscellaneous measures is proposed. These points are identical for all catchments:

- monitoring of rainfall resource and general climate data
- monitoring of surface water resource quantity and quality
- monitoring of groundwater resource quantity and quality.
- monitoring of users' interventions in the natural hydrological cycle.

- the development and use of a dedicated water management information system (Water MIS, see chapter 2 in this report).
- the formulation and introduction of a permit system for water use interventions. Details are provided in chapter 2.4.2
- the installation of a decentralized catchment water management office reliant on the RNRA-IWRM. Details are provided in chapter 0

1.9.6 OBSERVATIONS AND RECOMMENDED ACTIONS FOR THE NAKN CATCHMENT

The main observations and conclusions on the NAKN catchment are:

- predominance of good, deeply weathered soils with rather high infiltration rates in narrow valleys with steep gradients. There is significant erosion which is related to land use in particularly agriculture. The lower Akanyaru is a wide peat based wetland with a very flat gradient.
- medium to high rainfall with a relatively short dry season in the west and low to medium rainfall with more pronounced dry seasons in the east (Bugesera).
- significant surface flow generated from the catchment in Rwanda and a significant supplement generated in Burundi.
- significant groundwater reserves that, unless released from natural springs, are difficult to access with limited discharge (manual pumped borehole).
- population to double from 1.5 million to 3.1 million, urban population scheduled to grow from three hundred thousand to 1.3 million.
- very difficult accessibility outside of the main roads (axe - Muhanga - Huye and a crossing of the Akanyaru at Bisore (secondary road from Ruhango to Bugesera just north of Cyohoha South lake)
- the current level of water use is low (registered use at four percent of renewable resources; current demand estimated at slightly over six percent).
- the adjusted water balance for the Akanyaru catchment up to 2040 has been reduced as regards the irrigation from surface water (river and lake) because dry season resources are insufficient for that development by 2040. The current irrigation development along Cyohoha South Lake (50 ha) can be maintained but further development of this type of irrigation should not be allowed. Other essential demand and presumably viable commercial ventures can be developed with occasional restrictions and reducing allocations for environmental requirements during less abundant hydrological years.

Necessary developments and recommendations are:

- Water supply services in the rural domain is still insufficient for reasons of planning, investment, exploitation and repair, resources decline or inadequate service solutions. The development of a catchment based water supply plan is highly recommended and has been initiated by EWSA for this catchment.
- Water supply services in the urban domain seems rather satisfactory for most of the urban centers of the catchment. The district survey allowed making a list of emerging urban areas with insufficient supply that need to upgrade to an 'urban' water supply

status. The water supply planning for urban areas should be integrated in the catchment based water supply plan specified above.

- Urban sanitation is a growth sector aiming at 50% of urban water supply being centrally collected and treated by 2040. Reportedly there is a public waste water collection and treatment facility in one of the suburbs of Huye.
- Water requirements for industry, mining, coffee washing stations, livestock and non hydro-power power plants should be integrated in the catchment based plan specified above (under rural demand).
- water supply for livestock can be viably generated from rainwater harvesting. It is recommended that Minagri / RARDA investigates this option and promotes it.
- rain fed agriculture shall remain the mainstay of the catchment's agricultural production. Sustainable land use and the protection of the catchment's land resources are essential.
- with respect to the irrigation sector, the renewable resources of the catchment are insufficient to support all possible commercially viable developments. For each irrigation mode the recommendations are specified below.
- water supply from irrigation ponds is endorsed. Further research and additional training of farmers in the use of the ponds may raise the profitability at the family level.
- the catchments renewable resources are insufficient for the full development of the potential area of 59,000 ha of marshland for dry season irrigation and a reduced development of about 45,000 ha is proposed. This requires to select the best areas for development.
- the catchments renewable resources are insufficient for the development of hillside irrigation from surface water. The currently developed area of 50 ha north of Cyohoha Lake can be maintained but extension of such command area is not supported for lack of Rwandan renewable resources.
- irrigation from dams. This development allows carrying over resources from the wet season to the dry season and therefore not only supports irrigation but also dry season environmental flow and it provides opportunity for reuse. A list of 14 dam sites with a combined capacity of 47 MCM has been endorsed. All dam development should be geared to the maximum inter seasonal storage capacity even when the specific command area to be irrigated may require less.
- irrigation from groundwater. Groundwater is a prime resource in the sense that it does not carry sediment and its supply reliability is generally better than for surface water. It should therefore firstly be allocated to primary uses (drinking water supply) and only when surpluses remain to irrigation. We suggest developing about 600 ha of irrigation command area with supply from groundwater.
- Small hydropower is of interest for the catchment and a number of interesting sites is under study.

In order to manage the catchment adequately from its current condition with a few percentages of use to the 2040 situation whence about 44 % of the renewable resources may be mobilized for primary use and commercial ventures, a number of miscellaneous measures is proposed. A number of points is valid for all catchments but some are specific for the Akanyaru river catchment. The common points are:

- monitoring of rainfall resource and general climate data

- monitoring of surface water resource quantity and quality
- monitoring of groundwater resource quantity and quality.
- monitoring of users' interventions in the natural hydrological cycle.
- the development and use of a dedicated water management information system (Water MIS, see chapter 2 in this report).
- the formulation and introduction of a permit system for water use interventions. Details are provided in chapter 2.4.2
- the installation of a decentralized catchment water management office reliant on the RNRA-IWRM. Details are provided in chapter 0

Proposed measures that are specific to Akanyaru catchment are:

- The district survey in Gisagara district has exposed drought in some upstream valley bottoms. It is strongly recommended that this is further investigated for confirmation, possible cause and remedial measures that may reverse the tendency. In this respect it is mentioned that the water balance indicates a dry season stress situation as early as 2020, the Cyohoha North Lake has all but vanished in early 2000, the Akanyaru marshland is a peat marsh which is susceptible for irreversible settling when the water level recedes too low. In conclusion, we have indications of rising drought conditions and aggravating circumstances which call for a serious investigation.
- Further to the previous point, it is essential that the Cyohoha South Lake outlet, be fully and effectively protected against exploitation and the water and swamp land level be monitored against a fixed benchmark. Any settling of the marshland at the lake outlet may have very grave consequences for the Cyohoha South Lake.
- With the Akanyaru catchment being dependant on the creation of surface water storage for sustaining its dry season flow, the erosion protection measures should be reinforced, especially in catchments whose surface runoff is stored in the future reservoirs.
- There is need for local cooperation with Burundi for the management of shared water resources particularly the Cyohoha South Lake and the Akanyaru marshland in order to reconcile objectives and water management measures for the sustainable use and protection of these resources. A study on this subject by SHER Ingénieurs Conseils s.a. commissioned by NELSAP in 2011 is available.

1.9.7 OBSERVATIONS AND RECOMMENDED ACTIONS FOR THE NAKU CATCHMENT

The main observations and conclusions on the NAKU catchment are:

- a mixture of rich and poorer soils with predominantly high infiltration rates in small valleys with generally gentle gradients. The land remains vulnerable to erosion which is related to land use in particular agriculture. The Akagera valley is a very wide wetland with an extremely flat gradient and a water level dictated by the ridge of the Rusumo Falls.
- low to medium rainfall with a longer dry season that may extend up to over four months without any significant rainstorm (> 4 - 6 mm).
- major inflow from the lower Nyabarongo and the Akanyaru rivers.

- significant surface flow generated from the catchment in Rwanda and a significant supplement generated in Burundi; the inflow from the Ruvubu river just above the Rusumo falls effectively doubles the total international catchment area and the flow.
- significant groundwater reserves that are relatively easy to abstract from the alluvial aquifer of the Akagera floodplain and from mainland aquifers in the East of the catchment.
- population to double from 1.2 million to 2.4 million up to 2040; the urban population is scheduled to grow fivefold from three hundred thousand to 1.5 million. The fraction urban population increases from about 25 to 60%.
- difficult accessibility outside of the main roads (axes: Kigali - Nyamata- border with Burundi and Kigali - Rwamagana - Kibungo - Rusumo Falls).
- the current level of water use is still modest (registered use at five percent of renewable resources; current demand estimated at eight percent).
- the adjusted water balance for the upper Akagera catchment up to 2040 has been reduced as regards the irrigation from surface water for command area with a lift above 50 m. All other identified essential demand and presumably viable commercial ventures have been maintained which will require a transfer from upper Nyabarongo and Mukungwa catchments for dryer years of the 2031-2040 planning period.

Necessary developments and recommendations are:

- Water supply services in the rural domain is still insufficient for a variety of reasons including planning, investment, exploitation and repair, resources decline or inadequate service solutions. The development of a catchment based water supply plan is highly recommended.
- Water supply services in the urban domain seems reasonably satisfactory for most of the urban centers of the catchment. The district survey allowed to make a list of emerging urban areas with insufficient supply that need to upgrade to an 'urban' water supply status. The water supply planning for urban areas should be integrated in the catchment based water supply plan specified above.
- Urban sanitation is a growth sector aiming at 50% of urban water supply being centrally collected and treated by 2040. Reportedly there is a public waste water collection and treatment facility in one of the suburbs of Kigali.
- Water requirements for industry, mining, coffee washing stations, livestock and non hydro-power power plants should be integrated in the catchment based water supply plan specified above (under rural demand)..
- water supply for livestock can be viably generated from rainwater harvesting and is in that format ideally suited to complement the 'one cow - one family' concept. It is recommended that Minagri / RARDA investigates and promotes this water use option.
- notwithstanding major investments in the irrigation sector, rain fed agriculture shall remain the mainstay of the catchment's agricultural production. The protection of the catchment's land resources and its adequate use is a huge priority.
- with respect to the irrigation sector, the renewable resources of the catchment are insufficient to support all identified commercially viable command area but the deficits

that will surface during dry in the last planning period (2031 - 2040) and onwards, can be covered by transfer from the upper Nyabarongo and Mukungwa catchments. For each irrigation mode the recommendations are specified below.

- water supply from irrigation ponds is endorsed. Further research and additional training of farmers in the use of the ponds may raise the profitability at the family level.
- the catchments renewable resources are insufficient for the full development of the potential area of 36,000 ha for dry season marshland irrigation and a reduced development of about 25,000 ha is proposed. The dry season irrigation of such a reduced command area nevertheless requires a transfer from upstream catchments. The reduction of the command area calls for selective development of the most suitable areas.
- the catchments renewable resources are insufficient for the development of hillside irrigation from surface water. With a transfer from upstream catchment areas a total area of 13,500 ha can be developed for hill side irrigation from surface waters (river or lake is identical for this catchment) with a lift of less than 50 m.
- irrigation from dams. This development allows to carry over resources from the wet season to the dry season and therefore not only supports irrigation but also dry season environmental flow. When discarding extremely efficient irrigation equipment there is ample opportunity for water reuse. A list of 11 dam sites with a combined capacity of 26 MCM has been endorsed. All dam development should be geared to the maximum inter seasonal storage capacity even when the command area to be irrigated may require less.
- By 2040 there is need for a maximum dry season water transfer of 82 MCM (under least favorable conditions) by natural river flow from the Mukungwa and upper Nyabarongo catchments. For purposes of reference, this transfer is slightly less than half the average annual renewable resources of the Muvumba catchment in Rwanda (82 against 193 MCM/yr).

In order to manage the catchment adequately from its current condition with a few percentages of use to the 2040 situation whence about two third (65%) of the average renewable resources may be mobilized for primary use and commercial ventures, a number of miscellaneous measures is proposed. A number of points is valid for all catchments but some are specific for the Akanyaru river catchment. The common points are:

- monitoring of rainfall resource and general climate data
- monitoring of surface water resource quantity and quality
- monitoring of groundwater resource quantity and quality.
- monitoring of users' interventions in the natural hydrological cycle.
- the development and use of a dedicated water management information system (Water MIS, see chapter 2 in this report).
- the formulation and introduction of a permit system for water use interventions. Details are provided in chapter 2.4.2
- the installation of a decentralized catchment water management office reliant on the RNRA-IWRM. Details are provided in chapter 0

Proposed measures that are specific to the upper Akagera catchment are:

- The interplay between the Akagera River and its adjoining lakes is complex. The bi-directional flow patterns depend on the sequence, relative magnitude and duration of hydrological events in upsteam catchments and within the upper Akagera catchment itself. The width and depth of the channels between Akagera river and lakes are a crucial factor and any tampering with these channels may have far-reaching consequences for especially the lakes. The rigorous protection and strict interdiction of any agricultural use of the intersections between Akagera river and its lakes is crucial for maintaining the hydrological functionality. This is mostly identical to the situation between Cyohoha south lake and the Akanyaru river where very strict protection is however even more critical because of the imminent stress conditions in that catchment, the unavailability of a significant interbasin transfer and the absence of the Rusumo falls which secure a minimum water level for the upper Akagera river.

- With the upper Akagera catchment being dependant on the creation of surface water storage for sustaining its dry season flow, the erosion protection measures should be reinforced, especially in catchments that generate the inflow of the future reservoirs.

1.9.8 OBSERVATIONS AND RECOMMENDED ACTIONS FOR THE NAKL CATCHMENT

The main observations and conclusions on the NAKL catchment are:

- a mixture of rich and poorer soils with predominantly high infiltration rates in three relatively elongated valleys with generally gentle gradients (Akagera, Kamiramugezi and Karangaza). The land remains vulnerable to erosion which is related to land use in particular agriculture. The Akagera river has three distinct sections as follows: a narrow valley descending from Rusumo falls, an extremely wide wetland with lakes with an extremely flat gradient, and an overflow into a narrow valley with a more regular gradient up to the confluence with the Mukungwa river.
- low to medium rainfall with a longer dry season that may extend up to over four months without any significant rainstorm (> 6 mm).
- major inflow from the upper Akagera and Ruvubu rivers (catchment area in Tanzania and Burundi). The latter river more or less doubles the upstream catchment area and flow.
- significant surface flow generated from the catchment in Rwanda and a significant supplement generated in Tanzania. The two main tributaries in Rwanda (Kamiramugezi and Karangaza) reduce to a trickle at the end of the dry season (ephemeral flow) when demand is highest.
- significant groundwater reserves that are relatively easy to abstract from the alluvial aquifer of the Akagera floodplain and from mainland aquifers extending over much of the central part of the catchment.
- population to double from just over half a million to about 1,1 million up to 2040; the urban population is currently insignificant (forty thousand) but may reach half a million. The fraction urban population increases from about 7 % to almost half the catchment population which will bring fundamental societal changes.
- about a quarter of the catchment area is national park for wildlife conservation (Akagera National Park) where water use is minimal (some rare ponds and boreholes for watering wildlife that is restricted to roam within the park domain) .
- difficult accessibility outside of the main roads (axe: Kagitumba - Kayonza - Rusumo) .

- the current level of water use is still modest (registered use at one percent of renewable resources; current demand estimated at two and a half percent).
- the adjusted water balance for the upper Akagera catchment up to 2040 has been reduced as regards the irrigation from surface water with lift above 50 m. All other identified essential demand and presumably viable commercial ventures have been maintained which will require a transfer from upper Nyabarongo and Mukungwa catchments starting the 2031 - 2040 time horizon.

Necessary developments and recommendations are:

- Water supply services in the rural domain is still insufficient for a variety of reasons including planning, investment, exploitation and repair, resources decline, low population density and inadequate service solutions. The development of a catchment based water supply plan is highly recommended. The study for the improvement of the Rural Water Supply in Rwanda by JICA (2008 - 2009) covered seven districts of the Eastern Province and therefore most of the upper and lower Akagera catchments and part of the Muvumba catchment. The report is very commendable and useful but as the title states, it is limited to i) district boundaries which thwarts the finding of catchment based least cost solutions and to ii) rural water supply which is only part of the water demand and obscures the perception on the optimum allocation of limited available resources.
- Water supply services in the urban domain seems reasonably satisfactory for most of the urban centers of the catchment. The district survey allowed to make a list of emerging urban areas with insufficient supply that need to upgrade to an 'urban' water supply status. The water supply planning for urban areas should be integrated in the catchment based water supply plan specified above.
- Urban sanitation is a growth sector aiming at 50% of urban water supply being centrally collected and treated by 2040. No public waste water collection facility is available in the catchment.
- Water requirements for industry, mining, coffee washing stations, livestock and non hydro-power power plants should be integrated in the catchment based plan specified above (under rural demand). Any opportunity in these domains should be pursued making sure they are operated in a socially and environmentally sustainable manner.
- water supply for livestock can be viably generated from rainwater harvesting and is in that format ideally suited to complement the 'one cow - one family' concept. It is recommended that Minagri / RARDA investigates this option and promotes it. The cost for dedicated water supply systems for livestock watering in livestock intensification zones (Mutara) in the catchment is integrated in the catchment investment plan.
- notwithstanding major investments in the irrigation sector, rain fed agriculture and livestock production remain the mainstay of the catchment's agricultural production. The protection and optimum use of the catchment's land resources is a huge priority.
- with respect to the irrigation sector, the renewable resources of the catchment are insufficient to support all possible commercially viable developments but the deficits that will surface from 2030 onwards, can be covered by transfer from the upper Nyabarongo and Mukungwa catchments. For each irrigation mode the recommendations are specified below.

- water supply from rain dependant irrigation ponds is endorsed. Further research and additional training of farmers in the use of the ponds may raise the profitability at the family level.
- the catchments renewable resources seem just sufficient for the full development of the potential command area of 33,350 ha for dry season marshland irrigation leaving insignificant surplus for dry season flow for other irrigation methods.
- the catchments renewable resources are insufficient for the development of hillside irrigation from surface water as identified in the RIMP (33,000 ha). With a transfer from upstream catchments (upper Nyabarongo and Mukungwa notably) the command area with a lift of less than 50 m or about 18,000 ha can be developed for hill side irrigation from surface waters (river or lake is identical for this catchment)
- irrigation from dams. This development allows to carry over resources from the wet season to the dry season and therefore not only supports irrigation but also dry season environmental flow. When discarding highly efficient irrigation equipment (drip, localized irrigation), there is ample opportunity for water reuse. A list of 8 dam sites with a combined capacity of 21 MCM has been endorsed. All dam development should be geared to the maximum inter seasonal storage capacity (up to some 50 to 70% of the mean annual runoff at dam site) even when the command area to be irrigated may require less.
- irrigation from groundwater. While specifying that groundwater resources should be allocated with priority to primary use categories (drinking water supply), a tentative command area of about 5,000 ha has been endorsed for the development of irrigation.
- By 2040 there is need for a maximum transfer of 43 MCM (assuming the least favorable conditions) by natural river flow from the Mukungwa and upper Nyabarongo catchments.

In order to manage the catchment adequately from its current condition with a few percentages of use to the 2040 situation whence almost half (43%) of the average renewable resources may be mobilized for primary use and commercial ventures, a number of miscellaneous measures is proposed. A number of points is valid for all catchments but some are specific for the lower Akagera river catchment. The common points are

- monitoring of rainfall resource and general climate data
- monitoring of surface water resource quantity and quality
- monitoring of groundwater resource quantity and quality.
- monitoring of users' interventions in the natural hydrological cycle.
- the development and use of a dedicated water management information system (Water MIS, see chapter 2 in this report).
- the formulation and introduction of a permit system for water use interventions. Details are provided in chapter 2.4.2
- the installation of a decentralized catchment water management office reliant on the RNRA-IWRM. Details are provided in chapter 0

Proposed measures that are specific to the lower Akagera catchment are:

- The area directly East of Muhazi Lake and to its north and south over most of the Kamiramugezi catchment area, is suitable for large-scale motorized groundwater abstraction. Such abstraction is still quite the exception. Each permitted intervention should provide for regular or continuous monitoring of groundwater level either in the borehole itself or in a monitoring borehole at some tens of meters from the production borehole(s). The permitted user should relay this information to RNRA-IWRM which should analyze this information for water management purposes.
- The interplay between the Akagera River and its adjoining lakes is complex. The bi-directional flow patterns depend on the sequence, magnitude and duration of hydrological events in upstream catchments and within the lower Akagera catchment itself. The width and depth of the channels between Akagera River and lakes are a crucial factor and any tampering with these channels may have far-reaching consequences for especially the lakes. The rigorous protection and strict interdiction of any agricultural use of the intersections between Akagera river and its lakes is crucial for maintaining the hydrological functionality. This is identical to the situation for the upper Akagera and between Cyohoha south lake and the Akanyaru river. Except for the Lake Nasho complex (three lakes) all channels are located within the domain of the Akagera national Park.
- With the lower Akagera catchment being dependant on the creation of surface water storage for sustaining its dry season flow, erosion protection measures are essential for long term use of storage capacity.

1.9.9 OBSERVATIONS AND RECOMMENDED ACTIONS FOR THE NMUV CATCHMENT

The main observations and conclusions on the NMUV catchment are:

- there is a marked differentiation of land resources between the West and the East of the catchment. The West features predominance of good, deeply weathered soils with rather high infiltration rates in narrow valleys with steep gradients. There is significant erosion which is related to land use in particularly agriculture. The East presents poorer soils on undulating hills intersected by river valleys of the Muvumba river and its tributaries with much richer soils. The Muvumba is a rather small river (5 to 10 m wide) in a larger floodplain.
- medium to high rainfall with a relatively short dry season in the West and significantly lower rainfall with more pronounced dry seasons in the East (Mutara).
- significant surface flow generated from the Mulindi catchment (NMUV_1) in Rwanda which flows into Uganda for a roundtrip of about 50 km traversing significant extents of marshland near Kabale to finally return as the Muvumba river. The upper reaches of the NMUV_2 catchment (several tributaries in Gicumbi district) also generate significant surface flow. The entire northern part of the catchment is transboundary with the Kizinga and then the Muvumba River forming the border between Rwanda and Uganda.
- meaningful groundwater reserves that are accessible in the West (where it seems less needed) and from alluvial deposits in the main river valleys in the East.

- population to double from 0.6 million to 1.3 million, urban population scheduled to grow from less than one hundred thousand to half a million. The 2012 census data were found to be more than 30% in excess of the population projection data derived from the 2002 census. Rural demand data have been corrected for this underestimation.
- difficult (East) to very difficult (West) accessibility outside of the main roads (axes - Kigali - Gicumbi - Gatuna and Kayonza - Gabiro - Nyagatare and Kagitumba plus some secondary roads linking Gicumbi with Nyagatare and Gabiro.
- the current level of water use is low (registered use at 5.5 percent of renewable resources which is the highest level for the country; current demand estimated at slightly above 12 percent).
- the adjusted water balance for the Muvumba catchment up to 2040 has been reduced as regards the irrigation from surface water because dry season resources are insufficient for that development by 2040. The current irrigation development in Musheli sector (400 ha) can been maintained but any further extension of this type of irrigation in the eastern part of the catchment (NMUV_2) should not be allowed. Other essential demand and presumably viable commercial ventures can be developed with occasional restrictions and minimizing allocations for environmental requirements during less abundant hydrological years. It is further recommended that particularly water intensive industries be relocated and or develop in other catchments.

Necessary developments and recommendations are:

- Water supply services in the rural domain is still insufficient for a variety of reasons including planning, investment, exploitation and repair, resources decline, low population density or inadequate service solutions. The development of a catchment based water supply plan is highly recommended. The already mentioned JICA study (see preceding paragraph) covers the eastern part of the catchment.
- Water supply services in the urban domain seems more or less satisfactory for most of the urban centers of the catchment. The district survey allowed to make a list of emerging urban areas with insufficient supply that need to upgrade to an 'urban' water supply status. The water supply planning for urban areas should be integrated in the catchment based water supply plan specified above.
- Urban sanitation is a growth sector aiming at 50% of urban water supply being centrally collected and treated by 2040.
- Water requirements for industry, mining, coffee washing stations, livestock and non hydro-power power plants should be integrated in the catchment based plan specified above (under rural demand). Any opportunity in these domains should be pursued making sure they are operated in a socially and environmentally sustainable manner.
- water supply for livestock can be viably generated from rainwater harvesting and is in that format ideally suited to complement the 'one cow - one family' concept. It is recommended that Minagri / RARDA investigates this option and promotes it. The cost for dedicated water supply systems for livestock watering in livestock intensification zones (Mutara) in the catchment is integrated in the catchment investment plan.
- notwithstanding major investments in the irrigation sector, rain fed agriculture and livestock production remain the mainstay of the catchment's agricultural production. The protection and optimum sustainable use of the catchment's land resources is of paramount importance.

- with respect to the irrigation sector, the renewable resources of the catchment are insufficient to support all possible commercially viable developments. For each irrigation mode the recommendations are specified below.
- water supply from irrigation ponds is endorsed. Further research and additional training of farmers in the use of the ponds may raise the profitability at the family level.
- the catchments renewable resources are insufficient for the full development of the potential area of 26,000 ha for dry season marshland irrigation. The development of this domain is nevertheless supported on condition of the development of a series of 4 larger storage reservoirs with a combined storage capacity of 34 MCM that carry over surface flow from the wet to the subsequent dry season.
- the catchments renewable resources are insufficient for the development of hillside irrigation from surface water. The currently developed area of 400 ha in Musheli sector can be maintained if the Muvumba dry season flow is sufficiently regulated by storage capacity (see previous point). Considering that already 85% of the average renewable resources are allocated, any further development of this type of irrigation will only create further deficits elsewhere and is consequently ill advised.
- irrigation from dams. This development allows to carry over resources from the wet season to the dry season and therefore not only supports irrigation but also dry season environmental flow and it provides opportunity for reuse. All 9 dam sites in the catchment are endorsed. All dam development should be geared to the maximum inter seasonal storage capacity even when the command area to be irrigated may require less. A reasonable upper limit of the effective (combined) storage capacity is about 50 to 70% of the mean annual runoff at the dam site. A further increase of surface water storage capacity tends to increase evaporation losses more than effective use of the resource. The development of the two reservoirs in the Mulindi catchment (NMUV_1) is endorsed but has lower priority. The creation of storage capacity depending on runoff from Ugandan territory requires a bilateral agreement which Uganda may unlikely sign and respect.
- Small hydropower is of interest for the catchment and a number of interesting sites is under study.

In order to manage the catchment adequately from its current condition with a few percentages of use to the 2040 situation whence an extreme 85% of the average renewable resources may be mobilized for primary use and commercial ventures, a number of miscellaneous measures is proposed. With respect to the 85% targeted use, it should be realized that for most years there will be reduced availability of resources and a number of dry season uses may not always and entirely succeed. This situation calls for state of the art water resources - and allocation management including timely communication with water users. There is still time to develop this expertise over a significant number of years but a start should be made as soon as possible.

A number of points is valid for all catchments but some are specific for the Muvumba river catchment. The common points are

- monitoring of rainfall resource and general climate data
- monitoring of surface water resource quantity and quality
- monitoring of groundwater resource quantity and quality.
- monitoring of users' interventions in the natural hydrological cycle.

- the development and use of a dedicated water management information system (Water MIS, see chapter 2 in this report).
- the formulation and introduction of a permit system for water use interventions. Details are provided in chapter 2.4.2
- the installation of a decentralized catchment water management office reliant on the RNRA-IWRM. Details are provided in chapter 0

Proposed measures that are specific to the Muvumba catchment are:

- the dependency of the Muvumba catchment on surface water storage for sustaining dry season demand, imposes the reinforcement of effective erosion protection measures especially in catchments that generate runoff for its reservoirs.
- The imminent situation that the water resources of the Muvumba river are insufficient to cater for all (dry season) demand in combination with the fact that the lower Muvumba is a border river, makes it likely that cross border disputes will develop (if such is not already the case). It is suggested to establish contact for local cooperation with Uganda for the management of the shared waters especially the Kizinga and the lower reach of the Muvumba. A study by SHER Ingénieurs Conseils s.a. commissioned by NELSAP in 2011 presenting possible modes of transboundary management or Akanyaru, Cyohoha and Rweru water resources, is available.

1.9.10 RECOMMENDED ACTIONS AT THE NATIONAL LEVEL

The situation of limited use of the national water resources is undergoing some dramatic changes towards imminent stress conditions in Muvumba, Akanyaru and the Rubyiro tributary in the otherwise surplus Rusizi catchment, and looming stress conditions in lower Nyabarongo, and upper and lower Akagera catchments. The looming stress conditions at the latter three catchments can be managed by means of transfer from the long term surplus catchments of upper Nyabarongo and Mukungwa. It can only be concluded that the necessary improvement of water resources management in stressed catchments requires a similar improvement in surplus catchments.

From the preceding review of observations and necessary actions it is evident that most of these actions need to be implemented in all catchments. These actions relate to planning, management, available opportunities and possible threats. These will be discussed in the next sections:

1.9.10.1 FURTHER PLANNING ACTIONS

As regards planning of water resources the current water resources master plan is available as is the irrigation master plan, the JICA study on rural water supply in the Eastern Province and ongoing water use studies for Akanyaru and upper Nyabarongo catchment. Both the JICA study and the Irrigation Master Plan are useful documents but based on administrative boundaries which are unsuitable for water resources planning.

The water resources master plan comprises 9 catchment based Master Plans which can be seen as a useful first draft based on all available information of water resources plus a number of supplemental water resources investigations (especially on groundwater, small catchments and water quality issues) as presented in the Exploratory Phase Report. The catchment master plans are also a first projection of demand which is however not very detailed or precisely located within the catchment.

It is therefore recommended to add to the nine catchment Master Plans with a more detailed and localized resources and demand investigation quite similar to the studies currently commissioned by EWSA

The recommended approach per catchment is based on:

- exhaustive identification and assessment of demand areas and service volume (comprising rural, urban, industries, administration, and other known water demand like livestock, irrigation, hydropower, ecological requirements, etc.),
- identification of supply locations and zoning of adequate least cost services (spring - borehole - gravity pipeline - pumped pipeline - rainwater harvesting) considering exploitation and investment costs (in this order). The use of appropriate technology (notably the combination of pico hydropower to lift natural springs for potable water supply by several hundreds of meters) should be incorporated in this approach.
- prioritization of demand between primary use and commercial activities or more detailed as may be suitable and based on appropriate and manageable justifications (social relevance, economic relevance, environmental impact, level of investment of the user intervention, revenue per cubic meter, water market mechanism, etc.)
- more precise timing and localization of resources development implementation works (spring - borehole - piped water supply systems)
- more precise investment cost estimation specifically for potable water supply with due consideration for the areas that are 'hard' to supply because of extreme distance and or lift between source and supply level.

The planning exercise should apply GIS software with DTM layer and automation of dynamic height from source[10]. While the district is not a sound basis for water management planning, all districts of the catchment should be fully implicated in the development of the catchment water supply plan and they should derive from it for the formulation of their district development plans.

As further resources monitoring information comes available, the RNRA-IWRM should update the resources assessment per catchment and as needed per level 2 catchment (particularly for CRUS_1 (Rubyiro) and NNYL_1 (Nyabugogo)).

1.9.10.2 MANAGEMENT ACTIONS AT THE NATIONAL LEVEL

The imminent development of water resources demand of the level 1 catchments requires a number of measures that are implemented in each of the nine catchments. They were briefly mentioned in the presentation of each catchment and some additional details are here provided:

- monitoring of rainfall resource and general climate data. This is currently done by MeteoRwanda but the information is not systematically and timely relayed to RNRA_IWRM for analysis and interpretation. This information is essential to interpret

[10] This concept has been applied for the identification of irrigation command area from reservoir sites for the Feasibility study for the development project for modern large scale agriculture around lake Nasho. "*Réalisation de l'Etude de faisabilité du Projet de Développement d'une Agriculture Moderne à Grande Echelle autour du lac NASHO dans les Districts de Kirehe et Kayonza (Province de l'Est)" by SHER Ingénieurs Conseils s.a. - February 2011 for Minagri - LWH.*

extreme events (flooding, drought) and gradual shifts of resources availability whether or not caused by anthropogenic climate change.

- monitoring of surface water resource (currently done by RNRA-IWRM). As indicated in the Exploratory Phase report, this information need to be extended covering both large and representative small catchments including natural lakes and comprise water quality data. The collected information needs to be stored, analyzed and interpreted for the purpose of water management decisions (interventions in the natural hydrological cycle).
- monitoring of groundwater resource. As indicated in the Exploratory Phase report, specific groundwater strata need to be investigated in association with the surface water resources. Investigations shall comprise groundwater levels by logger and water quality. The collected information needs to be stored, analyzed and interpreted for the purpose of water management decisions (interventions in the natural hydrological cycle.
- monitoring of the interventions in the natural hydrological cycle. It has been indicated in earlier reports that very little is known about the user's actual interventions in terms of surface and groundwater abstractions, used water releases, flow regime changes, etc. Obviously it is not realistic for government entities to realize this monitoring effort and the recommendation is that water users report their interventions at regular time intervals truthfully to the water management authority which may or may not verify these data, prior to storing, analyzing and interpreting for the purpose of water management decisions.
- The above sources of information need to be lodged in a dedicated water management information system (Water MIS, see relevant details in main report) which facilitates storage, analysis and interpretation. A pilot system has been developed in the framework of this study; details are provided in the next chapter 2.
- There is need to regulate the interventions of water users' in the natural hydrological cycle and to inform them on their rights and obligations in that respect. This is ideally done by means of a permit system. One of the obligation of a water user is to inform the management authority at regular time interval on the user's intervention (volumes abstracted, released, water quality changes, etc.). A further recommended notion is to inform all water users within a catchment on their respective permits. This will favor permit compliant operations and control by the water users directly affected by any non compliant operations. Finally, in the face of scarcity of resources, it should be clear that a water permit is a permit and not a water right. The water user has obtained the permission to intervene in the natural hydrological cycle in a specific manner described in the permit. Whether that intervention actually yields any water is the risk of the water user and not an obligation to be fulfilled by the water management authority. Ample details are provided in chapter 2.4.2 on the Water MIS.
- It is highly recommended that each catchment will be serviced by a catchment water management office reliant on the RNRA-IWRM. This office can provide water management services to water users, liaise between districts and head office, assist in water related data collection, look into conflicts between water users, investigate transboundary conflicts at the local level (Muvumba, Akanyaru and upper Akagera (Rweru) catchments), inform water users on their respective permitted interventions, investigate issues on flooding, drought, pollution, water quality, etc. Considering the imminent stress situation for the Muvumba and Akanyaru catchments, the installation of catchment water management offices may start immediately with these two catchments.

1.9.10.3 OTHER POINTS OF ATTENTION AT THE NATIONAL LEVEL

The current master plan has identified the major consumptive water use categories with the possible maximum demand by 2040 for the primary use categories (all potable water supply, environmental and social demand, livestock including fisheries) and the resources remaining for the development of commercial ventures ((agro-) industries, mining, livestock, irrigation) and for non consumptive demand (hydropower, navigation, recreation, etc.).

Within this context there are a number of points that require to be addressed at the national level for a successful implementation at the catchment level. The main ideas are:

- it very clear from the catchment development plans that a major shift from rural water supply to urban water supply will take place during the master plan period. As regards EWSA, this urban water supply is still concentrated around 15 centers. The district survey has clearly indicated the existence of 'emerging' urban centers. It is recommended that EWSA reviews its list of urban centers (including urban centers like Nyamata) and extends it with the category of 'emerging urban centers'. The emerging urban centers in each catchment are listed in the respective catchment master plans (table in each chapter 3.3.3.1. on Urban drinking water supply of the nine catchment Master Plans).
- rainwater harvesting in urban high density areas. Rainwater harvesting is to some extent a standard approach for areas that are difficult to service in rural areas. The flooding study of the Nyabugogo has revealed the extreme impact of high density housing areas on flooding (Mpazi basin features +70 % of high density tin roof area - but there are quite a number of similar catchments in Kigali and elsewhere). The development of rainwater harvesting solutions for these high density housing areas may somewhat ease the intensity of the problem and it is further anticipated that such a development will have a significant positive impact on the chores of women and children. There is need to develop suitable technical solutions between RNRA and knowledge institutes in Rwanda and possibly abroad.
- rainwater harvesting for livestock watering. This approach is expected to marry smoothly with the 'one cow - one family' poverty alleviation concept as well as with small scale yet commercial livestock enterprises. A cheap prototype solution is since many years operational in Gicumbi in a high rainfall area. There is no reason that the concept wouldn't work in lesser rainfall areas but the optimum ratio between impluvium, storage capacity and demand (number of cows) should be investigated for different rainfall areas. One of the main problems is that stored water during the dry season has a value of about 10 RWF per liter (10,000 FRW/m^3 or 50,000 RWF for a 5m^3 reservoir) in non serviced areas, and consequently requires protection against theft during the dry season[11].
- it was already briefly mentioned in paragraph 1.9.10.1 on further planning actions, that the combination of pico hydro power development with potable water supply constitutes an important opportunity where pico hydropower development which typically requires a local use (flour milling, sawmill, utilities, etc.) because the connection to the national grid is too expensive, would be used to lift water captured from a natural spring. This is an opportunity that should be considered by EWSA but

[11] This also seems a plausible reason that most irrigation ponds are used at the beginning of the dry season and that they are not used to bridge the complete dry season.

local water resources know how (either from the district of the catchment water management office) may localize potential opportunities.

2 RWANDA WATER MIS

2.1 RATIONALE

The Water Management Information System (Water MIS) has been developed as part of the Rwanda National Water Resources Master Plan study (NWRMP).

Existing and new data have been collected and analyzed during the study phase for two major purposes:

- the establishment of the NWRMP and
- the preparation of datasets to be integrated in the Water MIS

The NWRMP is essentially a forward looking but static planning tool for water resources and their use; when resources alter (climate change) and water use and demand deviate from the scenarios foreseen in the Master Plan, the plan becomes obsolete and a revision will be the minimum requirement for the planning tool to remain relevant.

On the contrary, the Water MIS is a dynamic water management tool intended to support water managers in their day to day decision making on the basis of continuously updated information on resources and the interventions in the natural hydrological cycle.

To that effect, the Water MIS should facilitate a number of IWRM functions as follows:

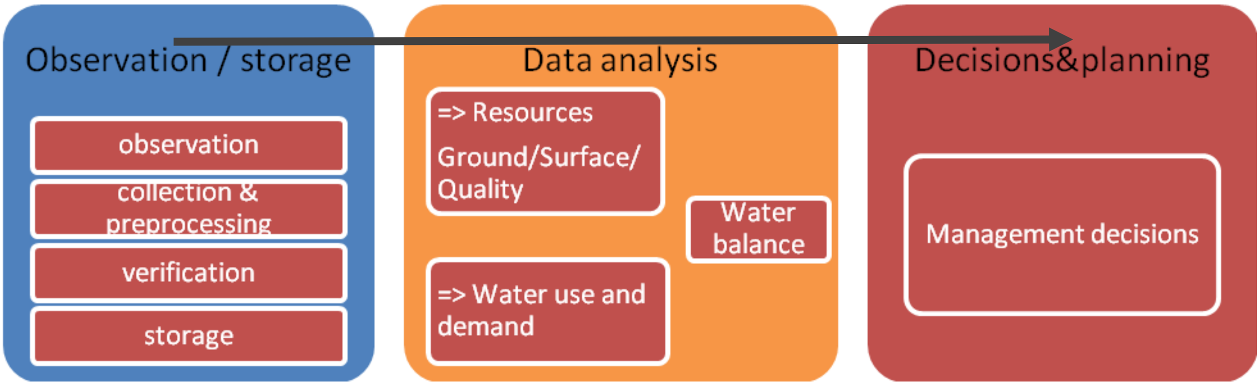
- monitoring of water resources
- issuance of water permits for intervention in the natural hydrological cycle
- management of issued permits including monitoring of water use
- recipient of all information pertaining to water and water management
- information portal for water professionals and water users
- automated production of reports
- etc.

In order to keep the system manageable and effective, specialist investigative functions which are heavy on data demand and may be relevant at specific locations only (e.g. flood simulation, groundwater modeling, economic and social simulations, etc.) are not included.

2.1.1 WHAT IS THE WATER MIS?

So what is this Water MIS? At its core, the Water MIS is a set of tools that has been provided to the RNRA-IWRM department to support efficient planning and appropriate water management decisions at catchment level.

The Water MIS can best be understood in the context of the information flow shown below:



The tools are essential for organized data collection, for processing and storage, for data analysis and research, for data publication and finally for adequate water management decisions.

These water management decisions take form in a Permit system. This permit system regulates permitted interventions in the natural hydrological cycle. A pilot water permit system has been developed during the NWRMP project as part of the Water MIS. This permit system is a "translation" of a Permit Procedure proposed by SHER Ingénieurs Conseils s.a. on the basis of the Water Law (N° 62 of 2008). This Permit Procedure (see annex C4_2) and the required institutional framework for its actuation are discussed in some detail in chapter 0 on the Institutional and Legal action plan.

For appropriate management decisions to be made there must be room for regular data analysis where the water resources are confronted with the current and projected water use and demand. Water resources versus use/demand balances are established at catchment level.

Water resources and use data are to be collected and/or observed. Water demand data need to be estimated[12]. The Water MIS provides for specific tools to effectively store, update, manage and publish water resources data and water use data. This data is needed for the data analysis (essentially to establish the water balances and calculate the available water).

2.1.2 Modular Design of the Water MIS

The Water MIS is not a software suite of integrated applications but a set of tools that are loosely linked and can be operated independently. It comprises of most relevant tools that have been used and been proved efficient during the Master Plan study or that have been developed where standardization and centralization of the storage and publishing of quality data was deemed crucial. The advantages of the implementation of a set of independent tools (compared with one integrated software suite) are:

- Flexibility: if one tool does not prove to be adapted or appropriate, it can easily be replaced by a similar tool.
- Appropriation: procedures, tools and technologies that are effectively in place are as much as possible conserved. The Water MIS only adds and replaces some instruments

[12] Water demand data has been estimated in the NWRMP project following three population growth scenario up to 2040.

in line with what exists and where the existing instruments are not sufficiently effective or missing.

- Durability: existing procedures can be improved in a more subtle way and some additional implemented tools/procedures. These interventions are less disruptive than putting in place a complete new integrated software suite; especially as the current NWRMP project does not provide for a long term support for implementation.

A number of steps are kept “manual” as most of the data workflow as well as the permit procedure are relatively new and should be tested and fully understood by the RNRA/IWRM department before automation.

Preference has been given to software and tools without or with low licensing costs.

The Water MIS consists of three major modules:

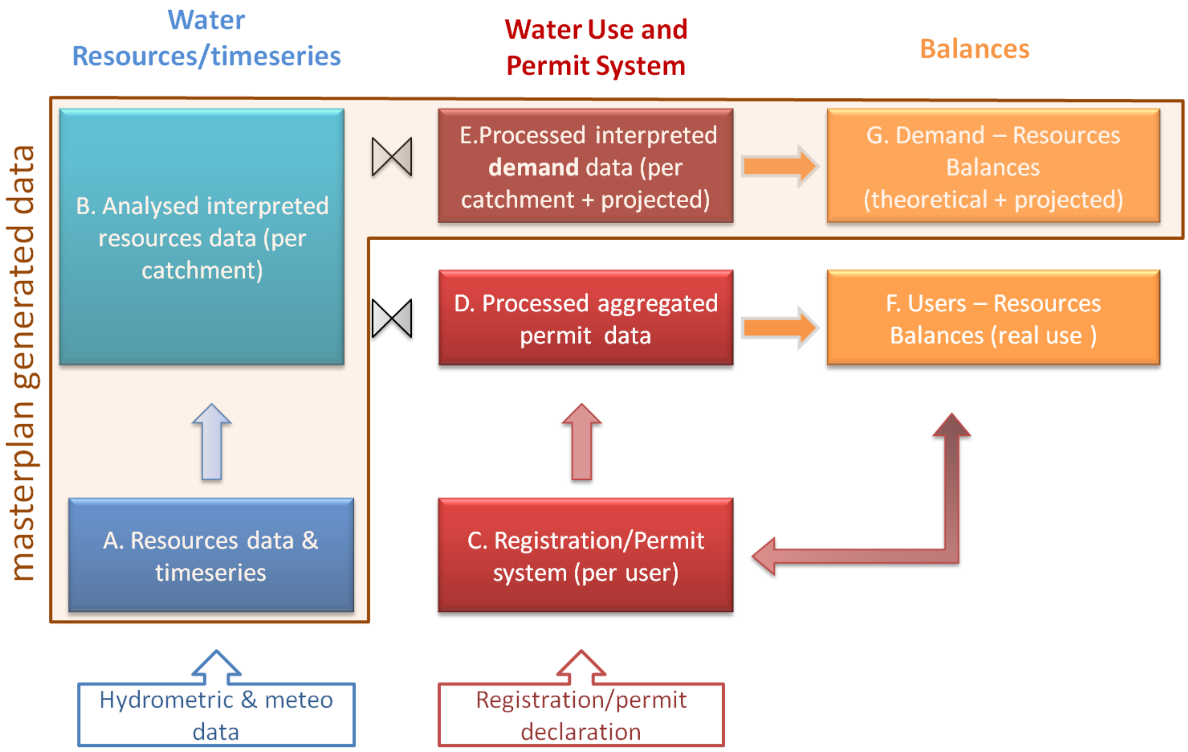
- the Water resources module,
- the Water use module (with the permit system) and
- the Water balances module.

All three modules are essential for adequate water management decision making.

Finally a “GIS Base” is provided by the Consultant. The GIS Base is a collection of files and directories with relevant collected and produced (geo-)data and software for the RNRA/IWRM department.

The overall configuration of the three modules is schematically presented in the figure below.

Figure 14: Schematic presentation of the modular nature of the Water MIS.



Data collection and input is organized for the Resources (A) and Use (C) Modules. The Water MIS provides for updating the system by adding data on available water resources and water use at any time by the RNRA staff.

Certain datasets have been generated during the NWRMP project: water resources (A & B), water demand (E; including projections) and water demand-resources balances (G; projected up to 2040). These datasets (essentially as presented in the preceding chapter **Error! Reference source not found.**) have been integrated in the Water MIS.

As soon as the proposed permit system is implemented and water users and RNRA-IWRM start exchanging information (decisions on permit requests by RNRA-IWRM and use information provided by the users), the permit system module (C) should generate actual water use data (not to be confused with water demand data estimations generated during the NWRMP project). Once the permit registration and monitoring has been put in place nationwide, covering the majority of the water users, the permit system can provide reliable water use data that also could be used (in the same way as demand data) in the calculation of balances.

Water balances per catchment are needed to estimate the available water after accumulated abstraction by the registered water users. The water resources versus demand balances are currently available up to 2040 (projections) from data generated during the NWRMP study:

- showing monthly variations throughout the year
- comparing different resources datasets and demand/use scenarii

The water balances are currently integrated in the Water MIS for the catchment level 1 divisions. They are of direct use in the management decisions (decision on a water use permit request).

2.1.3 WATER MIS LIMITATIONS

A number of limitations of the Water MIS system are presented and explained in the following paragraphs.

2.1.3.1 LIMITED REGIONALIZATION - WATER MANAGEMENT AT LEVEL 1 CATCHMENT

This version of the Water MIS is limited to water management at catchment level 1. Recall that the boundaries of the level 1 catchment subdivision have been defined with the aim to measure in- and outflow and to facilitate water management. The balance calculations as well as the management decisions (permit system) consequently refer to the catchment level 1 divisions, as they have been defined during the NWRMP project. Rwanda consists of nine catchments at level 1, each covering between 1 000 and 4 300km² (see map and table below).

Figure 15: Level 1 catchment division in Rwanda.

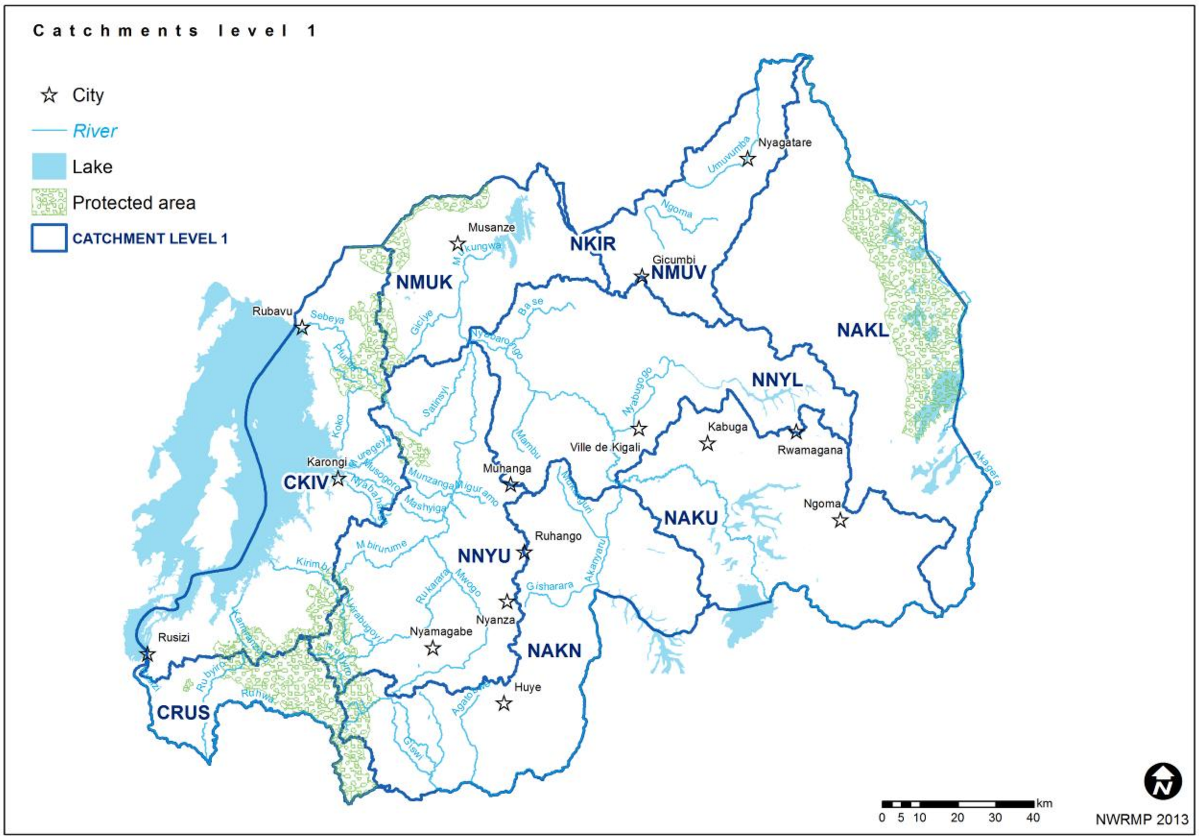


table 49: List of level 1 catchments in Rwanda

No	Code	Basin	Catchment Name	Surface [km²]
1	CKIV	Congo	Lake Kivu	2,425
2	CRUS	Congo	Rusizi	1,005
3	NNYU	Nile	Nyabarongo upper	3,348
4	NMUK	Nile	Mukungwa	1,887
5	NNYL	Nile	Nyabarongo lower	3,305
6	NAKN	Nile	Akanyaru	3,402
7	NAKU	Nile	Akagera upper	3,053
8	NAKL	Nile	Akagera lower	4,288
9	NMUV	Nile	Muvumba	1,565

It is highly recommended to extend the Water MIS to accommodate water management at catchment level 3 divisions. This will require a substantial effort but will allow for substantial improvement of water management decisions in highly committed catchments and parts of catchments.

The hydrologic characteristics have been analyzed at the catchment level 1 conform to the scope of the project. Further regionalization however is possible. Regionalization of hydrological data is defined as the transfer (extrapolation or interpolation) of the hydrological characteristics between spatial objects at different scales and at different locations. Thus, regionalization consists of the definition of a model and its parameter values that can predict hydrological characteristics at any scale or location for a certain period of the year.

There is a wealth of available information that could be used to further regionalize hydrologic characteristics at lower levels (level 3 or even at site level) in a computerized and systematic way. Thematic layers have for instance been prepared for hydrological characterization of the basins at a more detailed scale. They present the geological and lithological characteristics, the morphological and the land use characteristics for the whole country. For each catchment, the areas of spatial overlap with the different thematic classes have been calculated. This is needed to estimate the hydrological response of the measured hydrological catchments, which depends on the percentage of these different thematic units. The relationship between the measured runoff at the gauging stations and the basin characteristics with a multiple linear regression can be transferred to other catchments or locations. Changes in the catchment characteristics can be used to predict the hydrological impact.

The implementation of such a regionalization tool could allow the RNRA/IWRM team to:

- Predict the available water resources (surface and groundwater) at any location in Rwanda
- Establish specific water resources – demand/use balances at catchment level 3 or even at a specific (point) locations

The development of a more advanced regionalization tool has not been part of the ToR of the current project. With the currently produced data and knowledge, the path is open for further development and implementation of such a regionalization tool.

2.1.3.2 THE WATER MIS IS NOT AN ALERT SYSTEM

The Water MIS does not provide an appropriate framework for real time monitoring, needed for an alert system (flooding alert system for instance). Data collection and analysis frequency is done with the objective of sustainable integrated water resources management on a yearly or monthly basis.

2.1.3.3 THE CURRENT VERSION OF THE WATER MIS IS A PILOT SYSTEM

The implemented system should be understood as a pilot. It needs to be tested in practice and gradually improved along with the improvements of:

- the observation and pre-processing procedures of hydrometric data
- data analysis procedures
- procedures related to water permit application, exploitation (and monitoring) and closure

Except for data observation and collection, all these procedures are relatively new to the IWRM unit of the RNRA, as they have been, for the first time, outlined and described in detail during the NWRMP study.

For the Water MIS to be implemented as a complete toolset in an efficient and sustainable way, its implementation should be accompanied by substantial further training and support after the completion of the study.

It is recommended that the operation of the different components of the Water MIS is tested for one catchment (for instance a catchment showing water stress signs like the Muvumba catchment). After a testing period during which all the data management operations are done, the Water MIS and its operation should be evaluated. The data management operations can be summarized as follows:

> observation/reception of raw data ➔ data pre-processing ➔ data storage ➔ data analysis ➔ analysis of permit request or established water use ➔ delivery of a water permit ➔ monitoring of a water permit exploitation ➔ permit closure

This evaluation will enable to identify the measures to be taken to improve the system and to focus on institutional issues, human resources issues, data policy issues as well as technical issues related to the Water MIS hardware and software.

During this evaluation further training and support to the RNRA staff should be defined in detail. Specific training modules will most likely cover the following topics:

- Maintenance of the Water MIS modules hosted by BSC and managed by the ICT team of RNRA: management and maintenance of the Content Management Systems
- Data pre-processing and data analysis for the estimation of the available per catchment water resources; in dept use of software packages like Hydraccess and other related (GIS based) tools; per catchment resources-demand or resources-use balances estimations
- Deployment of the permit system from a more centrally managed system to a decentralized level
- Further automation of currently manual procedures

2.1.3.4 THE PERMIT MODULE HANDLES ONLY PART OF THE WATER PERMIT PROCEDURE

The Water Permit Procedure identifies 5 different types of interventions in the natural hydrological cycle for which a permit application would be required:

- abstraction of surface water from a water course, river or lake
- retention of surface water in a reservoir for later user
- abstraction of groundwater from an aquifer
- release of used water in the natural hydrological cycle
- miscellaneous interventions that do not involve the abstraction of release of water per se but which are likely to have some impact on the natural flow (regime changes, water level, habitat, etc.)

This first version of the Water MIS Permit System accommodates for the permit and data management of the three first intervention types. It is recommended that the intervention types are completed and extended once the system containing a limited number of intervention types has been tested. The monitoring of the permits (collection of monitoring data) can currently not be standardized, as it has never been done before.

A permit system on release of used waters is very complex and its development requires a substantial amount of time.

2.2 Water MIS Resources Module

The resources module of the Water MIS is the first module (see Figure 14) to be discussed in this section. The overall purpose, the data content and the constituent tools and processes will be presented in the following sub paragraphs.

2.2.1 Overall purpose of the resources module

The overall purpose of the resources module is as follows:

- Organize raw, pre-processed and interpreted data
- Secure access to resources data and secure data capitalization
- Efficiently redistribute / publish data sets via Web based interface
- Efficiently produce per catchment water resources parameters needed for the calculation of balances and water use management

The Water MIS does not provide for real time monitoring.

2.2.2 Data content of the resources module

The data content of the resources module is the following:

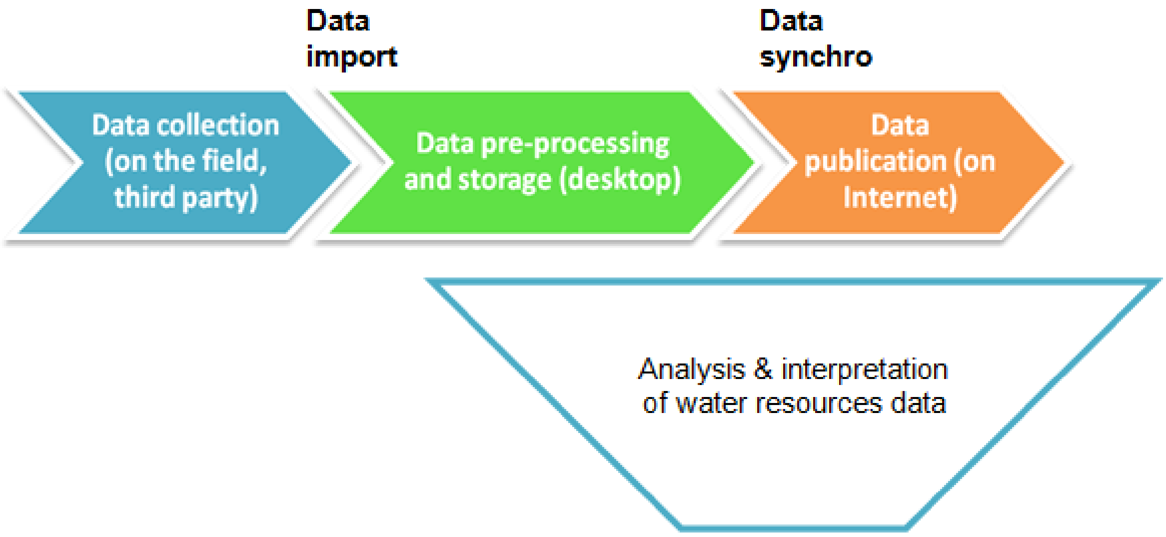
- The available stages measured in Rwanda (for surface and groundwater stations), the discharge measurements and discharge calculations (for the stations for which adequate rating curves are relevant and available) as well as related monthly aggregated data
- The rainfall data for relevant meteorological stations[13], as well as the daily and monthly aggregated data
- Other meteorological data (humidity, temperature) for a limited number of stations, as well as related aggregated data.
- Water quality data timeseries (per station or sampling location)
- Ground water data timeseries (for instance coming from ground water monitoring boreholes)

[13] 4 to 5 rainfall stations have been selected per catchment level 1.

2.2.3 PROCESS AND TOOLS OF THE RESOURCES MODULE

The Water MIS resources module is a set of tools that will facilitate to control the data workflow from raw water resources data collection to data publication and interpretation. This workflow is schematically presented in the figure below and discussed in the next paragraphs.

Figure 16: Schematic representation of the work flow for the resources module



2.2.3.1 DATA COLLECTION: MANUAL/SEMI-MANUAL

Hydrometric measurements are done manually (on paper) and are being sent via SMS by the data collectors to an online database. Measurements are typically being done twice daily.

Meteorological data is collected by the Meteo Rwanda and should be transferred on a monthly basis to the RNRA. An agreement on the data exchange should be reached between the RNRA and Meteo Rwanda. An example Memorandum of Understanding (MoU) between the RNRA and Meteo Rwanda has been drafted and is presented in annex C4_7.

Water quality measurements are currently done as ad hoc studies. No predefined water quality sampling network has been established to date. To obtain timeseries and to be able to monitor water quality over time, water quality sample stations should be defined to monitor water quality over time.

Ground water measurements are currently not collected, nor included in the water resources module. The resources module can cater for groundwater timeseries. It is entirely conceivable that groundwater monitoring boreholes are identified, the data collected and introduced into the system to monitor for instance ground water levels over time.

2.2.3.2 DATA PRE-PROCESSING AND STORAGE

For the purpose of data pre-processing and storage of water resources data, Hydraccess has been provided to the client.

The phases for water resources data preprocessing and storage are the following:

- Quality check of raw data (completeness, dates, formats, gaps, outliers) and putting the data in the right format before importing it. Because of the diversity of the sources of data, this is a manual procedure.
- Importing data in Hydraccess
- Establishment of stage-discharge relations, using rating curves, calculated discharges (tool: Hydraccess)
- Compensation of piezometric height measurements (tool: Diver office[14]). This data can also be integrated into Hydraccess
- Calculate aggregated timeseries (daily and monthly; tool: Hydraccess)

The RNRA and its predecessors have used Aqualium as the principal tool to store and analyze hydrological data. Aqualium is a desktop database application that has been developed in MS Access 2000 for the PGNRE (Projet de Gestion Nationale des Ressources en Eau). The consultant proposes to replace Aqualium by Hydraccess for the following reasons:

- Hydraccess has been developed by the IRD (Institut de Recherche pour le Développement, Montpellier, France). It is a software package that is very similar to Aqualium with regard to its interface (both have been developed in MS Access) and its functions, yet Hydraccess comprises much more functions than Aqualium. Some of the most relevant functions for the RNRA/IWRM are various graphic functions producing data performing hydrological calculations with simple or comparative graphs export options in Excel.
- Possibility of Stage – Discharge rating curves for bi-unique and not bi-unique stations (in this case, water level gradient or relative altitude difference methods are proposed), and plotting of discharge measurements on rating curve.
- Data aggregation on various time steps, from one minute to one year, passing through one day, 5 days, 10 days, 15 days and one month.
- Production of water yearbook tables, on a daily or monthly basis.
- Inventory and gap analysis of data existing in the database.
- Reconstitution of floods entering a small reservoir, knowing the reservoir stage variation, the spilled discharges, and rainfall above the reservoir.
- Hydraccess has an extensive documentation integrated in the Help system
- Hydraccess can be freely used by the RNRA/IWRM (confirmed by E-mail by the Hydraccess developer Philippe Vauchel - Philippe.Vauchel@ird.fr - on September 11th 2013).

[14] Diver Office is a desktop software package running on Windows XP or newer, designed to manage and process "Diver" data, piezometric data provided by divers (Schlumberger products have been used for the current study; many other producers are available). The RNRA received a set of divers within de framework of the NWRMP, together with Diver Office and the accompanying user manuals. These user manuals provide details on the manipulation of Diver Office or it's generated data.

- Hydraccess not only caters for meteo data and stages/discharges, but also for any water quality or groundwater data (measured or calculated)

Hydraccess is based on more than 30 years of development; its functionalities have been extensively tested and improved. It has been successfully tested by the Consultant and has been used as the primary tool for hydrological data processing during the NWRMP study.

The pre-processing and storage on desktop level can be done using tools and software packages such as Microsoft Excel, Diver Office (for the compensation of piezometric measurement time series generated by Divers), GIS software etc.

2.2.3.3 DATA PUBLICATION

Once the meteorological and hydrometric data have been pre-processed, they can be pushed through to a server side Relational DataBase Management System (RDMS) with secured Web access for publication allowing a controlled publication of data. The data publication is done via a Web portal.

Specific tools have been developed for the synchronization of pre-processed data with server side RDMS (online Water MIS Resources module). tools: Hydraccess Synchronization tool & Water MIS Resources Web application.

Anyone can access the available monthly aggregated water resources data – stages, discharges, discharge measurements, meteorological data,... - on the Water MIS Resources Web application by plotting it and downloading it in Excel format. Detailed data sets (daily aggregated or non aggregated data) can be accessed on the Water MIS Resources Web portal with an appropriate account.

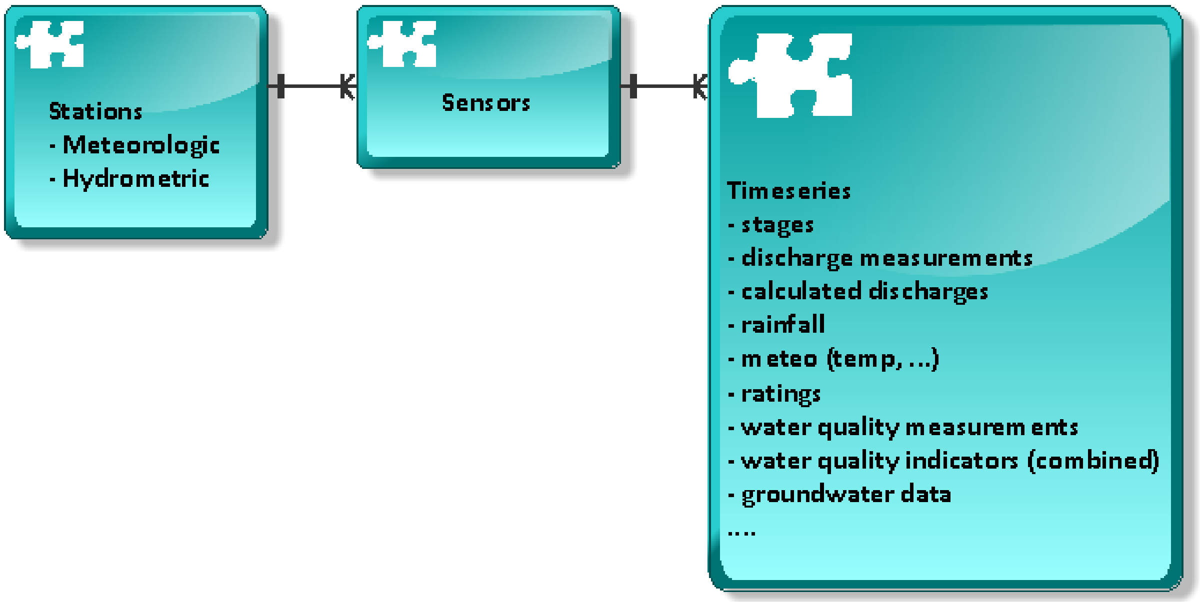
The technical specification defined for this Web based system are the following:

- Hosting of all relevant water resources data that are useful for hydrological studies
- Centralizing data in a unique database (avoid redundancy)
- Accessing station information and timeseries data anywhere via Internet
- Ease of use: find the data linked to the stations via a Web mapping application (online GIS); include also the following layers: level 1, 2 catchment division, district boundaries
- Securing data access
- Enforcing different security levels for data access, of which the most important are: “anyone can access station data and monthly aggregated timeseries” and “only (qualified) persons with an appropriate account can access the daily aggregated or non-aggregated timeseries data”
- Reducing the time of distribution of hydrologic data to third parties (just by providing a user account)
- Standardizing the data format for meteorological and hydrological data
- Be able to manipulate large datasets in a secure and fast way

The data in the Web based system can be synchronized with Hydraccess (implying that the Web based system is based on a data model similar to the Hydraccess data model). The synchronization is a ONE WAY synchronization from the Hydraccess database to the mySQL database of the Water MIS Resources Web portal.

The timeseries data related to the stations is structured in the following way: each station can have 1 or more sensors attached to it and each sensor possesses data (time series).

Figure 17: One-to-many relationships between Stations, Sensors and Timeseries.



<u>A STATION:</u>

- corresponds to a entity that is located in space (X and Y coordinates)
- belongs to catchments (level 1, 2 and 3), administrative entities (Province, District Sector) and that can be linked to a river
- can have one or more sensors

Example: Gisenyi 70001 Hydrological station (Latitude: -1.70757500, Longitude: 29.26421000, Altitude:1460

<u>A SENSOR:</u>

- belongs to a station
- can produce "measured data" OR "calculated data"
- has a unit, precision, is automated or not etc.
- holds timeseries of different kinds

Example: The 70001 can have 3 sensors:

I-H instantaneous heights measurements

M-H monthly aggregated heights measurements

M-D: monthly aggregated calculated discharges

TIMESERIES:

- Different kinds of timeseries exist: stages, rainfall etc…) which are stored in different tables in Hydraccess
- Each timeseries table is related to one sensor that explains how the timeseries was measured or how it was calculated.

Example: Sensor I-H has data for the period between 1/9/1985 and 31/7/1993

2.2.3.4 ANALYSIS AND INTERPRETATION OF RESOURCES DATA

The analysis, interpretation and regionalization of water resources data is not automated and has to be done using desktop tools by the RNRA specialists (hydrologists, data analysts…). The Water MIS does not provide for automated tools for the analysis and interpretation of resources data, such as the calculation and estimation of recharge, storage, yield, regimes, available water etc. Hydraccess features extensive functionality in this field of data analysis and interpretation.

2.3 WATER MIS BALANCES MODULE

The balances module of the Water MIS is the third module (see Figure 14) to be discussed in this section. Again overall purpose, data content and the constituent tools and processes will be presented in the following sub paragraphs.

2.3.1 OVERALL PURPOSE OF THE BALANCES MODULE

This module is designed for the publication of the water resources and water demand/use balances per catchment for a certain period. This information shows whether catchments are or will be under water stress for certain periods of time considering certain assumptions.

2.3.2 DATA CONTENT OF THE BALANCES MODULE

A water balance dataset consists of:

- a resources volume in a domain for a number of time steps
- a demand or a use volume in the same domain and time step

For the current version the domain is a level 1 catchment and the time step is a month. In as far as the interrelations between domains are currently not automated, the water MIS can in principle serve level 2 and level 3 catchments. Permit application evaluation in highly committed domains requires testing at level 3 catchments which requires evaluation of the interdependencies of resources and use in interrelated level 3 catchments.

Within the framework of the NWRMP study, monthly water resources availabilities have been calculated for 5%-35%-50%-65%-95% reliabilities for surface water and for 50% of ground water reliability for each of the nine catchments in Rwanda. Corresponding water demand estimations per catchment up to 2040 have been done for three demand scenarios: high, medium and low population growth, based on population data and the related water demand (agriculture, drinking water, environmental, etc.).

These water balance data sets have been entered in the Water MIS. They are of direct use in management decisions (Permit system) at catchment level 1. Before granting a permit to an important water user, the RNRA officer should verify water availability against cumulated water use for the catchment over the intended permit period.

It is of course possible to use different water demand or water use scenarios with projected data.

In the future the balances could be produced based on data provided by the water users (aggregated permit system data). Another example would be the establishment of the water resources - demand balances following the implementation of a nationwide irrigation strategy with a potential high impact of water availability.

2.3.3 PROCESS AND TOOLS OF THE BALANCES MODULE

2.3.3.1 DATA CALCULATION

The water resources and water demand or use parameters and values are entered manually in an Excel spreadsheet per catchment and per month. The balances are then calculated for the different water resources datasets and for the demand or use scenarios. The calculation of those parameters and values are not automated which would anyway not be very effective at a level 1 catchment.

Proper evaluation of permits in highly committed catchments and sections of catchment would require at least a level 3 assessment and when automation is considered, it should be done at this level 3. More details are provided in the section on Water Permits (section 2.4 and sub sections).

2.3.3.2 DATA PUBLICATION

The Water MIS Balances Web portal provides the Balances dataset of the NWRMP published on an interactive Web page.

2.4 WATER MIS WATER USE AND PERMIT MODULE

The water use and permit module of the Water MIS is the second module (see Figure 14) to be discussed in this section. The overall purpose, the permit procedure, the data content and the permit process will be presented in the following sub paragraphs.

2.4.1 OVERALL PURPOSE OF THE PERMITS MODULE

The main purpose of the Water MIS Permit System is:

- to facilitate the decision making process on permit applications; can the requested intervention be successfully operated without undue impact on other water users and therefore be granted as requested, granted after modification, granted with conditions or should the permit not be granted?
- to facilitate the collection and interpretation of actual water use data submitted by registered users, the comparison of actual use data with permitted interventions and with up to date resources data

The water permits module can be considered as a transformation of the Water Permit Procedure into an information system in line with the institutional framework. The Water Permit Procedure as formulated by the consultant is presented in annex C4_2.

In summary the Permit System module will:

- Host all water permits and related data
- Centralize this data in a unique database (avoid redundancy)
- Allow decentralized data insert, update and management over the Internet
- Secure the data access; Enforce different security levels for data access and manipulation: the non registered visitor, the Registered Water User and the Water Authority should, with different access permissions, be able to manipulate the system
- Include Web mapping for locating abstraction, restitution and storage of water; incorporating the following layers: level 1, 2, 3 catchment division, district and sector boundaries and rivers
- Standardize the permit data format
- Put in place a workflow reflecting the water permit process
- Trigger sending of emails on certain events within the workflow; also option to use scheduled triggers

2.4.2 THE WATER PERMIT PROCEDURE

In its core the rationale of a water permit is to regulate the access of water users to the natural hydrological cycle. The water permit is a prime tool to achieve best and efficient access to water through regulation. This tool should however be operated by a proficient water management organization equipped with proper tools (Water MIS, measurement, laboratory, …) and complemented by an up to date Water Resources Master Plan.

The water permit is a written agreement (or a contract) between a water user and the Rwandan government in the person of the Minister of State in charge of Water. Whereas this agreement should be beneficial to both parties it is essential to structure this agreement along their respective rights and obligations.

The water user aims to develop some water related activity with the objective to sustain livelihood and/or pursue a commercial venture. The 'right' of the water user is the permission to intervene in an explicitly defined manner at an explicitly defined location and for an explicitly defined time, in the natural hydrological cycle. The 'obligation' of the water user when granted the permit may likely be to provide information to the water management authority on his interventions at specified time intervals over the total duration of the permit, to pay agreed administration fees for services provided by government, to implement mitigation measures as specified during the total duration of the permit and to reestablish the conditions prior to the intervention when closing the permit. A water permit can not in any way guarantee that the user's intervention in the natural hydrological cycle will be successful in terms of quantity of water abstracted; in that sense the terms 'water right' is misleading and consequently inappropriate.

The Rwandan Government aims to secure the sustainable use of the natural resources, to protect the interest of other water users and to promote the use of the natural water resources for the purpose of sustainable development. The 'right' of the government is related to the power of decision on any envisaged intervention including the temporary suspension of any permit in case of emergency and or extreme conditions. The government should further have the right to unrestricted water related information during all phases of the intervention including access, inspection and testing of the water user's installations at any time and for any duration. The 'obligation' of the government is to provide state of the art water management services to all water users which assure optimal decision making considering economic, social and environmental criteria based on the best available knowledge. In order to live up to this obligation, the government is bound to collect, analyze and comprehend information on the state of the natural water resources and on each of the singular water use interventions.

In order to structure the possible interventions in the natural hydrological cycle, these interventions can be classified according to the following 5 types (intervention types):

- abstraction of surface water from a water course, river or lake
- retention of surface water in a reservoir for later user
- abstraction of groundwater from an aquifer
- release of used water in the natural hydrological cycle
- miscellaneous interventions that do not involve the abstraction of release of water per se but which are likely to have some impact on the natural flow (regime changes, water level, habitat, etc.)

The first version of the Water MIS Permit System will only accommodate for the permit and data management of the three first intervention types.

According to the law (62 of 2008) there are three regimes of water use or types of permit (permit types):

- Declaration regime; the declaration is intended for interventions that are unlikely to have a major impact on the natural hydrological cycle or on other water uses; the declaration can be operated without much supervision or control from water management authorities
- Authorization regime; the authorization is intended for interventions that have some to significant impact on the natural hydrological cycle or on other water uses; the authorization requires regular supervision and control from water management authorities
- Concession regime; the concession is intended for interventions that are expected to have major impact on the natural hydrological cycle and or on other water uses; the concession requires frequent and in depth supervision and control from water management authorities.

The table below gives some suggested examples of interventions according to ‘intervention type’ and ‘permit type’. The precise boundaries between the permit types require a decision by the Rwandan Authorities; the values here suggested are just that; suggestions.

table 50: Examples of intervention- and permit types

Example	Intervention type	permit type
small garden watering from river; < 5 are	surface flow abstraction	declaration
10 ha irrigation project along river		authorization
500 ha hill side irrigation project river abstraction		concession
not available: all surface flow storage requires at least an authorization	surface flow storage	~~declaration~~
small dam (<15 m or …)		authorization
large dam (>15 m or vol>… or vol/km>…)		concession
borehole / well with hand pump	groundwater abstraction	declaration
borehole / well with motorized pump average capacity		authorization
borehole / well with motorized pump and large capacity		concession
not available: all used water disposal requires at least an authorization	used water disposal	~~declaration~~
disposal of waste water quality RURA compliant		authorization
disposal of waste water quality RURA non compliant		concession
embankment protection plantation	miscellaneous intervention	declaration
bridge with embankment construction works		authorization
floodplain drainage works, floodplain embankment		concession

2.4.3 DATA FOR THE PERMIT PROCEDURE

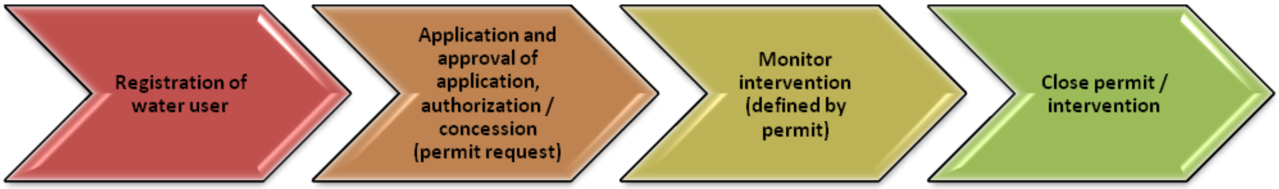
The successful operation of the permit system (prior evaluation of 'success' and data collection for exploitation) requires the following information:

- The identification of the water user
- The natural system in which the proposed intervention will be operated.
- The description of the intended and actual (monitoring) extraction-retention-restitution process and the planned infrastructural works with sufficient detail on dimensions, capacities, etc. Information should be provided on anticipated impact on the 'natural system' and other users if any. Further information should be provided on proposed mitigation measures if any.
- The purpose of use
- The (aspired) duration of use
- The payment modalities

The data collection for application, operation and closure of a permit is described in detail in the Water Permit Procedure in Annex C4_2.

2.4.4 Process and tools of the Permit module

The sequence of the permit procedure is presented in the figure below:



These steps are discussed in the following paragraphs.

2.4.4.1 Registration of the water user

The registration of the water user involves the following steps:

- The Water user registers him/herself through the web portal making sure that communication details (phone, email, address, etc.) are up to date. If needed the water authority may assist the water user in the registration process and the water user may also submit a paper form to this effect.
- The water authority validates the user registration making sure he or she is not already registered: the Water user gets an account from the Water Authority and becomes a Registered Water User (RWU)

2.4.4.2 Application for a water permit

The next step is the application for a water permit. Only RWUs can apply for a water permit.

- The RWU submits an application for a permit (for water use). A minimum of information has to be provided by the RWU (see details in the permit procedure in annex)
- The Water Authority verifies and assesses the permit application in two steps
    - application completeness check (are all necessary data submitted?)
    - hydrological viability check at level 1 catchment (is the permit likely to be successful?)

Especially for highly committed areas it may be mandatory to check the permit viability at the level 3 catchment. This is currently not possible but highly recommended.

A further issue is the EIA study. This is normally required for any intervention that requires an authorization or a concession permit. The proper assessment of the EIA can only be made when the actual abstraction volumes are known hence when the hydrological viability check has been done.

It is suggested that both applications proceed in parallel but that the EIA is only approved when the hydrological viability check is available.

While assessing the permit application, the WA completes the permit application. Once the checks have been done, the Water Permit is issued as applied for, or with adjustments (intervention calendar, duration, quantities, capacities), or with conditions (mitigation measures) or the permit is declined.

The WA may be required to assist the RWU in the application process.

2.4.4.3 PERMIT EXPLOITATION MONITORING

The Water Permit is a contract concluded between the RWU and the WA. The Water Permit will contain information on how much, how and when water will be abstracted, retained, or released (or a combination). It will also contain information on how the RWU will perform the water use monitoring (by providing water use data on a regular basis to the information system of the WA).

- The RWU provides water use data
- The WA can do complementary investigations and complete water use data

2.4.4.4 PERMIT CLOSURE

On permit closure (due to duration expiry, on request of the RWU or demanded by WA for a specific reason), information should first be provided by the RWU and then by the WA.

2.5 GEOSERVER MAPPING SERVER

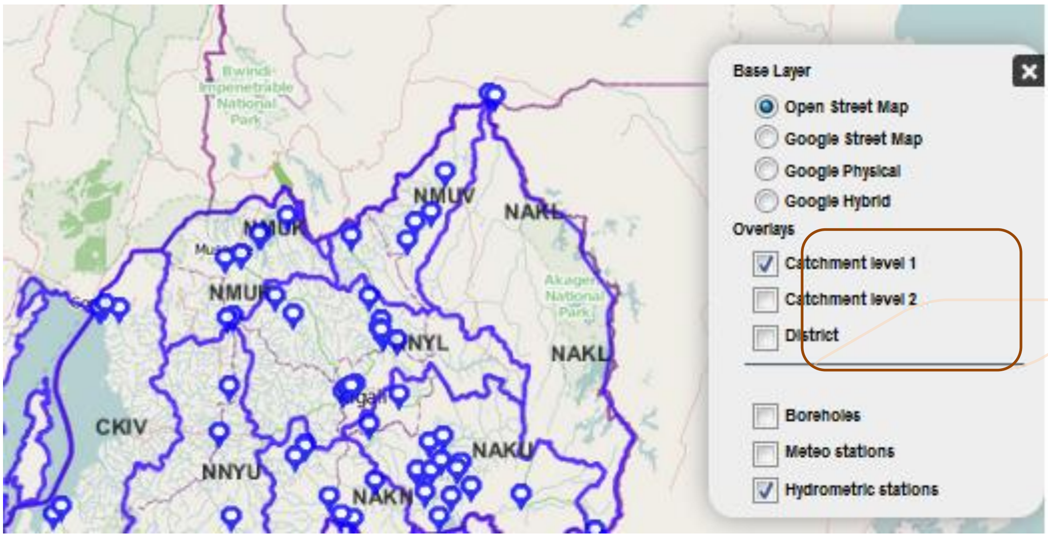
The information in this paragraph has mainly been obtained from the following source*:* *http://geoserver.org*. The site was accessed in September 2013.

GeoServer is a free and *open source software server written in Java that allows users to share and edit geospatial data* in web mapping applications (online maps). *Designed for interoperability, it publishes data from any major spatial data source using open standards*. Implementing the Web Map Service (WMS)[15] standard, GeoServer can publish maps in a variety of output formats.

GeoServer is used in the Water MIS to publish specific layers using the WMS protocol. Those layers are for instance, like shown in the red rectangle below, the Catchment level 1, 2 and 3, the Administrative boundaries and the Rivers layers. They can be visualized in Web Mapping clients, such as the Water MIS resources start page. The overlays are WMS layers published by a GeoServer.

[15] http://www.opengeospatial.org/standards/wms

Figure 18: Geoserver example data (e.g. Catchment level 1 boundaries)



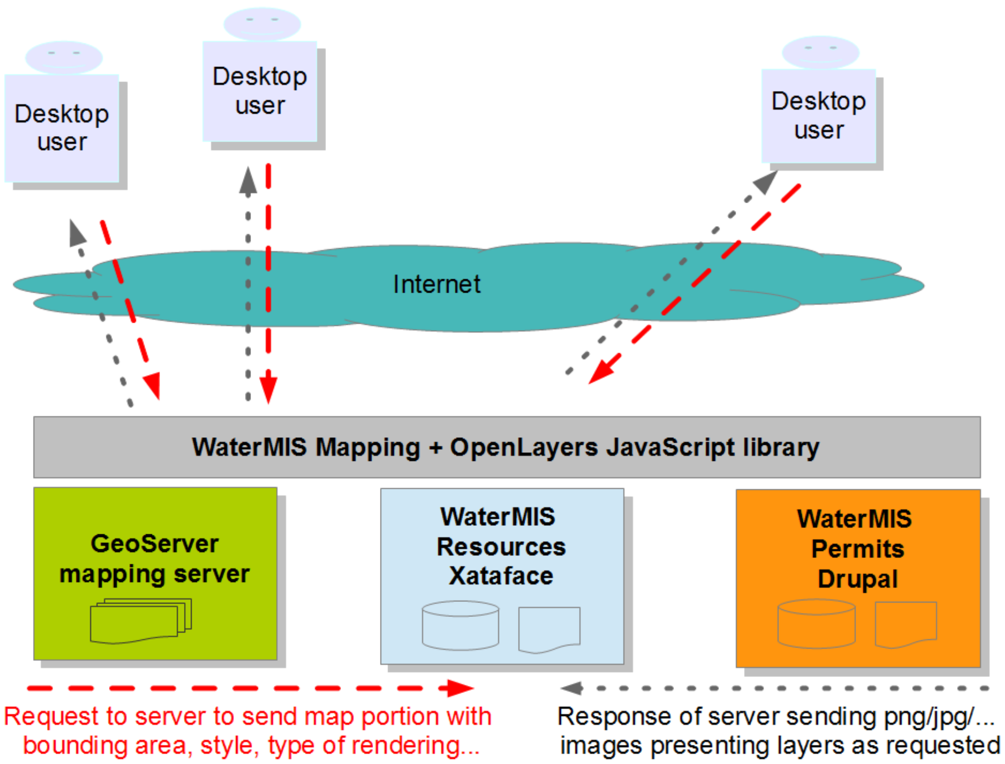
The diagram in Figure 19 below shows that both the Water MIS Resources and Water MIS Permits Web portals use Web Mapping Services published by the GeoServer. The following WMS layers will be published by Geoserver to be used in the Water MIS Resources Web portal and the Water MIS Permit System:

- level 1, 2, 3 catchment division (3 layers)
- district and sector boundaries (2 layers)
- rivers.

Notes:

1. The Stations (meteorological and hydrometric) and boreholes are produced and published by the Water MIS Resources database directly (not via GeoServer).
2. The abstraction locations and return flow locations are managed and published by the Permit System database (not via GeoServer).

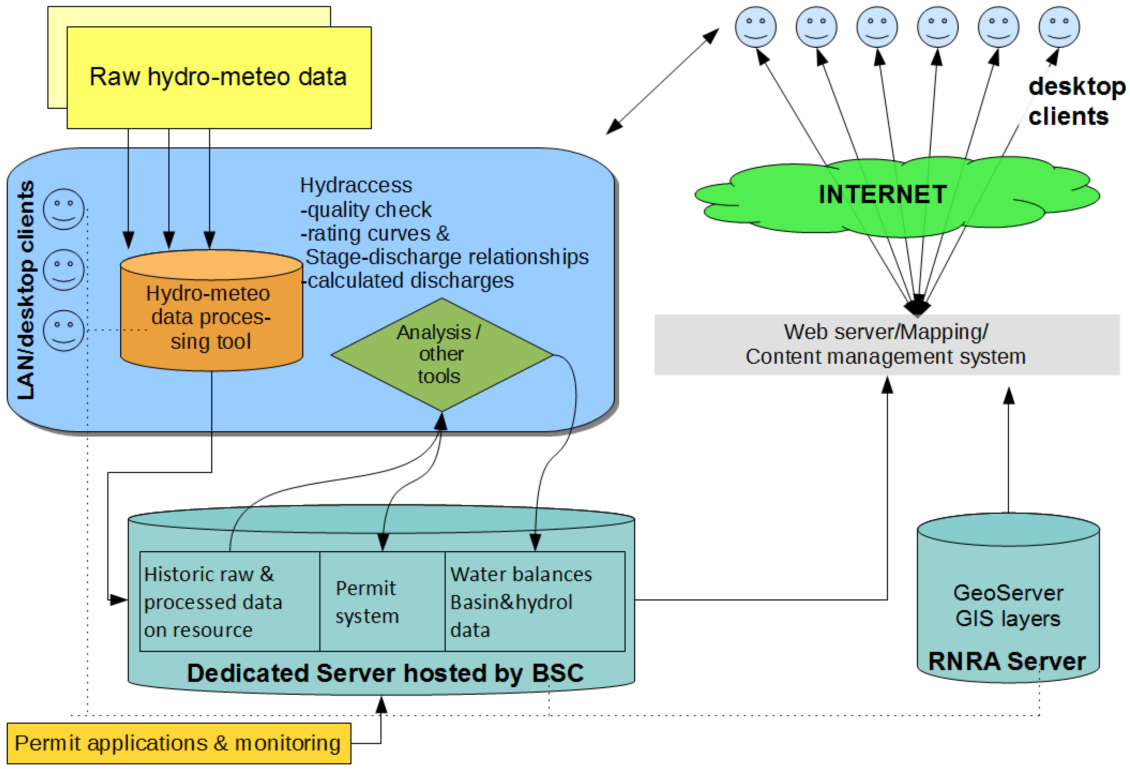
Figure 19: Webmapping services configuration diagram



2.6 WATER MIS ARCHITECTURE

The overall Water MIS architecture is presented in the figure below.

Figure 20: Diagram of the Water MIS architecture.



The different tools and data of the Water MIS are partly hosted in desktop environment and partly on servers. The Hydraccess application is a MS Access desktop database application and hydrology tool. This tool can connect to a Hydraccess working database. A "Master" version of the Hydraccess working database contains all the UP-TO-DATE resources data of the department. This version should be maintained with care by the person in charge of the Water MIS; regular backups should be made before and after each update of the database.

This desktop database can be synchronized with the database containing the Resources data on a dedicated server hosted by BSC (Broadband Systems Corporation, www.bsc.rw), the company where the RNRA Website is hosted. The Water MIS Resources, Balances and Permit System Web applications are hosted on this server. GeoServer, used for publishing WMS services could be hosted on RNRA servers or on the BSC servers (if technically and administratively feasible). The ideal hosting situation would be dedicated server hosted by BSC.

The Permit applications and the monitoring (orange rectangle) represents the data input which can be done via the Internet clients.

2.7 WATER MIS INSTALLATION, OPERATION AND MAINTENANCE

2.7.1 MANUALS

The installation and deployment manuals as well as the end user and administration manual for the Water MIS can be found in appendixes 11 to 15 respectively:

- app_11_WATERMIS_Software requirements definition and specifications_vN.N
- app_12_WaterMIS_Installation_Deployment_Manual_vN.N
- app_13_WaterMIS_Resources_Balances_User_Manual_vN.N
- app_14_WaterMIS_Geoserver_User_Manual_vN.N
- app_15_WaterMIS_WaterMIS_PermitSystem_User_Manual_vN.N

2.7.2 HOSTING ISSUES

The Web applications are currently not installed on BSC hosted servers (the web services provider for the RNRA). The hosting package of the RNRA at BSC is currently not adapted for the hosting of the Water MIS Modules. A new hosting package should be acquired with the following specifications:

- Amount of dedicated storage space for the 3 Water MIS modules and Geoserver: minimum 5Gb to preferably 10Gb
- Data transfer: given the context of the Water MIS being a portal dedicated to professionals in the Water sector, the expected data transfer will not be exceptionally high, even though the front page includes a map. An important limiting factor of data transfer is the fact that only a selected number of users can download non monthly aggregated data. The public ("anonymous") user has only access to monthly aggregated data, which are very "light" pages (see table below).

Table 51: Data transfer analysis in the Resources module (module requiring the most transfer demanding module)

Page	Download amount when loading page for the first time	Download amount when loading page for the second time in the same browser
Start page (with map)	approx 1500KB(*)	100KB (the rest from cache)
Stations overview page (table)	approx 700KB	approx 300KB (rest from cache)
Graph plotting with 30 years historic monthly aggregated data	approx. 200KB	approx 40KB (rest from cache)
Graph plotting with 30 years historic instantaneous synoptic data (8 measurements/day)	approx. 6.2MB	approx 6MB (rest from cache)
Graph plotting with 30 years historic daily data	approx. 1MB	approx 1.9MB (rest from cache)

- For the initial launch of the system (first few years), 2GB per month would be sufficient (assuming 400 new users a month for the 3 modules and 20 users a month that download large datasets of 10MB). The data transfer should be monitored monthly.

- Uptime of the website[16]: minimum 95% (approx 36 hours down / month; as long it's mostly out of office hours)
- Access to a dedicated sub-domain for the Water MIS: (name to be defined by RNRA-IWRM). The subdomain name could be for instance http://water.rnra.gov.rw
- Backup facilities (either cloud backup or on secured media)
- Dedicated server: the upload of large datasets, specifically for the Resources module, requires the specific PHP settings which are most likely against the BSC policy (which might include longer script execution times)

Geoserver:

Specifically for the Water MIS, the Geoserver does not require extraordinary performance because of the following reasons:

- the published maps are very simple and few,
- the number of users is expected to be less than 100 to 200 users a day (as the portal targets water professionals),
- only vector layers are to be published (no need to deal with raster mosaics or pyramids, tiling or rendering issues).

2.7.3 Collaboration with Meteo Rwanda

A data exchange collaboration should be implemented with Meteo Rwanda (as previously mentioned). This collaboration could take the form of a memorandum of understanding (MoU). An example of an MoU can be found in the Annex C4_7.

2.7.4 Operation and maintenance costs

The tentative operation and maintenance costs for the Water MIS are presented in the table below. The costs for installation of the system are indicated in the upper part of the table.

table 52: cost estimation for the installation and operation and maintenance of the Water MIS.

Cost for putting into production			
Activity	Unit	Quantity	Comments
Server hosting costs (for Resources, Balances and Permit System Web modules	€/month	Unknown (BSC or other)	BSC could not provide the Consultant with a quotation; to be finalized between the RNRA/ICT and BSC
Domain name creation	€/month	Free	Available from RNRA (sub-domain)
Putting system into	days	3	Including installation of local mirror

[16] Measured by the percentage of time during which the website is publicly accessible and reachable via the Internet.

production			
Training	days	3	Both RNRA-IWRM and RNRA ICT (backups,…)
Documentation	days	1	Client and server side (most of the documentation is done)
Operations & Maintenance Costs			
Activity	Unit	Quantity	Comments
Database management - RNRA/ICT	days/month	0.5	1 day per 2 months for maintenance
Web application management - RNRA/ICT	days/month	0.5	1 day per 2 months for maintenance
Geoserver management	days/month	0.17	1 day every 6 months

The core Water MIS operational procedures like the data manipulation of Hydraccess, the synchronization with the Water MIS Resources Web portal and the operation of the permit system, should in the beginning be done by at least 2 or preferably 3 RNRA/IWRM permanent and full time staff.

The exploitation of the system not only relates to the specific manipulation of Water MIS tools but foremost to the overall process and procedures related to Water resources estimation, balances calculation, data formatting and processing, permit application handling, issuing of permits, monitoring etc.

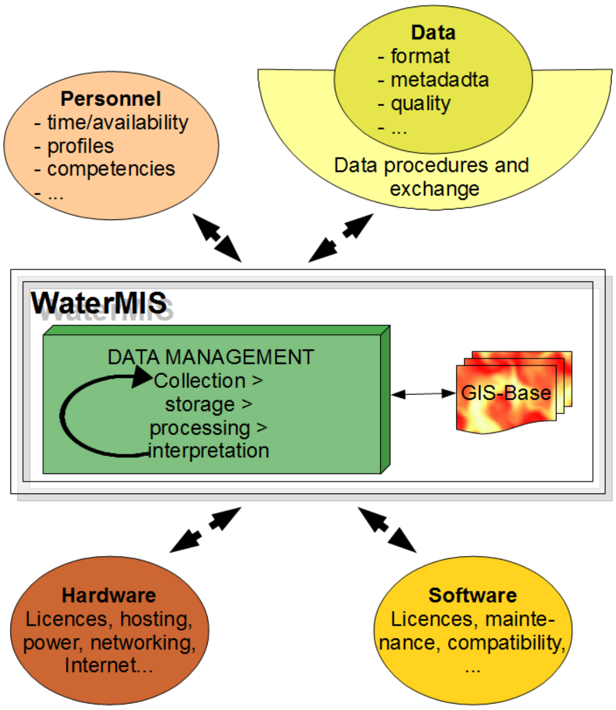
2.8 Conclusion on the Water MIS and the way forward

The Water MIS toolset consists of a number of tools, software packages and procedures for their operation (the latter being described in the manuals). The tools have been selected and developed within the rationale of an integrated per catchment water resources-uses management. Even though there are linkages between the tools, every tool can be operated independently and is by consequence replaceable; this modular construction enhances the opportunities for a more efficient appropriation of the tools (or possible replacement of a tool if deemed inappropriate), for their targeted improvement and for acquiring specific technical support.

The different Water MIS tools and modules should be regularly critically evaluated towards the opportunities and risks, the toolset should be consequently improved and completed.

The current context of the IWRM department of the RNRA presents interesting opportunities with regards to the operation and exploitation of the Water MIS. But we should also be aware of the risks that could hamper the Water MIS operation and how the risks could be circumvented. The following figure represents the theoretical components on which a successful operation of the Water MIS depends.

Figure 21: Schematic presentation of the components acting upon the Water MIS operation.



The opportunities and risks are presented in the table below for each of the mentioned components (Personnel, Data, Software, Hardware).

Table 53: Opportunities and risks related to the Water MIS

OPPORTUNITIES / STRENGTH	***RISKS / WEAKNESS***	***SOLUTIONS / ACTIONS***
	PERSONNEL / USERS	
The RNRA/IWRM department has recently expanded its technical staff. Staff members have been appointed to the specific units (e.g. water resources, permit delivery, etc.) at central level	Staff turn-over (risk of loss of technical know-how) Lack of technical competences with regard to (1) operating the Water MIS tools and (2) executing procedures for IWRM	a) Staff retention policy b) Training of staff (on technical matters, on software operation, on IWRM procedures), exposure of staff members to the overall IWRM procedures
	Currently lack of personnel at decentralized level (support to Catchment committees); this risk is real when the system will be rolled out/decentralized	Recruitment / training of additional staff
The RNRA/ICT department has recently expanded its technical staff.	Lack of technical competences with regard to the maintenance of server	Training of staff

OPPORTUNITIES / STRENGTH	***RISKS / WEAKNESS***	***SOLUTIONS / ACTIONS***
	based Water MIS tools	
Water user can register and apply online for water use as well as follow-up it's permits (opportunity of reducing the RNRA staff workload and potentially improving data quality)	Water user has insufficient knowledge to do so	Additional support, information and training needed (to be provided by the Water Authority to the Water User)
DATA AND DATA PROCESSING		
Data is available for a number of hydrometric stations	Poor quality/non usable data for certain stations Incomplete data for certain sub-catchments	Perform discharge measurement and establish rating curves Rehabilitate stations/establish new stations
Data is available for a number of meteo stations	Collected and pre-processed by Meteo Rwanda: data quality, formats and provision not 100% under control of RNRA	Establish own network for data collection Establish agreement with Meteo Rwanda
Water MIS can accommodate water quality and ground water data time series	No monitoring network has been established (incl. data transfer procedures)	RNRA needs to establish a monitoring network
Water use data can be collected within permit system	Permit system is not fully operational (currently pilot system)	Make permit system operational; putting permit system in production[17]
Hydraccess allows advanced data processing of hydrometric and meteo data	Technical mastering of data processing is insufficient	Additional training is needed
SOFTWARE		
Hydraccess has been introduced as major desktop tool for hydrological data processing; Hydraccess can be used for free	Lack of Microsoft Access License on the computers of staff using these tools	Licenses needs to be acquired for staff using those tools
Other MS Excel and MS Access tools have also been provided	Lack of Microsoft Access / Excel Licenses	Licenses needs to be acquired for staff using those tools
The client-server packages (accessible via network or the Internet) have been developed using open source solutions	-	-

[17] This issue has been discussed in chapter 2.4 and sub paragraphs. Full details on process and rationale of the permit procedure is provided in appendix 10.

OPPORTUNITIES / STRENGTH	***RISKS / WEAKNESS***	***SOLUTIONS / ACTIONS***
(allowing further extension and development)		
Decentralized operation and access of the resources Web portal and Permit systems is possible	Lack of Internet access in Districts, at catchment level or at Water User level will not allow decentralized access	Provide Internet access
Pilot system[18]: The online modules have currently been installed in test version on the RNRA/ICT servers allowing extensive testing	Due to lack of support the in-house testing will not be concluded and the online modules will not migrated to a production environment (on BSC servers)	Seek external assistance for migration Acquire adequate hosting solution
HARDWARE/HOSTING		
BSC (the current RNRA Web services provider) disposes of the right infrastructure for hosting the client-server (Web based) tools in production *Remark: The RNRA/ICT does currently not dispose of the right infrastructure to host the Water MIS online modules*	The RNRA hosting package with BSC is currently insufficient *Remark: even though the RNRA/ICT staff has been trained on installation and configuration of the different modules, unforeseen problems might occur when migrating to BSC servers*	A new hosting package is needed with a dedicated server solution External specialized support should be seeked for additional training of RNRA/ICT staff
Backup infrastructure implementation has been planned for	Backup infrastructure is not put in place	Put in place backup infrastructure OR outsource backup services to the hosting company
RNRA disposes of a network with shared storage; the shared storage for the department is possible with secured (password protected) access	Moving to a new building could (temporarily) interrupt access to the network and shared storage space	Network access and shared storage should be requested by IWRM to the ICT department

The limitations of the current version of the Water MIS have been discussed earlier in chapter 2.1.3.

The principal recommendation for the Water MIS to be implemented in an efficient and sustainable way, <u>is that its implementation should be accompanied by substantial further training and support.</u> After a testing period of maximum a few months, the Water MIS tools and all related operations should be evaluated towards their opportunities, strengths,

[18] This issue has been discussed in chapter 2.1.3.

weaknesses and threats and adequate solutions should be proposed for the improvement of the system.

Over time, the IWRM Department should extend its toolset by further developing the tools and integrating additional tools in the Water MIS. Certain procedures could be automated after sufficient testing, but also according to the institutional framework that will be put in place. The modular and open nature of the Water MIS allows for such developments.

Institutional and legal action plan

2.9 INTRODUCTION

Rwanda has adopted the notion of Integrated Water Resources Management (IWRM) as the basic premise for the management of its national water resources.

According to the technical committee of the Global Water Partnership, IWRM is "*a process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems*".

One of the principles of IWRM is 'subsidiarity' or the notion of decision making at the most appropriate level. The UNDP's 1997 report on decentralization[19] noted that the principle of subsidiarity is an important motivation for decentralizing governance: "*Decentralization, or decentralizing governance, refers to the restructuring or reorganization of authority so that there is a system of co-responsibility between institutions of governance at the central, regional and local levels according to the principle of subsidiarity, thus increasing the overall quality and effectiveness of the system of governance, while increasing the authority and capacities of sub-national levels."*.

Although decentralization is not a condition 'sine qua non' for the implementation of IWRM, it is clear that there are very significant benefits when optimizing information exchange and management functions between different strata:

- the Central level: management functions are provided by RNRA-IWRM and a series of other central government entities. Communication protocols and coordination platforms are required to synchronize the management functions between the government entities as well as between the central to the decentralized levels. This aims especially at coherent strategies, planning and resources development;
- Decentralized level: management functions are provided by catchment, district and sector entities. Similar communication protocols and coordination platforms are required to optimize information exchange and management functions at catchment, district and sector levels. The launch of these intermediate levels is essential to enrich possibly abstract planning concepts with the situation on the ground;
- User level: water users (professional organization, NGO, private person, ...) are numerous and extremely diverse in intervention method and magnitude. The relevance of their implication in management can hardly be over stated because they are the ones who may actually know what they are doing.

This chapter on the institutional and legal framework required for IWRM will render these notions much more concrete based on the following structure:

- the first step in the next paragraph 2.10, is a further elaboration of the actual content of IWRM, developed with the aim to highlight the management decisions,
- with this background, the institutional structure 'under construction' as defined by the water law (N° 62 of 2008) is presented in paragraph 2.11 with the aim to identify

[19] UNDP, Decentralized Governance Programme: Strengthening Capacity for People - Centered Development, Management Development and Governance Division, Bureau for Development Policy, September 1997, p.4;

possible omissions and inconsistencies. Most of this has already been presented in great detail in chapter 8 of the exploratory phase report.

- from here the next paragraph 2.12 depicts an 'ideal' institutional framework for the implementation of the different IWRM compliant management functions. Different identified management functions are elaborated in sub - paragraphs.
- whereas the governments decentralization approach is operated through the districts, the next section (paragraph 2.13) explores need and practical modalities for catchment oriented water management services in Rwanda while maintaining the districts' mandate on development policy and associated financial dealing in their respective domains. This is essentially a transition mechanism for catchment management while maintaining district territorial hegemony. It closes with some ideas on the institutional structure under lean government conditions.
- the next two paragraphs (2.14 and 2.15) present a road map with concrete actions for respectively the implementation of the institutional structure and the corresponding legal framework.

2.10 IMPLEMENTATION OF IWRM

IWRM means pro-active management of water resources in a domain by means of implementation of effective water management decisions. The key issue that needs to be answered each time is whether an aspiring water user can be permitted to intervene in some way in the natural hydrological cycle at a specified location and for a specified time.

Such a request from an aspiring water user can be declined, partially approved, conditionally approved or approved as requested by the applicant.

In order to provide a rational response to the aspiring user's request, he or she needs to make very clear what intervention is intended:

- what is the resource (rainfall, surface flow, groundwater from aquifer, re-use option)
- where exactly will the intervention take place?
- when (calendar, months, weekdays, time of day, ...) with starting date?
- for how long (from a few months or weeks to 20 years or more)?
- what is the method of intervention?
- how much water is intended to be abstracted / needed?
- what is the use (primary or commercial; if commercial what is the expected benefit per m^3; what are the consequences of a reduced permit (for both types of use)? what are the consequences of a temporary reduction of abstraction volume?)
- is any or all water returned to the natural hydrological cycle?
- if so, where will the water be returned?
- if so, what flow will be returned?
- if so, is there any change of water quality?
- to what extend is the natural resource going to change from the intervention?

- to what extend are established water users going to be affected by the intervention?
- if anything, does the aspiring water user envisages to undertake any action to mitigate his impact on the resource and / or on other water users?

Of course, it is needed that the owner and the operator (if not the same legal person) of the intervention in the natural hydrological cycle, are known and can be contacted by the relevant authorities.

In order to proceed with the formulation of a rational response to the aspiring user's request for permission to intervene in the natural hydrological cycle, it is further needed to know how much water is available in the natural hydrological cycle, and what other water users are doing with or without permission.

Therefore the following information is needed

- assessment of total reserves and annually and monthly renewable resources of the domain where the intervention is envisaged.
- continuous monitoring of the state of the resources in this domain
- management of water demand and use in the domain where the intervention is envisaged:
    - strategy development and implementation (what are our principles? how are we going to proceed? - protection of resources, water quantity, water quality, environment as a user, what uses of what resources are permitted (DWS, Industry, irrigation, non consumptive uses, miscellaneous interventions), disposal of used water, (de-)centralized management, prioritization of use according to what principles (priority date, equitable distribution, market mechanism), mitigation measures, payment / subsidy for water use, promotion of water use for development, ...)
    - planning (development of a master plan; in the core this is a calendar of necessary and advantageous future works and interventions in the natural hydrological cycle with all consequences (investment and exploitation costs, operation and maintenance, staff and training, etc.))
    - implementation (of resources development works based on viable and authorized short or long term intervention under the declaration, authorization or concession regime; it is the consultants opinion that the interventions should be grouped according to the following:
        - direct abstraction of surface waters
        - significant storage of surface water for subsequent use
        - direct abstraction of groundwater
        - disposal of used water in surface or groundwater
        - miscellaneous interventions other than abstraction and or disposal; fisheries, construction works, drainage, ...)
    - exploitation of intervention works (actual exploitation should generally adhere to the intervention for which an authorization has been requested and granted or conditionally granted. Change in actual availability of resources due to extreme meteorological conditions in the area or elsewhere (upstream or downstream), or erroneous granting of permits, or inappropriate exploitation

of authorized interventions may all lead to temporary or even permanent changes of the authorized intervention. A prioritization of authorized interventions should be defined in the strategy

- monitoring of use interventions (this is in the first instance the registration of the actual interventions in the natural hydrological cycle of each and every intervention under an authorization or concession regime. It may likely include monitoring of the natural resource at the abstraction and/or disposal location, and possibly monitoring of the impact on other water uses due to changes in regime or water quality.)

The final step in the formulation of the rational response to the aspiring user's request for permission to intervene in the natural hydrological cycle, is the analysis of all this information:

- quality control of data
- storage and registration
- development of 'what-if' scenarios with the available information (current situation, future situation, extreme conditions, climate change, ...) in order to define:
  - if the intervention is likely to be successful over the requested intervention period (water balance remains positive over the lifetime of the permit)
  - if the impact of the aspired intervention on the natural resources is acceptable
  - if the impact of the aspired intervention on standing permits is acceptable
- decision taking on permit request; it is especially the 'what-if' simulation that will guide the decision to grant the permit entirely as requested by the aspiring water user, or otherwise to impose adjustments on water quantity (water quality for disposal permits), intervention calendar, permit duration, or mitigation measures towards the natural resource or other resources (water, land, or other) users.

Once that the permit has been granted (unconditionally without adjustments, conditionally, partially, time restriction, ...) it may well occur during the life time of the permit, that unforeseen conditions prevail and that permits in a certain area should be temporarily or definitely be adjusted in order to protect and preserve the natural resource. This case may be triggered by unavailability of the resource to certain permit holders or by monitoring of the natural resource (or both instances). For this case a similar sequence of investigations applies:

- quality control of data (on the exploitation of the permit and/or monitoring of natural resource)
- storage and registration
- what is the cause of the unforeseen conditions (natural cause, improper assessment of resources availability or authorized interventions, improper operation of some or all authorized interventions).
- development of 'what-if' scenarios (current situation, future situation, extreme conditions, climate change, ...)
- decision taking on permit exploitation (no adjustment, temporary adjustment, long term adjustment, cancellation of permit)

The last phase of a permit is its closure. The closure can be requested by the water user (at the end of the lifetime of the permit or earlier) or imposed by the water management authority (at the end of the lifetime of the permit or earlier if the permit holder does not comply with the obligations of the permit, or if resources proof to be insufficient (in the latter case an authorized water user may possibly claim compensation)). The principle water management investigations are:

- what will be the impact of the closure (discontinuation) of the authorized intervention on the natural resources (principally land and water) using 'what-if' scenarios for current and future conditions.
- what will be the impact of the closure of the permit on other water users, using 'what-if' scenarios
- decision taking on permit closure which will normally be granted but should include mitigation measures related to the re-establishment of the conditions prior to the intervention in the natural hydrological cycle.

The listing above is a concise summary of the issues that need to be investigated and the services that need to be provided for the effective implementation of IWRM.

Hence, in the following paragraph we will specifically address the following matters:

- when these investigations and services are as yet not developed, who should 'design' them?
- when properly designed and formulated, who should perform these services and with what means
- who should pay for these services?

These issues will be addressed in the next paragraph 2.12 and its subsections. In order to provide the proper perspective

2.11 UPDATE ON THE INSTITUTIONAL STRUCTURE FOR IWRM 'UNDER CONSTRUCTION'

This paragraph presents a summary of institutional structure depicted in the Law 62 of 2008 (the Water Law) which contains elements that are already fully operational as well as elements 'under construction'. The institutional structure will be discussed against the backdrop of the water management functions, i.e. strategy, planning, implementation, operation and monitoring.

The diagram in Figure 22 shows the principle entities of the institutional framework for water management at four different levels:

- user level; individual water users, water user organizations, commercial entities, ...; their concern is local interest and access to the resource
- district level; comprising the district government as well as district and sector committees, their concern is the water management function within the district
- catchment level; these entities are not explicitly provided for in the current legal framework, their concern is the water management function within a clear hydrological management unit which normally comprises a number of districts
- central level; these entities look at national level and tend to be oriented per sector

The entities presented in the diagram have different colors with the following meaning:

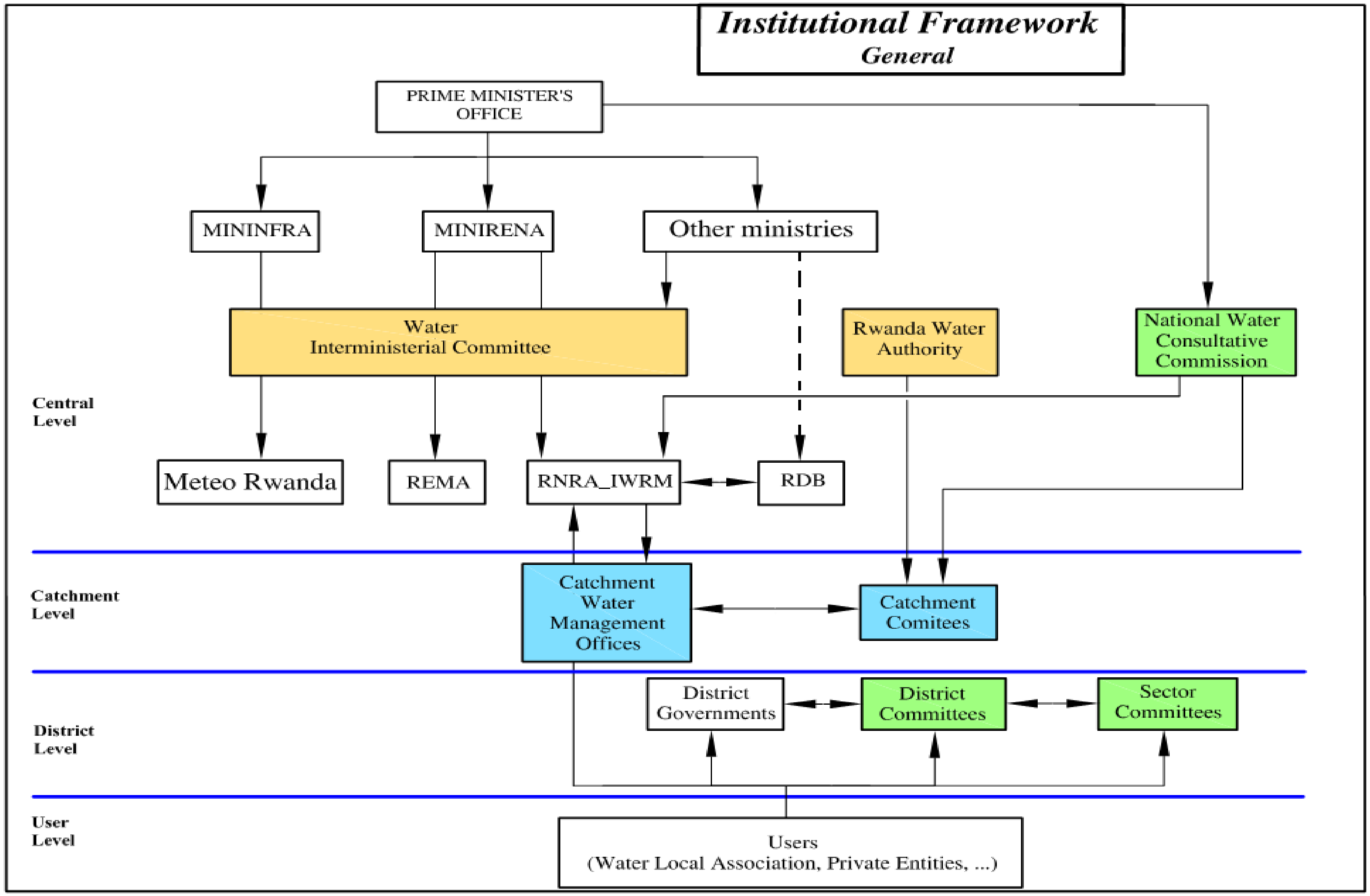
- White blocks represent existing institutional entities as the Prime Minister's office, different ministries, governmental agencies and most of the water users.
- Green blocks embody institutional entities identified and defined in legal documents but not yet operational (of fully operational). The National Water Consultative Commission and Districts and Sector (Consultative) Committees.
- Yellow blocks symbolize institutional entities identified in the Water Law but not yet defined by a ministerial order as the Water Inter-ministerial Committee and the Rwanda Water Authority.
- Blue blocks characterize institutional entities not identified in existing legal documents but recommended by the consultant for the purpose of IWRM. These are the structures required at Catchment level: Catchment Councils and Catchment Water Management Offices.

The arrows in the diagram symbolize a link between institutional entities:

- Down arrow →: hierarchical link between the higher entity and the lower entity
- Up arrow ←: consultation/participation link; for example the User consults the RNRA-IWRM for an envisaged intervention; representation of District Consultative Committees in Catchment Committees, etc.
- Double arrow ↔ : communication link; for example between Catchment Committees and Catchment Water Management Offices, between District Governments and District Consultative Committees, etc.

The entities presented in the diagram and their role in water management according to the different identified functions, strategy development, planning, implementation, operation and monitoring, will be briefly discussed in the next paragraphs

Figure 22: Diagram of the institutional framework for water management in Rwanda



2.11.1 STRATEGY

The Ministry of Natural Resources (MINIRENA) defines the national water policy according to the following principles and priorities:

- protection of the resource
- regulation of appropriate use,
- precautionary management aiming at the prevention of irreversible risks, prevention of pollution,
- application of the principles of user-payer and polluter- payer and
- creation of user's associations for administrative management of resources use after consultation with other ministries and institutions concerned.

The Ministry of Natural Resources also represents the Government in intergovernmental organizations for international and regional cooperation on matters related to water.

Numerous other ministries stipulate their strategy with respect to the use of water resources for their respective missions. These ministries assemble during the Water Inter-ministerial Committee.

2.11.2 PLANNING

At the National level, the Water Law put in place in its article 16 the National Water Consultative Commission. The Prime Minister's order n°143/03 of 24/05/2013 determines the organization, functioning and composition of this Commission.

The law n°53 of 2011 establishes the Rwanda Natural Resources Authority (RNRA) and determines its mission, organization and functioning. The Water Resources Planning function is undertaken through its IWRM department, implemented since October 2012, with its Water Resource Planning Unit (Water use planning, Permit Administration and Water regulation). According to the article 3 of the law establishing the RNRA, this authority and consequently its IWRM department has many missions. It is responsible for implementing national policies, laws, strategies and regulations relating to the promotion and protection of natural resources, including the water resource.

Consequently, the RNRA should advise the Government of Rwanda (GoR) on appropriate mechanisms for conservation of natural resources and investment opportunities. For this specific purpose regarding water resources, the IWRM department should institute regulations and guidelines and initiate research and studies on water resources and publish its results. This authority is also responsible of matters regarding the international level of IWRM. It should implement international conventions ratified by the GoR and establish cooperation and collaboration with other regional and international institutions with an aim of harmonizing the performance and relations on matters relating to the management of water resources.

At the decentralized level, the Water Law specifies, in the articles 20 and 21 the establishment of Basin District committees and in the article 22 and 23 the establishment of Basin Sector Committees, charged with the formulation of orientations and guidelines for planning of the waters at the level of the sub-basin or aquifer. The ministerial order n° 005/16.01 of 24/05/20013 defines the composition of these "hydrographic basin committees" with different representatives of the civil society from the district and sector levels.

These Basin District and Sector Committees have not yet been created. It should be noted that the development of district and sector based Master Plan can only be successful when processed at the level of a hydrographic basin which normally comprises a number of districts whose territories are almost always divided between two or more "hydrographic basins".

2.11.3 MANAGEMENT (IMPLEMENTATION AND EXPLOITATION)

The management of water resources (implementation and exploitation of resources development works) is currently done by many private entities but implemented without considering other demand which may easily lead to conflicts and sub optimal use of scarce resources, both of which are largely preventable.

To remedy this problem, according to the law n°53 of 2011 establishing the RNRA the role of the RNRA-IWRM is to provide supervision and follow up on activities in the sphere of water management with firm technical advice on proper use of the resource, protection (with the rehabilitation of places where natural resources are damaged in the country) and valuation of natural resources.

In order to conserve the natural public water domains, the creation of a permit system is essential. The Water Law stipulates, at its article 11, that: “The Authority having the water resources under its responsibilities shall maintain register in which all issued authorizations and concessions are recorded.”. Consequently, RNRA-IWRM, specifically its Water Permit and Administration Unit (at the moment with two officers), has to provide this service. The Water Law defines three regimes of water use (at the chapter V of the law), completed by the Ministerial Order n°002/16.01 of 24/05/2013 determining the procedure for i) declaration, ii) authorization and iii) concession for the utilization of water.

Whereas this classification of permit regimes according to their anticipated impact is a very sound principal, it does not consider the mode of intervention in the Natural Hydrological Cycle. In order for the RNRA-IWRM to provide supervision and follow up on activities in the sphere of water management, it is absolutely essential that a distinction be made between the type of intervention, i.e. groundwater, surface water, storage, etc.

In order to get a better grasp on the different modes of intervention in the Natural Hydrological Cycle, the Consultant proposes a classification according to 5 types of intervention:

1. abstraction of surface water from a water course, river or lake
2. retention of surface water in a reservoir for later use
3. abstraction of groundwater from an aquifer
4. release of used water in the natural hydrological cycle and
5. miscellaneous interventions (bridge and road construction in / across a floodplain, flood retention and protection works , (temporary) deviation of a water course, river training, erosion protection works, etc.)

During its lifetime, a permit for intervention has three distinct stages, involving different actors and institutions: the application of the permit, the operation and the closure. The classification of water permits according to intervention type has not been specified in any legal text for Rwanda. It is understood that so far four water permits have been issued by RNRA-IWRM.

Conflicts of water use are currently solved between the users with a possible intervention of sector or district staff; interventions from central level are rare and dealt with at ministerial level. With an increase of water use, the frequency and intensity of conflicts is bound to rise. The support for conflict resolution at the decentralized level will start at the user level and may gradually rise to sector, district and hydrographic basin level (catchment). It is suggested that the Rwanda Water Authority may possibly be put forward as the highest instance of conflict resolution. This Authority, which creation is already proclaimed by the Water Law (article 17), may provide this service. The Water Law (or any other legal document for that matter) does not define the function of the RWA.

2.11.4 MONITORING

In order for the monitoring of water resources to be comprehensive, it is necessary to monitor the resource in the natural hydrological cycle (rainfall, surface water, groundwater) as well as to monitor the use interventions.

The monitoring effort of the Government on the state of the water resources is laudable, yet there are a number of weak spots which make that this monitoring effort is not fully exploited and that the level of knowledge on the water resource may be increased for a very modest supplemental effort:

- rainfall monitoring data is generally satisfactorily;
- surface water monitoring data is generally acceptable for large catchments but station data is insufficient, lacking absolute topographic reference level, discharge measurements are absent or at best out of date
- surface water monitoring data is largely insufficient for small catchments
- groundwater monitoring data is largely insufficient
- Water quality monitoring is insufficient
- Data management and interpretation of data is very weak

About water resources (rainfall, surface flow and groundwater), according to the Ministerial order n°006/16,01 of 24/05/2013 determining the organization of water resources data collection, treatment, management, exploration and communication, the RNRA-IWRM shall put in place a water resources data monitoring network. This network can be integrated in the Water Monitoring Information System (Water MIS) developed under the current Master Plan study. According to this ministerial order, the RNRA-IWRM shall make a follow up on water data collection activities. The Agency should manage (process, analyze, gather and store) the water resources data in its database for decision makings. The Agency shall be required to disseminate data on water resources through modern print or electronic communication media. For the moment, four officers in the Water Resource Monitoring Unit are working on quantity and quality monitoring.

Rainfall data are currently collected by MeteoRwanda. These data are essential for the analysis and interpretation of surface and groundwater resources. A protocol for the sharing of data between MeteoRwanda and RNRA-IWRM is under preparation and will be defined in a Memorandum of Understanding between the MINIRENA (for IWRM) and the Ministry of Infrastructure (for MeteoRwanda)

The monitoring of water use is not enforced with the result that water use data may be recorded by a select few water users yet that the parameters collected serve the purpose of the water user and not necessarily those of the water manager. This information is not exhaustive and RNRA-IWRM does not have the tools to register and analyze this information.

The law n°53 of 2011 establishing the RNRA specifies that RNRA-IWRM has the duty of follow up and supervision of activities relating to the proper use of natural resources. The implementation of a permit system is an opportunity to impose water users to collect and transmit essential information on their intervention in the Natural Hydrological Cycle. The monitoring obligation of the water user should be specified in full detail in the permit. Where needed, the user may obtain assistance from the RNRA-IWRM department with guidelines and indications about correct procedures.

2.12 PROPOSITION OF THE INSTITUTIONAL STRUCTURE FOR THE IMPLEMENTATION OF IWRM

This chapter contains a detailed review of the operational or proposed actors and tools (meteo- hydrological stations, water MIS, ...) for above indicated IWRM actions and processes.

The institutional structure as identified in the exploratory phase report forms the basis for the review which comprises essentially existing institutional operators. Where needed additional entities will be suggested and for all entities (operational and proposed) the functions and necessary tools (monitoring stations, water MIS, permit system, ...) will be reviewed. The need for consultancy services for the formulation of processes and training of actors will be indicated as will be the role of research partners for special investigations like environmental flow, reserved areas, etc.

Finally, inadequacies of the legal framework will be identified.

These aspects will be discussed in the following sub paragraphs of this chapter for each of the identified processes for IWRM:

- monitoring of the state of water related natural resources and interpretation of data for the assessment of total reserves and annually and monthly renewable resources at level 1 catchment and lower levels
- strategy development for the management of water demand and use
- planning for the development of water resources for their use (Master Plan and water balances)
- implementation of resources development works (consider 3 levels, international, national, local) including the handling of the permit request (5 types) leading to a rational decision (based on water balances) followed by an EIA (and handling of finances of the permit)
- Exploitation of resources development works (again 3 levels) for the operation of the permit according to 5 types leading to rational decisions for adjustment of permit operation (based on water balances) if needed
- Monitoring of use interventions
- Closure of the permit for intervention in the natural hydrological cycle

2.12.1 MONITORING OF WATER RELATED NATURAL RESOURCES

Water resource monitoring, in the strictest sense, are the actions undertaken to track the state of the water resources in the natural hydrological cycle.

The monitoring effort on the state of the water resources is laudable, but yet there are a number of weak spots which make that this monitoring effort not fully exploited. The level of knowledge on the water resource may be increased for a very modest supplemental effort:

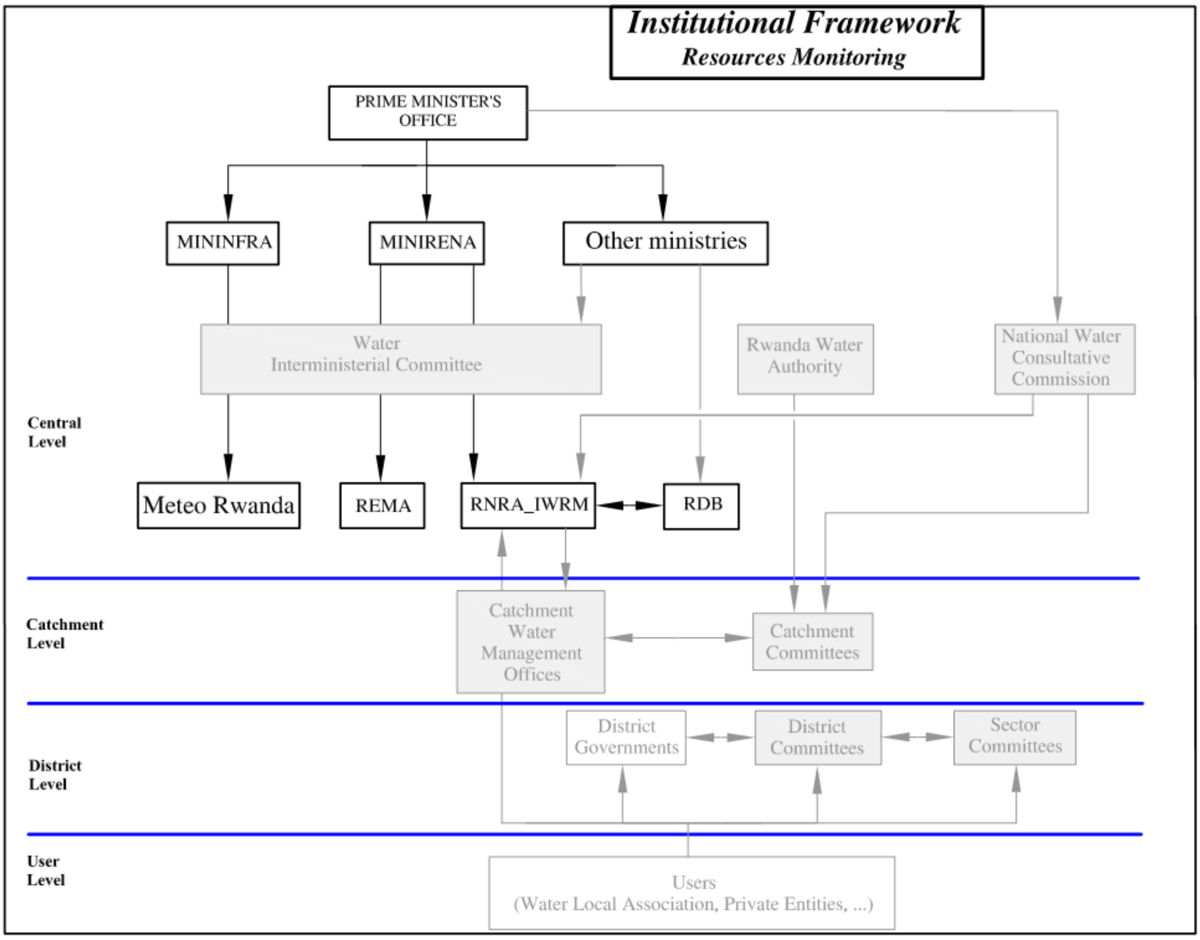
- rainfall monitoring data is generally satisfactorily;
- surface water monitoring data is generally good for large catchments but station data is insufficient, lacking absolute topographic reference level, discharge measurements are absent or at best out of date. For small catchments the monitoring is not sufficient while there is a lot of development actions that depend on this kind of information
- groundwater monitoring data is systematically unavailable (unless from dedicated projects of a temporary nature (this NWRMP study).
- Water quality monitoring is insufficient

Data management and interpretation of data is generally rather insufficient. While matters have improved with the availability of division and ministry wide servers, data are still found stored on computers of different employees of the government institution with multiple copies of the same dataset with slight alterations for corrections, omissions, errors, etc. Analysis of data is typically done within the framework of a project. Hence, government spends substantial efforts in the collection of water resources data but these data are mostly not professionally handled and analyzed.

The principal entities involved in water resources monitoring are highlighted in Figure 23 (Meteo Rwanda of Mininfra, RNRA-IWRM and REMA of Minirena and divisions of other ministries for instance RBC of Health Ministry for drinking water quality control).

Except for the highlighting of the responsible entities, this is the same diagram as presented in Figure 22.

Figure 23: Main institutional entities involved in water resources monitoring



2.12.1.1 METEOROLOGICAL DATA MONITORING

Meteorological including precipitation data in Rwanda are monitored by MeteoRwanda through a sufficiently dense network of automatic weather stations (10), climatological stations (72), agro-synoptic stations (14) and simple rainfall stations (77). MeteoRwanda is an autonomous institution that operates under MININFRA.

On request, the information on precipitation (and other meteorological phenomena (wind, radiation, temperature, humidity)) will be transmitted free of charge to other ministries. Third parties are required to pay for meteo data from MeteoRwanda.

The main issues with this function are:

- RNRA - IWRM does not receive up to date (and historical) information on rainfall in the country which is nevertheless essential in order to keep track of the nation's water resources.
- RNRA - IWRM does not receive real time information on rainfall events which is essential for interpretation of extreme events and adequate flood management.
- The same applies to MIDIMAR which should receive real time information for early warning on imminent problems from excessive rainfall and risk of hail. Part of this function as regards public information, is directly organized by MeteoRwanda itself.

In order to solve these issues it is recommended that there be established a direct communication link between MeteoRwanda and RNRA-IWRM for both real time and quality controlled transmission of meteorological and precipitation data between the two institutions:

- Real time monitoring rainfall data (including hourly rainfall intensity) stations should be selected for the needs of both MeteoRwanda and RNRA-IWRM. These real-time data should be shared between the two institutions
- Daily rainfall data for a number of stations should be selected for the needs of both MeteoRwanda and RNRA-IWRM (this report suggests about 30 stations). These data should be transmitted on a minimum monthly but preferably weekly basis and be up to date for water management needs. The quality control for these data lies with MeteoRwanda.

2.12.1.2 MONITORING SURFACE WATER RESOURCES QUANTITY/QUALITY

The RNRA-IWRM is in charge of the monitoring of surface and ground water resources. To this effect it has developed the Rwanda Water Resources Information System (RWRIS) which holds the records of a Surface Water Quality and Quantity Hydrometric stations network. It comprises the former PGNRE database (which was based on the old administrative boundaries) and allows for quality control and analysis of data. The average daily flow for 6 important stations across the country is published through a bimonthly bulletin.

This is a good development yet more is needed in terms of assessment of available resources especially at small catchments (~100 km² which are important for especially irrigation and small hydropower projects), flow quantity abstracted (see paragraph 2.12.6 on monitoring of water use), and water quality issues (especially sediment, nutrients, toxic substances) at vulnerable locations (downstream of urban areas, mining sites, industrial complexes, agricultural areas and at vulnerable locations e.g. river - lake interfaces).

The main issues with this function are:

- The level of knowledge on the surface water resource remains limited; there is systematic observation of water levels and discharge at the major catchments intersections but this information is not sufficiently analyzed and used for water management decision making.
- Surface water resources monitoring on small catchments has essentially been introduced by this study (exploratory phase) and needs to be incorporated in the monitoring strategy of RNRA-IWRM, especially since these small catchments support important development activities in water supply, small hydropower and irrigation.
- The hydrographic stations are lacking benchmarks and absolute water levels, precise coordinates, up to date discharge curves, and station data are not properly maintained. Some of these problems could be solved by this study (station data, flow measurements, correction of staff levels, etc.) but RNRA-IWRM needs to continue the flow measurements.
- Water quality monitoring is limited, implemented by a series of agencies for different purposes, and not shared between those agencies (RNRA, RBC, REMA, EWSA, knowledge institutes, ...).

Taking into account the needs described above, the following structure has been proposed (see also chapter 6 on Monitoring in the Exploratory Phase Report:

- The National Water Resources Monitoring Network comprising 8 stations that are equipped with direct data transfer to RNRA and automatic water level and velocity measurement and 5 stations for flood warning on large rivers. (Total of 13 stations)
- The Hydrometric Network comprising 28 stations on rivers in Rwanda and 12 limnimetric stations on major lakes and wetlands
- The Impact Monitoring Network comprising 10 stations equipped with data loggers that are used to investigate emerging issues on small catchments that can be easily shifted after some months (or a limited number of years) of investigation

The monitoring network of the NRNA-IWRM should serve the following purposes:

- the renewable surface water resources as has been defined in the National Water Resources Master Plan can be updated by additional data sets and the renewable resources are updated at 3 to 5 year intervals;
- provide background information for extreme events (floods and droughts - how extreme is the extreme event; once in 6 months or once in 30 years?) and constitute a framework for an early warning system and give directions for sound solutions (retention, conveyance, flood (drought) proving)
- indicate water scarcity from meteorological drought or over-abstraction in a catchment or sub-catchment early enough to take necessary action to prevent social and or economic damage and resources degradation

The surface water monitoring network provides the basic data to do all hydrological calculations and assessments within RNRA-IWRM. These include:

- estimation of runoff generation of different basins
- flood frequency analysis for regions and catchments
- validation of groundwater recharge estimates obtained with other methods
- basic design data for infrastructural works (bridges, embankments, weirs, water supply projects, irrigation projects, hydropower projects, etc.) - average flow, base flow, flow duration curves, peak discharges, seasonal and monthly flow, probability assessment, etc.
- water quality status with specific emphasis on sediment, nutrients, toxic substances, etc. within a context of cause (identification of the polluter) - effect (vulnerability of the natural resources and different users for reduced water quality, restoration and possible mitigation measures)
- fundamental data for developing water resources sustainably e.g. for hydro-power (flow duration curves), irrigation (sustainable yield),
- data for the development of surface and groundwater resources for water supply on a sustainable and reliable basis

State of the art hydrometry is an essential part of the services of the IWRM department of RNRA. RNRA-IWRM must be equipped and have the capacity, budget and staff to carry out the necessary missions.

2.12.1.3 MONITORING GROUNDWATER QUANTITY/QUALITY

Groundwater resources need to be monitored for several reasons:

- Groundwater is driving the surface flow (springs, rivers).
- Groundwater level and quality is an indicator of the long term state of the water resources in a catchment area.

RNRA-IWRM is the entity in charge of monitoring of the ground water resource. Apart from a few stations that have been monitored during the exploratory phase of this study, RNRA-IWRM is not monitoring any groundwater data and the RWRIS is only registering surface water data.

Hence, at the current state the RNRA-IWRM is not sufficiently aware of the natural state of the groundwater resources in terms of total volume available, water levels and essential water quality parameters, nor is it aware of the annual recharge, interaction with surface water resources, and the current abstraction and used water infiltration.

It is needed that RNRA-IWRM identifies a series of observation wells for monitoring purposes and starts monitoring of water levels and appropriate water quality parameters.

The current Master Plan study has provided a proposal for the monitoring of the essential aquifers by RNRA- IWRM (see Exploratory Phase report chapter 6).

The proposed groundwater monitoring network needs to take into account two main uses:

- Urban drinking water supply: EWSA is currently extending the use of groundwater for urban water supply. Abstraction schemes from the Nyabarongo River floodplain for Kigali and near Musanze town are in operation and extensions for both are planned.
- Rural water supply: groundwater is crucial for local water supply in rural areas: A large number of boreholes are equipped with hand-pumps and in some cases with electrical pumps supplied from the national grid or from solar panels. The development and protection of natural springs is equally important for local water supply and in some cases for gravity fed or pumped piped systems.

Groundwater quality is currently monitored by EWSA for its large drinking water abstraction schemes especially for the purpose of water treatment needs (sediment) and by RBC (Ministry of Health) specifically for pathogens and WHO compliance of the (rural) water supply

The proposed RNRA - IWRM groundwater monitoring network consists of:

- a select number of boreholes (minimum 9) which comprises one borehole in each of the nine catchments and one borehole for each of the eight aquifer types where water levels are monitored along with a surface water monitoring station and rainfall monitoring station in order to assess the interaction between surface and groundwater resources.

  The water quality is also monitored for essential parameters (see chapter 6 of the Exploratory Phase report) at regular time intervals (preferably at a three monthly time interval but a lesser frequency - six months - is still acceptable)
- New production boreholes along the Nyabarongo need to be equipped with data-loggers and EWSA needs to monitor and report water levels along with abstraction volumes to RNRA-IWRM.

- EWSA should also share its water quality data with RNRA-IWRM.
- The RWRIS needs to be updated in order to cater for groundwater data. The Water MIS which has been developed in the framework of the current Master Plan study can accommodate groundwater data (water stages, production data and water quality). If the RWRIS does not provide specific functionalities beyond what is fully tested and readily available in Hydraccess, it may be incorporated in the Water MIS as soon as the Water MIS is operational and successfully tested.

The groundwater monitoring network provides essential information for all hydrological calculations and assessments within RNRA-IWRM. These include:

- catchment based total groundwater storage
- estimation of average monthly and annual recharge of groundwater
- special investigations on groundwater level 2 catchments

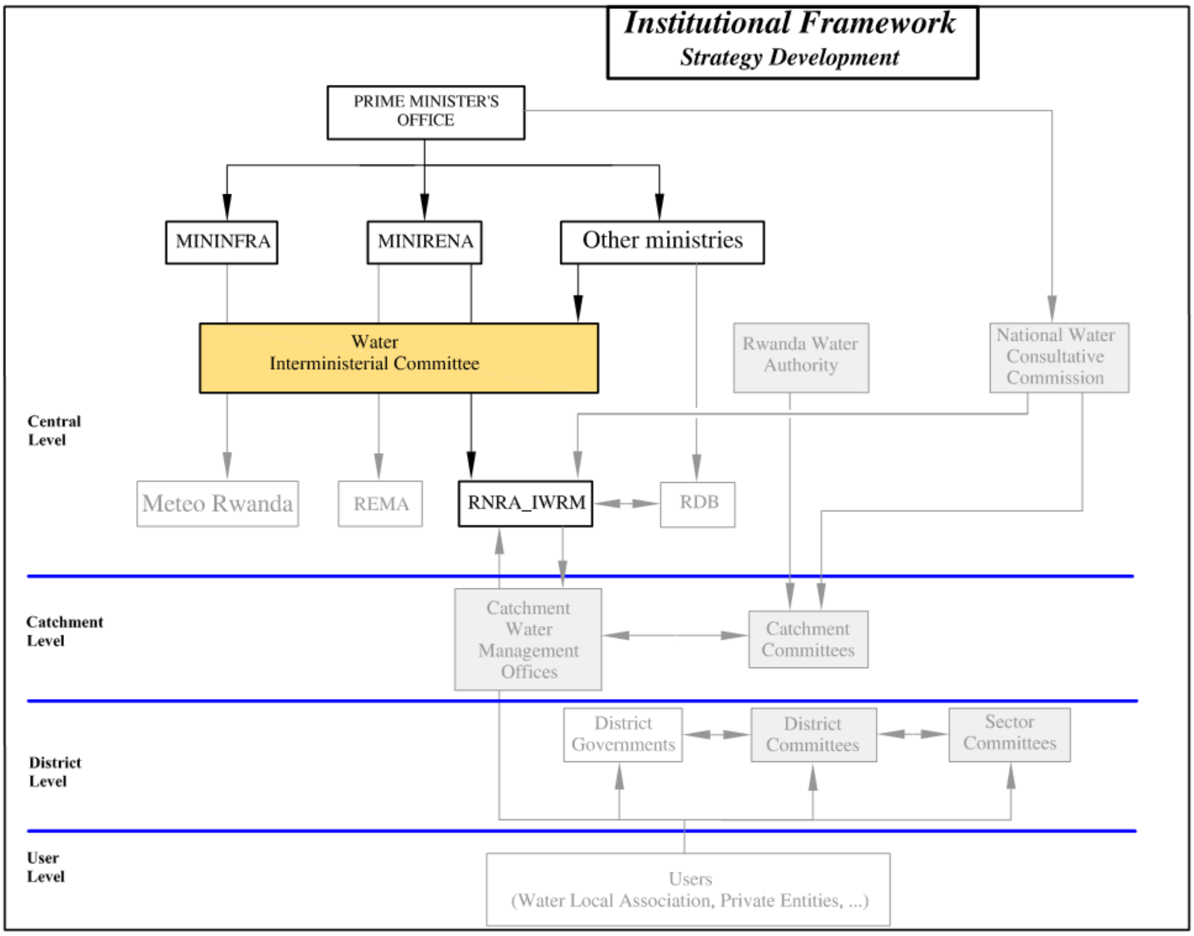
The first two investigations (catchment based storage and annual and monthly renewable recharge; the latter by means of three different methods) have been conducted within the framework of this Master Plan study. RNRA-IWRM needs to continue these findings and update the Master Plan study findings at level 1 catchments and conduct or command further studies at specific level 2 high yielding groundwater catchments as may be required for the development of specific uses (water supply, irrigation, ...)

2.12.2 STRATEGY DEVELOPMENT FOR MANAGEMENT OF WATER RESOURCES AND THEIR USE

Institutional actors involved in the water resources management strategy development function are depicted in the diagram of Figure 24 below. The Ministry of Natural Resources (MINIRENA) is the principal actor in charge of strategy development for water resources management. However, numerous ministries concerned with water resources and its use elaborate their own strategy. In order to harmonize this state of affairs and to check compliance with the guiding principles below, the creation of the Water Inter-ministerial Committee, foreseen by the Water Law, could be an adequate tool. The RNRA-IWRM will play an important role in this committee as Technical Coordination Secretariat. This department is foreseen to elaborate the groundwork for the committee's reviews and recommendations.

Although the Water Interministerial Committee is not yet operational, it is fair to mention that the harmonization of the strategies between the ministries has so far been secured rather efficiently by means of workshops attended by staff of the different ministries and by the development of a number of guiding documents discussed in the following section.

Figure 24: Main institutional entities involved in IWRM strategy development



2.12.2.1 GUIDING PRINCIPLES

In its document "Water Resources Management sub-sector strategic plan (2011-2015)", the MINIRENA presents its WRM Policy with three main objectives while its main challenge for the next 5 years is "meeting increasing multiple water demands, in the face of declining water quantity and quality, and an inadequate governance framework".

The first objective is to protect, conserve, manage and develop water, which is considered as "a strategic natural resource for the country's socioeconomic development and ecosystems sustenance […] a strategic tool for Rwanda's geo-political cooperation and security."

The second objective is based on the assessment that "Rwanda's waters resources are severely degraded - primarily due to land degradation resulting in siltation of water bodies; pollution from point and non-point sources, including agricultural chemicals, inappropriate human settlements and poor urban and industrial waste management". The resulting objective is to *ensure that water resources are available in adequate quantity and quality for the socio-economic and ecological needs of the present and future generations*.

The third objective is "to ensure that decisions affecting water resources management are made in a coordinated manner and with the participation of all stakeholders at local, national and trans-boundary levels". This objective of coordinated internal use and enhanced transboundary water cooperation is a critical and immediate priority for the Government of Rwanda (GoR) as well as for the Lake Victoria Basin Commission (LVBC), the Nile Basin Initiative (NBI), and the Lake Kivu and Rusizi River authority (ABAKIR).

In order to attain these objectives, the WRM Policy 2011 has identified seven strategic actions for IWRM that should be put into operation in or prior to 2015. Strategic actions are formulations of approaches to ensure that the Vision 2020 and MDG targets are achieved:

1. Effective Water Governance framework that reflects the principles of IWRM
2. A Cost-effective Water monitoring system, water resources assessment and national water resources Master plan is established
3. Critical watersheds and catchments are rehabilitated and basic ecological functions restored by June 2016
4. Efficient and equitable water allocation and utilization framework
5. An effective framework for water-related disaster management and climate change mitigation and adaptation is in place and implemented
6. Effective framework for management of shared waters (transboundary cooperation framework)
7. Basic capacities installed and effective framework for sustained WRM capacity development and knowledge management established.

N.B. Further details on the 7 strategic outcomes and their 39 outputs are provided in annex C4_3.

This WRM policy document (2011-2015) emphasizes a number of priority actions; most notably the elaboration of the Water resources Development and management master plan (NWRMP) "*since this has implications for the delivery of planned and on-going investments in irrigation, hydropower, tourism, industrialization and water supply master plans*".

Further highlighted are the review of the water governance framework with a view of putting in place a new institutional structure and capacity development in the WRM sub-sector, the mobilization of technical assistance to establish the coordination mechanism and provide technical guidance to WRM staff and policy-back stopping to MINIRENA leadership and finally the development of a resource mobilization strategy (in consultation with MINECOFIN) as a guideline for a dialogue with potential financing partners.

This WRM Policy fits into the National Development Vision and Strategic framework which includes the Vision 2020, the 7-year Government Plan (2011- 2017) and the Economic Development and Poverty Reduction Strategy (EDPRS).

The Vision 2020, which is a leading development roadmap, has important implications for IWRM. One of the main premises of the Vision 2020 is the strategic shift from an agriculture and natural resources-based economy, to a knowledge centered economy. Given that agriculture accounts for nearly 70% of the total water use, reducing dependency on agriculture could reduce pressure on water resources but it will increase water use in other sectors e.g. industry. Moreover, a productive, high value and market oriented agriculture will intensify the use of fertilizers and pesticides, thereby increasing pollution risks and boost irrigation demand which will actually increase agricultural water demand.

Another main pillar of Vision 2020 is private sector-led development: it will facilitate public-private partnerships in water service delivery and the GoR will divest from service provision in favor of more strategic areas like watershed rehabilitation, water resources monitoring and regulation.

Among the 231 priority activities identified by the GoR in the 7-year Government Plan (2011-2017), several have particular implications for WRM, especially on environmental issues and transboundary cooperation: - climate change management; - establishing a national fund for environmental protection; - rehabilitating critically degraded ecosystems and watersheds; - mainstreaming environmental conservation/protection into all development activities; - consolidating decentralized governance and participatory service delivery; and - promoting regional integration.

Water is also very significant for the realization of four priorities of the EDPRS (2007-2012). It is i) an important input for the realization of increasing economic growth, ii) developing the Private Sector, iii) improving land administration, and iv) enhancing sustainable land use management practices.

Moreover, water is a vital input to tackle extreme poverty, especially to improved food security. Reducing population growth by reducing infant mortality, promoting family planning and education outreach programs has direct implications for sustainable WRM. Finally, IWRM will contribute to the attainment of ensuring greater efficiency in poverty reduction by promoting stakeholder participation, equity and social inclusion.

2.12.2.2 THE WATER INTER-MINISTERIAL COMMITTEE: AN ADEQUATE SOLUTION FOR A BETTER WATER RESOURCES STRATEGY DEVELOPMENT

In Rwanda, water is dealt with by many ministries (agriculture, transport, navigation, power, industry, mining, health, gender, environment, security, ...) but there is insufficient coordination between them. Their focus is likely to be more on development of sector issues than on integrated water resources management. All ministries develop their explicit strategy to reach their objective which includes for a large number of ministries a specific approach on water resources which is not necessarily fully compatible or cost effective between themselves.

To change this practice, creation of an Interministerial Committee (IMC) could be a practical platform for a single and comprehensive inter ministerial water management strategy development. As per the 2008 Water Law (art.18), MINIRENA has to consult the Water IMC prior to the submission of any strategic tool to the appropriate institutions. However, the Water IMC is not yet established. Currently, MINIRENA applies a practical procedure for stakeholder participation in the development of the policy documents: the Sector Working Group. This group ensures coordination and monitoring of the sector program, including dialogue and communication accross sector stakeholders (in particular other sector institutions, cross-sectoral planning and regulatory bodies, NGOs and the private sector) and provides an active platform for gathering and disseminating information. Yet, a comprehensive vision comprising all ministries across all sectors (WASH, Minagri, Mininfra, Minecom, Midimar, Minirena, Minisante, and many others) is not likely to evolve from one sector inviting the others. The Water Interministerial Committee should be composed of all Ministerial department representatives concerned with water resources and its use in their domain.

Based on the fact that there is no ministerial order determining the composition, organization and functioning of the Water IMC; given the point that MINIRENA is in charge of the strategy function according to the law; and considering that several ministries have their own water strategy, the Consultant proposes the following composition for the Water Interministerial Committee:

- the **Minister of Natural Resources** coordinates the Committee, he or she is in charge of integrated water resources management and strategy development (or his/her representative)
- the **Minister of Infrastructures,** responsible for urban and rural potable water supply and hydropower strategy development; further, the MININFRA is indirectly implicated in surface flow resources and flood management and in the rainfall resources management (by MeteoRwanda, by the Rwanda Housing Authority and by the Rwanda Transport Development Authority) (or his/her representative)
- the **Minister of Finance and Economic Planning**, responsible for urban and rural potable water supply strategy development and for its role of financier in large water projects (or his/her representative)
- the **Minister of Agriculture and Animal Resources,** responsible for agro-industrial use, livestock water demand, agriculture, irrigation, fisheries and flooding management strategy development (or his/her representative)
- the **Minister of Disaster Management and Refugee Affairs**, responsible for disaster management and consequently, flood management and reserved areas strategy development (or his/her representative)
- the **Minister of Local Government**, responsible for urban and rural potable water supply strategy development and the District and Sector Committees supervising (or his/her representative)
- the **Minister of Trade and Industry**, responsible for policy formulation, oversight and monitoring in the sectors of industry and tourism, urban and rural potable water supply (by the action of the RBS for quality regulation and standards setting) and mining use (or his/her representative)
- the **Minister of Health**, responsible for urban and rural potable water demand strategy development (or his/her representative)
- the **Minister of Foreign Affairs and Cooperation**, responsible for transboundary and international water resources management and downstream commitments (or his/her representative)
- the **Minister of Education**, responsible for awareness campaigns on hygiene for children (or his/her representative)
- the **Minister of Gender and Family Promotion,** responsible for the promotion of a gender-conscious approach for water resources strategy (or his/her representative)
- the **Minister of Defense,** for its implication in flood management (or his/her representative)
- the **Minister of East African Community**, for its implication in the transboundary and international water issues and commitments (or his/her representative)
- the **Minister in Charge of Cabinet Affairs,** responsible for supervision of the

Interministerial Committee work (or his/her representative)

In case of absence of the Minister of Natural Resources, the Minister of Infrastructures will coordinate the Committee. Members could appoint representatives when they cannot assist at sessions of the Committee.

The Committee will meet on invitation of the coordinator, on his initiative or on the request of other members.

The principal mission of the Water Inter-ministerial Committee is to be consulted on all legislative draft bills regarding the water domain elaborated at the national level, as well as on matters of national, regional or international level. The Water IMC will be a harmonization tool between ministries, in order to assure coherence and coordination for the water resources strategy development. The participation of cross-sectoral ministries will clarify the issues and will make possible overall agreements on water resources strategy development. Furthermore, the IMC will have to check compliance with the following priorities:

- Water is a good belonging to the State public domain. Its use constitutes a recognized right accessible to all within the scope of applicable laws and regulations.
- Protection and the appropriate use of water resources are of general interest and constitute an imperative duty to all, including the State, local communities, private sector, civil society and citizens.

Further, the Water IMC may prepare policy briefs and recommendations, and approve sector investments plans and projects, in accordance with the following principles:

- The principle of precaution aiming at preventing serious and irreversible risks for water resources, by the adoption of the efficient measures;
- The principle of prevention of pollution aiming at increasing the efficiency of a process, thereby reducing the amount of pollution generated at its source. With a comprehensive pollution prevention strategy, most pollution can be reduced, reused or prevented.
- The principles "user-payer and polluter-payer" according to which the users of water resources and the polluters support the expenses resulting from their use and pollution. The payment may be a direct payment or payment in kind through measures of prevention, of pollution reduction and restoration of the resource in quality and in quantity;
- The principle of users associations for administrative management of water use wherever such association is efficient and effective;

The Consultant proposes the creation, along with the Water Interministerial Committee, of a Technical Coordination Secretariat, in order to facilitate the work of the Water IMC. This Secretariat has to do the groundwork for the committee's reviews and recommendations. The Secretariat will work in close cooperation with the represented ministries in order to prepare the Committee's decision taking meetings. More precisely, the Secretariat has to:

- Advise the Committee on the formulation of national policies on water resources
- Prepare guidelines for the establishment of an effective legal and institutional framework for the implementation of the national policy on water resources
- Obtain any information deemed necessary by the Committee for its rational and

adequate decision taking

This Technical Coordination Secretariat could be entrusting to the RNRA-IWRM officers. The leader of the staff could be the Head of the RNRA-IWRM Department, assisted by directors of all RNRA-IWRM units (see section 2.12.3.1 for details on the staff composition of RNRA-IWRM).

The establishment of a Technical Secretariat to strengthen the Committees operations (decision taking on matters of water management strategy) requires an update of the Water Act with subsequent formulation of the Prime Minister's Order for the formulation of role, duties, organization, staff composition and other amenities.

The forthwith establishment of the Water Interministerial Committee in combination with a Technical Coordination Secretariat will constitute an adequate and efficient procedure for water resources strategy development. In order to create the Water IMC, the Prime Minister's Order is required to define its role, duties, organization, staff composition and other amenities.

2.12.3 PLANNING FOR THE DEVELOPMENT OF WATER RESOURCES FOR ESSENTIAL AND BENEFICIAL USE

According to IWRM concepts that are the foundation of the EC's Water Framework Directive, the primary purpose of planning is to provide a "*Plan as an instrument for making decisions in order to influence the future. Planning is a systematic, integrative and iterative process that is comprised of a number of steps executed over a specified time schedule. Planning culminates when all the relevant information has been considered and a course of action has been selected. The plan is then produced and implemented in order to achieve the goals and objectives. Planning has the capacity to increase the legitimacy of decisions to be taken by enabling open and wide dialogue between the public, interest groups and authorities. It's crucial for the legitimacy of a planning process to start dialogue as early as the phases of problem defining and setting the agenda*"[20]. Awareness of the interests of those concerned by the planning process is essential.

The diagram below indicates the institutional entities involved in planning for the development of water resources for essential and beneficial use.

Recalling the meaning of the colors of the different entities the currently operational planning, the white boxes are currently operational entities, the green ones are defined by law (defined by law and ministerial order) but not yet operational, the yellow ones are identified by law (no ministerial order for its definition) but not yet established, and the blue ones are deemed necessary but not indicated in any legal text.

Currently the entities involved in planning are the MINIRENA/RNRA at central level which liaises with other ministries at central level and with district governments and users at decentralized level.

As has been duly demonstrated in the Exploratory Phase Report, the planning at central level is very much sectoral with each ministry making its own plans without much knowledge on the resource yet considering the presumably available water resource its exclusive asset.

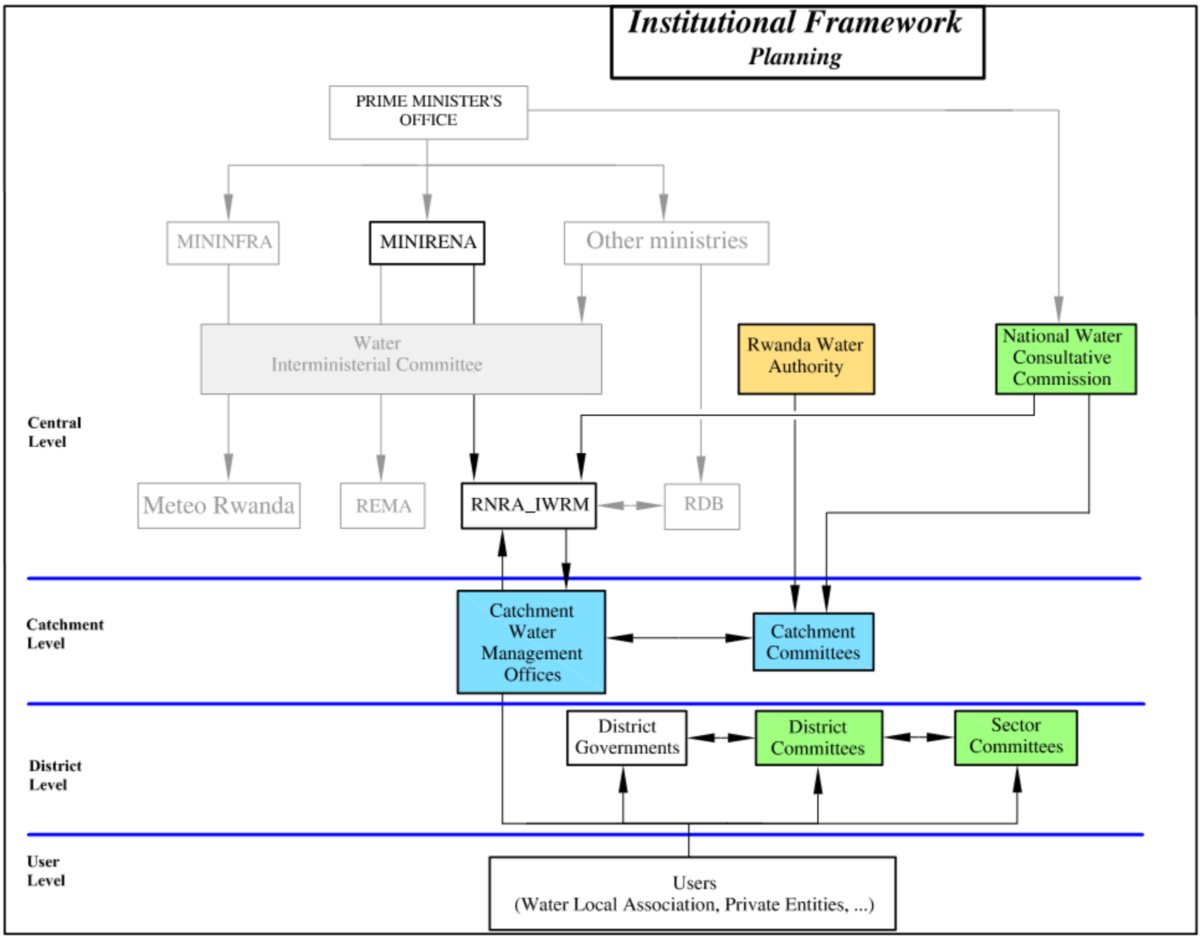
[20] European Commission Common Implementation Strategy for the Water Framework Directive 2000/60/EC, Guidance n°11 – Planning Process, p12

At the district level the water resources planning function is being included in the District Development Plans which are five year plans developed by each district. There are many reasons why the water resources planning at district level is not working: planning period is too short, planning area too small (any cohesive catchment in Rwanda covers at least three districts), planning area dissected (no district in Rwanda is entirely located in a single catchment, many districts are located in three or even more catchments), ...

In order to circumvent these difficulties there is need for an intermediate planning level at the catchment. It is proposed that two new entities are formed at the catchment level:

- the 'catchment committee'; this is a representative body of covered district authorities, district technicians involved in matters related to water (water supply, sanitation, health, business development, irrigation, etc.) and representatives of water users (same listing) to debate the development (and exploitation) of the common resource. This entity being a representative body, there is need for professional water managers at district level:
- the 'catchment water management office'; this is proposed to be a decentralized office of the RNRA-IWRM division operational in each of the nine catchments. Their role is to support the catchment committee, to develop a medium to long term catchment development plan and to make sure that the water matters of each DDP are coherent and realistic with respect to the DDPs of the further districts located in the catchment.

Figure 25: Main institutional entities involved in IWRM planning



The RNRA-IWRM should evolve to the lead coordinator in charge of an integrated planning function at central level and, with its decentralized entities in each catchment, the 'Catchment Water Management Offices', at the decentralized level. It has the lead role for the redaction of the Catchment water management plans (see annex C4_4 for details). These plans are written in cooperation with Sector and District Committees which are the decentralized representatives of local governments and users (water local associations and private entities). RNRA-IWRM will provide technical support to the Catchment, District and Sector Committees as needed.

The Rwanda Water Authority may act as overseer and highest instance of these catchment committees and monitor and coordinate their implementation and activities.

Public participation in planning is further possible by means of the National Water Consultative Commission. This entity should be involved in all development actions that are likely to have a major impact on natural resources, other water users and the society in general. The NWCC should be involved in the decision process on any concession permit (see section 2.12.4 for information on the types of water permits) and shall represent civil society.

The NWCC should also be involved in the approval of the Catchment Water Management Plans as and when they are developed by the RNRA-IWRM.

Further entities assuring public participation in planning of water resources and their use, are the District and especially Sector Committees.

The role of the Ministry of Natural Resources (MINERENA) is mostly strategic and it should be less involved in planning other than being the ministry in command of the RNRA-IWRM.

Details of the planning function of the main entities will be presented in the next paragraphs. The entities discussed are:

- RNRA-IWRM
- the National Water Consultative Commission
- the catchment water management offices
- the catchment committees
- the Rwanda Water Authority
- the district committees
- the sector committees

2.12.3.1 RNRA-IWRM AS COORDINATOR OF THE IWR PLANNING FUNCTION

Rwanda National Resources Authority (RNRA) is a young institutional body under the Ministry of Natural Resources, created by law n°53 of 25/01/2011 establishing RNRA and determining its missions, organization and functioning with the aim to manage natural resources (land, water, forest, mines and geology).

The IWRM department was established later as part of the RNRA and started its mission in October 2012. Consequently, the RNRA-IWRM is still at its infancy. The main issues that seem to affect its mission are the situation of human resources, financial means, and lack of recognition by civil society and governmental institutions. These aspects are briefly discussed here below:

HUMAN RESOURCES:

The staffing schedule cum organization chart of the RNRA-IWRM is provided in annex C4_1_1 to this report. On a total specialist list of 26 staff, 5 positions remain vacant i.e:

- Director of Water Research, Monitoring and Quality management unit yet all of the 12 staff members of this unit have been recruited; (1 position vacant)
- Director of Water Resources Planning and Regulation Unit; from the 5 staff members of this unit have 4 have been recruited (Water Regulation officer position is still vacant; (2 positions vacant)
- For the Transboundary and International Water Affairs unit, the Director is recruited but none of the two officers have been recruited (Regional Water Programme Officer, and International Water Affairs Officer). It seems that the duties of the officers are effectively fulfilled by the director of this unit. (2 positions vacant)

As regards human resources position of the RNRA-IWRM, the following comments can be made:

- the staffing of the RNRA-IWRM is nearing completion but is somewhat thin in the higher echelons (two of the three unit directors have not been recruited).
- it seems that staff members are insufficiently trained on their duties which are insufficiently defined. It is the novelty of the work processes and the partial absence of senior staff which hold back the precise formulation of the staff members duties and the on the job training.
- staff members that are not educated on environmental and water related issues are at a loss for their actual duties; they mention that they should receive additional training on the principal environmental and IWRM concepts.
- the RNRA-IWRM does not have staff at decentralized level (other than contract staff in charge of data observation of hydrological stations)

In order to redress these issues it is suggested that i) the staffing is completed, ii) staff duties are finalized (see also annex C4_1_1 on RNRA-IWRM organization) and staff members obtain on the job training, iii) non 'technical' staff receives additional training on technical issues, and iv) the staffing schedule of the RNRA-IWRM is extended with field officers that run the 'Catchment Water Management Offices' (ideally 2 specialist staff per CWMO).

FINANCIAL MEANS:

Currently, the RNRA-IWRM does not generate income from water resources management (levee a fee for its services) but receives payment from government that is however not directly granted to the IWRM department but to the RNRA. Financially, the IWRM department is therefore not autonomous.

It tries to finance some of its activities through direct project activities with donors.

It is recommended that administrative, monitoring and inspection functions in future be financed by water users. This requires a substantial accounting effort. It is likely that this effort be shared between RNRA and MINECOFIN.

For services provided in the sphere of climate change and environment, RNRA-IWRM could access funding from FONERWA (national climate change and environment fund) which would likely be in cooperation with REMA.

INTERNATIONAL COOPERATION; AN OPPORTUNITY FOR CAPACITY BUILDING

At international level, Rwanda is included in two hydrographic basins: the Nile and Congo River Basin. International projects for the development of shared water resources (trans-boundary) are typically managed by an international cooperation platform (several ministries of several nations with NBI, NELSAP, ABAKIR and or regional projects like LVEMP) and implemented through the private sector for study, implementation and construction supervision. These international development activities are inherently political, with substantial economic, social and environmental implications requiring strong engagement of diplomatic institutions.

RNRA-IWRM, through its Transboundary and International Water Affairs Unit and its Water Resources Planning and Regulation Unit, has an important role to play in this international cooperation.

As suggested by RNRA-IWRM officers, the Consultant endorses close cooperation on water resources management with neighboring countries. Particularly the experience of Uganda since 2004 with its Water Permit procedure (see section 2.12.4 on water resources development and section 2.12.5 on water resources management), which is a novelty in Rwanda, may be very valuable as it seems to work rather well.

Uganda is also implementing the decentralization of water resources management to regional "Water Management Zones" and catchments through creation of Catchment Management Organizations with effective participation of citizens and local governments.

Finally, it is especially for the Muvumba catchment that Rwandan and Ugandan water resources are closely connected and international cooperation on planning and implementation for its limited resources will be very beneficial to both countries

The two Ministries (Ministry of Natural Resources in Rwanda and Ministry of Water and Environment in Uganda) and the two departments (the RNRA-IWRM department in Rwanda and the DWRM in Uganda) could work towards this cooperation by means of study tours and seminars.

THE LACK OF RECOGNITION OF THE RNRA-IWRM

The RNRA-IRWM is a young institution with insufficient recognition by the public and other governmental entities. First, there is a lack of knowledge about the importance of water resources management. This is a new concept in Rwanda and few people are aware of its importance for the future. It is the role of the RNRA-IWRM to point out the need for a rational water resources management plan, at national and catchment level and the essential tools to the formulation and continued updating of this plan (based on resources monitoring and analysis, permitted use interventions monitoring by the water users themselves, analysis, demand projections and updated planning).

The function of the Water Users' Capacity Building Officer is to reinforce Water Users' capacities by supporting the creation of Local Water Users Associations, assisting them with the identification of their water needs, the registration as a water user, the formulation of a water permit and in general supporting their involvement in water resources planning, implementation and exploitation of resources.

The availability of catchment Water Management Offices has the potential to bring the mission of the RNRA-IWRM close to the water users.

It is recommended that a nationwide awareness campaign be implemented with the following key elements:

- the importance of integrated water resources management and the building blocks of IWRM and the consequences of maintaining the current status quo (water resources use is entirely unregulated
- the role of water users in integrated water resources management
- how to become a registered water user
- how to acquire a water permit (for surface water abstraction, storage, or groundwater abstraction)
- the rights and obligations associated with a water permits
- the interdependency between the EIA and the water permit
- the role of the RNRA-IWRM department in integrated water resources management
- the division of IWRM responsibilities between RNRA-IWRM and EWSA (a water user), REMA (environmental agency in charge of environmental monitoring including EIA compliancy), RDB (issuing EIAs), RURA (defining water quality standards)

Details on the water permit procedure and rationale are presented in appendix 10. The campaign methods should be multiple: website, poster campaigns, national tv and radio broadcasts, educational awareness in schools, etc.

THE RNRA-IWRM AND OTHER WATER RESOURCES PLANNERS

The water resources planning function essentially entails a repetitive cycle of monitoring of resources, monitoring of interventions in the natural hydrological cycle (abstraction, retention, disposal, other changes), analysis and interpretation of monitoring data, demand projections and updated planning. Traditionally some of these functions have been performed by other institutional entities and it is very clear that this leads to a variety of problems that need to be recognized before they can be solved.

The required cooperation between RNRA-IWRM and some entities that are traditionally involved in some aspect(s) of water resources planning will be discussed here below for:

- MeteoRwanda
- EWSA as a water supply and sanitation service provider
- EWSA as an electrical power supply service provider
- MINAGRI and its projects (LWH, RSSP, RARDA, etc.)
- District governments

MeteoRwanda is in charge of rainwater monitoring. The MeteoRwanda website (http://www.meteorwanda.gov.rw) informs as follows on its mission: *to provide accurate, timely weather and climate information and products for the general welfare of the Republic* *of Rwanda*. It has already been discussed in detail that the main issue is the timely transfer of a selected set of rainfall data between MeteoRwanda and RNRA-IWRM; at least a monthly transfer of up to date data. This may likely require that information transfer within MeteoRwanda requires speeding up.

EWSA as a water supply and sanitation service provider is the company that provides water in Rwanda and is considered as a national utility since 1976 (under the name ELECTROGAZ). Nowadays, EWSA is a recognized institution, well-known by water consumers and other governmental bodies.

EWSA generates potable water supply for urban areas as well as for rural areas. Recently, EWSA has started the production of Water Supply Master Plans per catchment (the Akanyaru and upper Nyabarongo catchment Water Supply Master Plans are the first two on their list) which is a sound approach.

This approach should be based on resources assessment and demand projections for urban population, rural population, and industrial and other uses. Obviously the resources assessment is an issue for which RNRA-IWRM is responsible and EWSA demand projections cannot include a comprehensive assessment of other uses, e.g. irrigation, fisheries, mining, hydropower, energy, livestock, etc.

Within the context of this study, a series of nine 'catchment master plans' has been produced which specifies renewable resources at catchment level and reasonable development per demand category. These 'catchment master plan' provide a sound basis for a more potable water supply oriented planning exercise at catchment level specifically searching for the most efficient way of maintaining a satisfactory service level for potable water supply (and sanitation) for a variety of domestic, industrial and administrative uses in rural and urban areas of a catchment

In the perspective of RNRA-IWRM, EWSA is a water user and should apply for water user registration and permit registration of all its production sites, as soon as RNRA-IWRM has finalized these procedures (user registration and water permit registration).

EWSA as an electrical power supply service provider. The second mandate of EWSA is the provision of electrical power to the general public. In as far as the power production is generated with hydropower, geothermal power or heat exchange processes there is a substantial water demand which has been considered in this study.

With respect to hydropower, this demand is based on the projects identified in the hydropower atlas study. A batch of potential hydropower sites (20 large and 69 small sites) is under study for delegation to private investors. This study is essentially based on a large number of site investigations (about 320 sites investigated). However, for a comprehensive assessment and optimization of hydropower potential by means of river based optimization of in and outflow locations and stream flow regulation, a more comprehensive catchment based study would be recommended. The study would be GIS based keeping track of inflow area and river gradient while progressing downward followed by summary site inspections.

EWSA should apply for a water permit as any regular water user should do as soon as RNRA-IWRM has finalized the user registration and water permit registration processes.

Minagri and its delegated projects are very active in the irrigation sector with numerous projects of marshland development, dam construction and direct abstraction from river or lake water resources. Minagri is continuously developing its expertise in these techniques. As has been found during the preparation of this master plan study, it appears that these projects are identified on a piece meal basis with limited or insufficient knowledge on the renewable resource and without consideration for other water uses (even ignoring claims from other uses within the ministry).

In order to correct this situation, the catchment master plan limits proposed in this study (e.g. no direct abstraction for irrigation development in Akanyaru and Muvumba catchments) should be followed by this ministry and its delegated projects. It may be recommended that the RIMP study be updated with the findings of the current study; the potential irrigation area (600.000+ ha) indicated is unrealistic at least as regards water resources availability.

Further, Minagri or any beneficiary formal water user organization should apply for a water permit for any water resources development activity (marshland development, direct abstraction from surface or groundwater, reservoir sites, etc.) and the works should not be started prior to obtaining a permit from RNRA-IWRM.

The relation between **district governments** and the RNRA-IWRM is also somewhat difficult. While RNRA-IWRM does not have any field officer (it seems that no field officers are foreseen), it tries to obtain part of its information from water or environmental districts officers. Generally these officers do not have specific experience in water management and they work for the district (or sometimes for EWSA). Consequently, RNRA-IWRM cannot fully rely on these officers to obtain information or to provide adequate service to water users. It appears that the cooperation between district staff and REMA is far more effective.

This issue may improve substantially when RNRA-IWRM is represented at catchment level by Catchment Water Management Offices who can engage in a more frequent and closer cooperation with the district staff than the current head office staff. A further solution to the problem is the implementation of the awareness campaign previously mentioned (this chapter under the heading 'lack of recognition of the RNRA-IWRM'.

2.12.3.2 THE NATIONAL WATER CONSULTATIVE COMMISSION IN IWR PLANNING

Due to a lack of horizontal (cross sector) and vertical (national - local) planning, the planning function is currently weak and conflicting. The National Water Consultative Commission, foreseen by the Water Law (article 16) and the Prime Minister’s Order n°143/03 of 24/05/2013 determining the composition, organization and functioning of the NWCC, could become a tool for improved planning. Moreover, the Commission may be one of the principal tools contributing to the respect of the Integrated Water Resources Management theory and the Aarhus convention[21], namely the public participation.

The main purpose of public participation is to improve decision-making, by ensuring that decisions are soundly based on shared knowledge, experiences and scientific evidence, that decisions are influenced by the views and experience of those affected by them, that innovative and creative options are considered and that new arrangements are workable, and acceptable to the public.

“Key potential benefits that can result from public participation are (which are not mutually exclusive):

- Increasing public awareness of environmental issues as well as the environmental situation in the related river basin district and local catchment;

[21] UNECE's “Convention on access to information, public participation in decision-making and access to justice in environmental matters”, Aarhus, Denmark, on 25 June 1998.

- Making use of knowledge, experience and initiatives of the different stakeholders and thus improving the quality of plans, measures and river basin management;
- Public acceptance, commitment and support with regard to decision taking processes;
- More transparent and more creative decision making;
- Less litigation, misunderstandings, fewer delays and more effective implementation;
- Social learning and experience–if participation results in constructive dialogue with all relevant parties involved then the various publics, government and experts can learn from each other's "water awareness"."[22]

Through participation, long term, widely acceptable solutions for planning can be arrived at. This can avoid potential conflicts, problems of management and costs in the long term. The NWCC has the potential to be this tool at central level.

The mission, composition and functioning are presented below.

MISSION

In order to facilitate the RNRA-IWRM work and to reach a better cross-sector planning function, the article 16 of the Water Law proposes the creation of the National Water Consultative Commission. This organ should be consulted on the following matters:

> "1° planning projects in the water domain elaborated to the national level or the large hydrographic basin level and on the revision of these projects, in order to assure quality standards and optimum use of available resources;
>
> 2° projects of water supply and water transfer from basin to basin, with national character as well as in the large-scale projects of the same category of provincial character;
>
> 3° any water related issue, in case the Minister deems it necessary."

The National Water Consultative Commission shall be consulted for projects at the national- and the hydrographic basin level (to be understood as either Nile or Congo basin) and should review all projects envisaged across all sectors. Moreover, the NWCC may issue a statement on decrees and orders regarding water field, either by the Government's demand, or by its own initiative. This institution may also give its opinion about catchment master plans and, in case of authorization (sometimes) or concession (always), on the draft permit and on RNRA-IWRM assessment. Its competencies extend on the whole natural and anthropogenic water cycle.

COMPOSITION

The Prime Minister's Order n°143/03 of 24/05/2013 determining the organization, functioning and composition of the National Water Consultative Commission defines a composition presented in annex C4_1_4) dominated by senior level civil servants with three representatives for the private sector, knowledge institutes, and NGOs in as far as these are related to water.

As a public participation tool, and following the recommendation of the article 16 of Water Law, the National Water Consultative Commission could be reinforced with representatives of decentralized government and representatives of various public and private water users.

[22] European Commission *Common Implementation Strategy for the Water Framework Directive 2000/60/EC*, Guidance n°8 – Public Participation in Relation to the Water Framework Directive, p14

Hence, the Commission should comprise members who represent industry, middle class, farmers, workers, fishermen, consumers, environmental protection associations, cities and villages, water and sanitation operators etc. A list of suggested members to be considered for inclusion in the NWCC is presented in annex C4_1_4.

Mandates are personal and for a period of four years. The commission comprises a board composed of the president, the secretary and a representative of each college. It organizes the work of the Commission, ensures day to day management and handles the annual budget allocated to this organ.

FUNCTIONING

According to the Prime Minister's Order n°143/03, "the NWCC is a consultative organ without legal personality and financial and administrative autonomy. It's recommendations are not mandatory. The Commission's recommendations are implemented by the Ministry of Natural Resources.

The Commission will be chaired by the Minister of Natural Resources; in case of his/her absence, he/she shall be deputized by the Minister in charge of water supply (MININFRA). The director of RNRA-IWRM shall act as the Secretary of the Consultative Commission. The Office of the Prime Minister shall be the supervising Authority of the National Consultative Commission at the national level. The commission shall meet once in six months and whenever it is considered necessary. Decisions will be taken with absolute majority."

2.12.3.3 THE CATCHMENT WATER MANAGEMENT OFFICES AND IWR PLANNING

Considering, that the preparation and formulation of the water management plan is entrusted to District Committees in the Water Law, that the district domain is not appropriate for elaborating an integrated water management plan, and given the Committee member's skills, it is the IWRM department of RNRA that has the real resources (information and know-how) for elaborating and submitting water plan to the District Committees.

Inside the two hydrographic basins (Nile and Congo River basins), nine catchments were defined. These catchments could be managed by decentralized branch offices of RNRA-IWRM: the Catchment Water Management Offices (CWMO). Please note that these entities are proposed by the consultant and that they are currently not foreseen by the law.

The goals and objectives of the CWMOs are to make more efficient and targeted the management and the protection of water resources of the given basin in accordance to the catchment master plan, the Water Law and the National Water Policies. To achieve these aims, the CWMOs may fulfill the following functions (planning and other functions):

- Based on the National Water Resources Masterplan and the Water Law, develop catchment master plans by coordinating sector and public interests into development of those plans;
- Implement catchment master plans in coordination with the Catchment, District and Sector Committees;
- Develop draft prospective/long-term projects for management, use and protection of water resources of the catchment based on the peculiarities and problems of the catchment;
- Serve as a link between the RNRA-IWRM, the Catchment Committees and the

community served by the Catchment;

- Support waters users during the water permit procedure and intervene on the field to investigate the local situation (for complex cases) or for information purposes; CWMOs could express their approval or concern about the application and the corresponding RNRA-IWRM assessment;
- Receive complains and solve issues raised by communities concerning water resources management and protection at local level;
- Control water extraction records, reliability of water metering devices according to the water permit specifications, as well as the water protection zones;
    - Control and ensure that water use does not exceed limits allowed by water permits and submit a report on that to RNRA-IWRM;
    - Periodically conduct qualitative and quantitative control analysis of water and wastewaters discharged into water catchment by means of specialized laboratories (controlled by REMA);
    - Submit report on the conducted works to RNRA-IWRM.

These branch offices would optimize the RNRA-IWRM functioning. The major interest of these decentralized offices is to accommodate the relation between central administration, decentralized committees and water users in a proper water management domain. Considering the limited financial resources, the number of branch offices and their functions could at first be developed for highly committed and vulnerable catchments (for instance, Muvumba, Akanyaru catchment).

The Consultant suggests that these CWMOs being composed of at least two officers (see annex C4_1_5 for tentative job description of these officers):

- A planning and monitoring officer (profile: environmental engineer or public administration degree with experience in the Water Sector and Water Users' Capacity Building)
- A, hydrologist (profile: technician with a hydrology degree and a strong field experience in Water Sector)

These two officers may be supported by one or two permanent staff as a driver and/or office manager. They may have their own office or be accommodated government offices at a suitable urban center within the catchment.

2.12.3.4 THE CATCHMENT COMMITTEES AND IWR PLANNING

The creation of Catchment Committees at the level of the nine catchment is highly recommended because the territorial division of the 30 districts does not overlap with the nine catchments whereas a territorial coherence is mandatory for elaborating and implementing an integrated water resources management plan per catchment. Please note that these entities are proposed by the consultant and that they are currently not foreseen by the law.

The aim is to create a platform for catchment wide planning and water management by all districts and sections comprising a catchment area. These CCs are « Inter-district committees », comprising representatives of district committees and representatives from civil society, in order to allow a public consultation on the Catchment master plan.

These Inter-district committees could be formed by representatives located in the concerned catchment area with a college of representative of district authorities and representatives of civil society.

A detailed list of suggested representatives of the CC is given in annex C4_1_6.

The President of the CC should be elected by all the members of the CC, among the Presidents of all the District committees located in the concerned Catchment area for a short duration (for instance one year).

The principal function of these CCs is to be a platform for an inter-district dialogue regarding the elaboration of the Catchment master plan and management issues that may arise. CCs should only have an advisory role on the elaboration of the Catchment master plans and follow-up its implementation.

The Catchment Committee is assisted by an Executive Secretary with following activities:

- Responsible current management of catchment affairs;
- Coordinates planning and implementation activities;
- Supports staff's work within the execution of all their activities;
- Reports CCs meetings and submits a copy the MINIRENA, the RNRA-IWRM, the CMWOs located in the concerned Catchment area and the District Committees located in the concerned Catchment area

This Executive Secretary is nominated among the persons in charge of environment/water of all the districts located in the Catchment area. CCs may seek advice from experts depending on certain items on the agenda; notably the experts of the Catchment Water Management Office, the branch office of RNRA-IWRM.

2.12.3.5 THE RWANDA WATER AUTHORITY AND IWR PLANNING

The Rwanda Water Authority is identified in the Water Law but not yet defined by a ministerial order.

As the Rwanda Water Authority is already enshrined by the Water Law at the article 17 but without specific missions, the consultant proposes its creation as Arbitrator to Conflict resolution for administration cases and Catchments Committees Coordinator.

Further details on this authority are presented in annex C4_1_3.

2.12.3.6 THE DISTRICT COMMITTEES AND IWR PLANNING

In order to clarify and simplify water resources management at decentralized level, the Water Law, in its article 20, defines the District Committees for hydrographic basins.

MISSION OF THE DISTRICT COMMITTEES

The Water Law defines the missions of District Committees for hydrographic basins (art.21):

1. to propose the initial version of the master plan and management of the basin waters as provided for in this Law;

2. to propose the delimitation, if necessary, of under-basins and the designation of the aquifer for which an integrated management of the water resource must be done;
3. to formulate orientations and proposals concerning the planning and management of the waters of under-basins or aquifer;
4. to formulate propositions of arbitration or solution in case of conflict of water uses;
5. to formulate opinions on all technical or financial questions that is submitted to it by the administration.
6. to value the relevance and the feasibility of basin organisms, to prepare their installation in the event that it would be judged necessary.

Please note that District Committees are consultative: they can “propose” or “formulate” orientations on the water management. The development of a master plan for the integrated management of water resources at district level is essentially impossible at this level because it does not overlap the hydrographic basin. A single district may exceptionally be located within a single hydrographic basin, but most of districts are divided between at least two if not three or more hydrographic basins. Further a single hydrographic basin will comprise a number of districts (typically 5 to 10 districts to form a single hydrographic basin). A map showing the overlap between level 1 catchments and the districts is presented in annex C4_5

Hence, in practice, the district should not be commissioned to produce a basin water management plan because it has inappropriate territorial boundaries for that task. All districts with territory in a specific catchment should however be implicated in the formulation and implementation of the catchment master plan. The realization of the plan can be assigned to the RNRA-IWRM and the Catchment Water Management Offices.

<u>COMPOSITION AND FUNCTIONING OF THE DISTRICT COMMITTEES</u>

According to Ministerial Order nº005/16.01 of 24/05/2013 determining the organization and functioning of hydrographic basin committees, the hydrographic basin committee at district level shall be composed of by different actors of civil society and district officers (see annex C4_1_7 for details on the composition of District committees.

We suggest that the composition of the District Committee may be reconsidered because of its essentially advisory role:

- the presence of representatives of the central administration relating to water does not need to be mandatory.
- the representative of the administration may forego their right of vote (i.e., “the staff in charge of agriculture, animal resources, land, urbanization, urban development, infrastructure forests, environment at the District level” and “the staff of the National Authority in charge of Natural Resources operating at the level of the hydrographic basin”); the rights of vote would be granted to the:

On the contrary, it is suggested that the right of vote be delegated to:

- Representatives of the elected members at the decentralized level: “representatives of committees for hydrographic basins at Sector level”
- Representatives of the different water users organizations: “representative of National Women Council at District level”, “a representative of the National Youth Council at the District level”, “ two (2) representatives of farmers at District level”, “a representative of water user organizations in the field of agriculture at District level”, “a representative of water users in domestic activities at the District level”, “two (2)

representatives of non-government organizations operating in the field of water in the District" and "a representative of the Private Sector at the District level".

The President would be elected by the representatives of these two groups. Representatives from the administration may participate as observers and advisors.

As the Ministerial Order n°005/16.01 of 24/05/2013 determining the organization, and functioning of hydrographic basin committees declares: "the representatives of different organs shall be nominated and made available by the respective organs that they represent. The Mayor of the District shall convene the first meeting of the hydrographic basin Committee at District level in which management members shall be elected. The officer in charge of water resources (if he/she exists) or environmental affairs shall be the Secretary of the Committee. The meetings of district committees are held once per quarter and whenever it is considered necessary. The President shall convene the meeting in writing, through the Mayor of the District. Invitations shall reach the Committee members at least fifteen (15) days before the meeting is held. The invitation must indicate the items on the agenda of the meeting. An extraordinary meeting shall be convened whenever it is considered necessary. All meetings of the District Committee shall be reported. The reports shall be submitted to the hydrographic basin committee at a higher level in a period not exceeding fifteen (15) days after the meeting is held. The President of the hydrographic basin Committee at the District level shall submit the report to the Mayor of the District who further shall submit it to the Minister in charge of water resources in a period of fifteen (15) days after the reception of the report. Members of the District Committees shall operate on a voluntary basis. "

District Committees may seek advice from experts depending on certain items on the agenda; notably the experts of the Catchment Water Management Office, the decentralized entity of RNRA-IWRM at level of catchment.

2.12.3.7 THE SECTOR COMMITTEES AND IWR PLANNING

The mission of the sector committees is rather similar to the mission of the district committees. At sector level, basin committees could exist "where it is deemed necessary" (art.22 of the Water Law). They may take place occasionally for dealing with particular cases and for a limited period of time. According to the Water Law (art.23), responsibilities of committees at sector level are the following:

1. to propose the initial version of the local master plan;
2. to fix management procedures for the under-basin waters or the aquifer, provided for under this Law;
3. to formulate at its level propositions and opinions

In this respect, the 'local master plan' should be understood in two stages. Prior to the formulation of the catchment Master Plan, the local Master Plan is a valuable contribution with specific local know-how but cannot in the wider context of the catchment be more than a 'wish list' of required development actions (primary use - water supply) and inactions (primary use - environmental restrictions) as well as of development opportunities (demand for commercial ventures - irrigation, hydropower, industries, etc.).

The second stage is after the formulation of the catchment master plan when the local 'wish list' options have been analyzed and optimized in the larger context of the catchment and these options upgrade to development actions with defined location, capacity, timing and entity in charge of implementation and exploitation.

Details on the organization and functioning of the Sector Committee are provided in annex C4_1_8

2.12.4 IMPLEMENTATION OF RESOURCES DEVELOPMENT WORKS

2.12.4.1 INTRODUCTION

The diagram below highlights the main actors involved in the water resources implementation function.

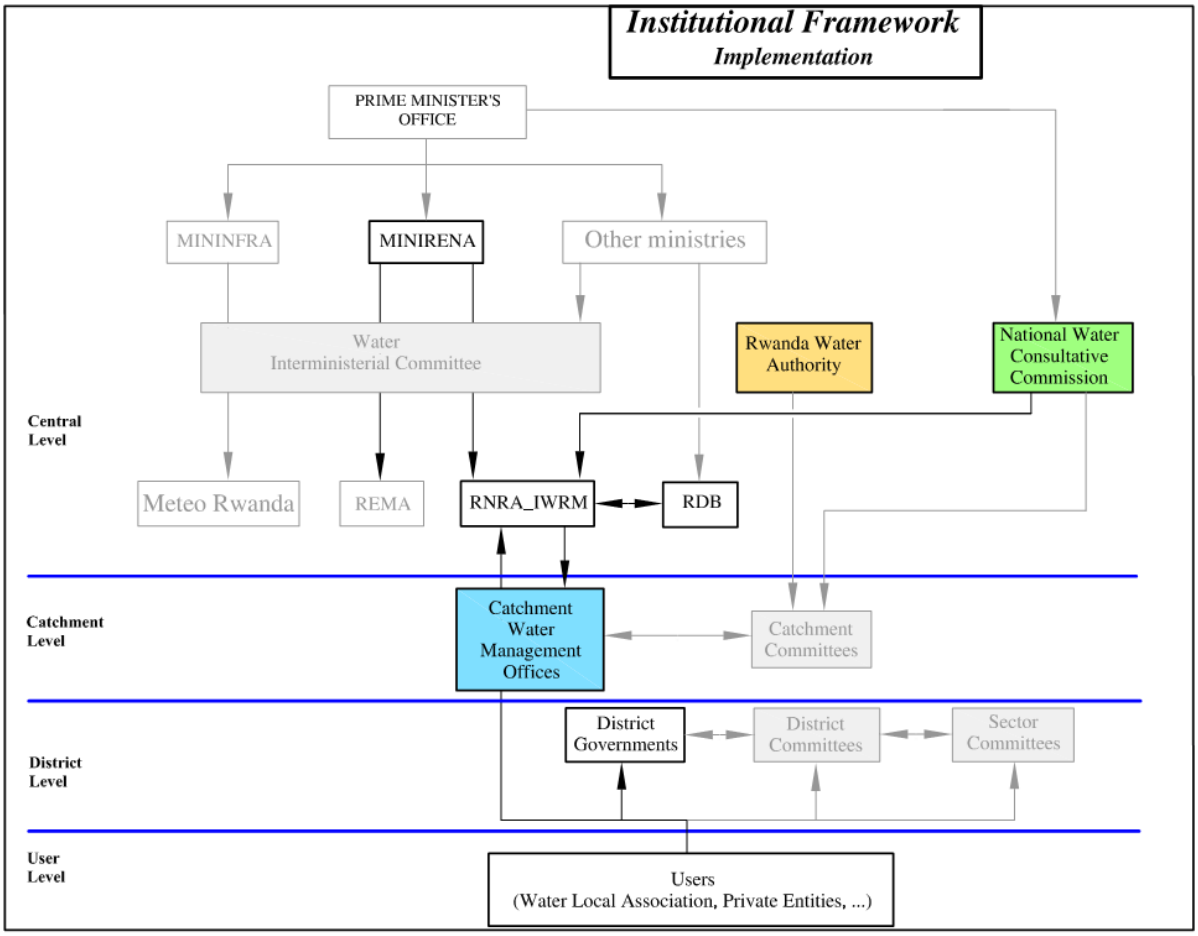
All water resources development activities require a permit. The permit can be applied for through the Water MIS. An aspiring water user first has to register to become a 'registered Water User (RWU). Only registered Water Users can apply for a water permit.

Water users can get help from district officers in charge of water and, in the future, by the Catchment Water Management Offices.

For large projects, the draft permit and the RNRA-IWRM assessment have to be submitted to the National Water Consultative Commission which could revise this document and give its approval or opposition, and/ or comment it.

For projects expected to have significant impact on the environment or other water users, an Environmental Impact Assessment (EIA) is needed which the aspiring water user may obtain with the RDB. REMA is in charge of the compliance monitoring of the EIA. Where the EIA study requires the level of intervention in the natural hydrological cycle to be known, the hydrological assessment needs to be completed prior to the EIA study.

Figure 26: Main institutional entities involved in water resources development



2.12.4.2 THE WATER PERMIT APPLICATION PROCEDURE

The Water Law specifies three different regimes of water permits. The declaration regime, intended for interventions that are unlikely to have a major impact on the natural hydrological cycle or on other water uses. The authorization, intended for intervention that have significant impact on the natural hydrological cycle or on other water uses. The concession regime, intended for interventions that are expected to have major impact on the natural hydrological.

Further, in order to structure the possible interventions in the natural hydrological cycle, a classification of 5 types of permits is suggested: abstraction of surface water from a water course, river or lake; retention of surface water in a reservoir for later user; abstraction of groundwater from an aquifer; release of used water in the natural hydrological cycle and miscellaneous interventions.

During its lifetime, a water permit has three distinct stages, involving different actors and institutions: i) the application , ii) the operation and finally ii) the closure. In this chapter on resources development for use, we will discuss the water permit application procedure and the actors' involvement. An detailed write up of the permit procedure suggested by the consultant is presented in appendix 10 to this main report.

The application will start at the level of users: the water user aims to develop some water related activity with the objectives to sustain livelihood and/or pursue a commercial venture; he has rights and obligation, given the fact that the water permit is a written agreement between himself and the Rwandan government.

To start a permit procedure, he must first register himself on-line as a “water user” with a unique ID according to his nature (NGO, WLA, company...). In this process, the District staff (or, in the future, the 'Catchment Water Management Office') could intervene in order to help the user[23]. After this stage, he should register for a water permit, entering all data through the Water MIS (ID, type of intervention, location, type of permit regime…). At this level, the water user should receive the help of a district/sector/catchment water management officer to fulfill the application without mistakes.

For the next step, the permit is processed mostly at central level where RNRA-IWRM will intervene when the permit application has been entered in the Water MIS by means of a completeness check and a hydrological viability check. The RNRA-IWRM is committed to send a copy of its assessment to the water user within 20 working days.

With the creation of the “Water Permit System”, in case of an authorization or a concession, an EIA is required to obtain the water permit, “showing the quantity of water which will be used compared to its overall quantity” (art. 37 and 38 of the Water Law) and insuring that licensed investment comply with the Country’s environmental laws. The EIA is “a systematic, reproducible and multilevel process of identification, prediction and analysis of significant environmental impacts (positive or negative) of a proposed project or activity and its practical alternatives on the physical, biological, cultural and socio-economic characteristics of a particular geographic area in order to provide information necessary for enhancing decision making”[24]. According to RNRA-IWRM Water Permit staff, the demand for an EIA has to come from the applicant himself. The user has to go to the RDB with his project brief. After a field inspection by this institution, the dossier is submitted to a REMA registered consultant who products a report and a positive or negative opinion on the project. RDB could comment this recommendation and deliver the certificate; a copy is directly sent to REMA. When projects concern RNRA competencies (mines, water…), a copy is sent to this institution also.

The workflow between RDB and RNRA-IWRM officers is not yet established as the water permit system is still not known by RDB officers. Moreover, the user has to go himself to RDB and after recuperating the certificate, he has to come back to RNRA-IWRM with his EIA. To improve this situation, the Consultant recommends the redaction of a memorandum between these two institutions in order to formalize the workflow. Further, RNRA-IWRM may proceed with the accreditation of suitable consultants for the assessment of water permits.

If the water user does not agree with the permit assessment of the RNRA-IWRM, he shall have the right to bring his case to a competent court or to the Rwanda Water Authority.

Without any opposition of the water user or the RDB/REMA, RNRA-IWRM will send off its assessment to the CWMO and/or the District for information purposes. Without negative opinion, and in the case of authorization (sometimes) or concession (always), the draft permit and the RNRA-IWRM assessment will be submitted to the National Water Consultative Commission, which could revise these documents.

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[23] This help could be located in a « one-stop center » at each district; the population is used to this platform, already used for land issues or water supply problems.

[24] REMA, General Guidelines and Procedure for Environmental Impact Assessment , 2006, p.1

When the permit application process has been finally concluded, the draft permit will be printed in two originals and submitted to the water user for signature. Then, the two originals will be send to the Minister of Natural Resources for signature and send to water user and RNRA-IRWM (stored in the Water MIS).

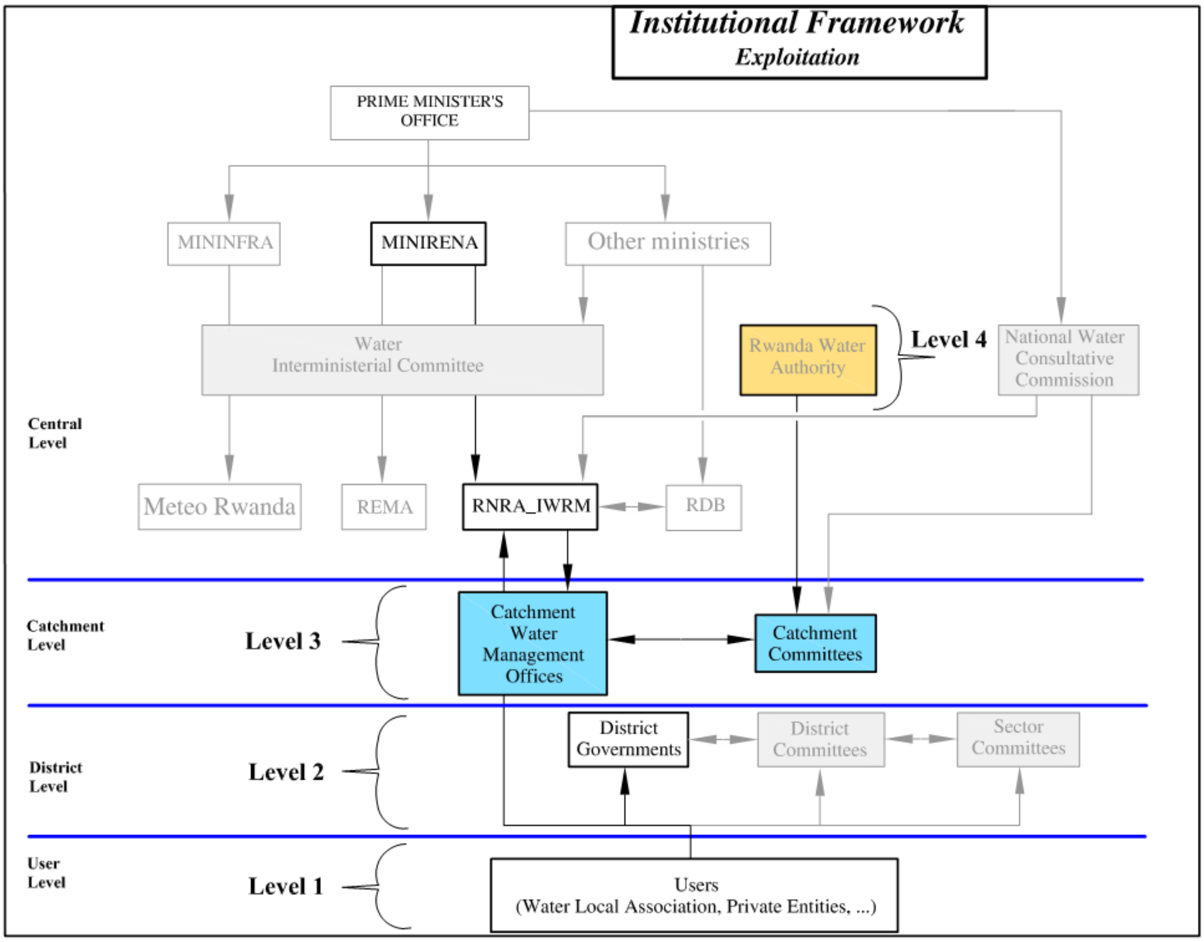
2.12.5 EXPLOITATION OF RESOURCES DEVELOPMENT WORKS

2.12.5.1 INTRODUCTION

The diagram below highlights the institutional entities involved in the exploitation of resources development works. Exploitation is by many users as EWSA, water local associations and cooperatives of farmers. The control of exploitation is done within the permit granted by MINIRENA with the technical support of the RNRA-IWRM and its decentralized entities at the Catchment level, CWMOs.

In this section, the Consultant elaborates some propositions for the resolution of disputes on water resources use and permit exploitation. While the first step is between users themselves, the conflict could be submitted at superior levels: first the sector, than to the district government authority with the district environment officer, then at the Catchment level with CWMO's and Catchment Committees. If at this stage, a solution is not found, it can be dealt with by the Rwanda Water Authority with technical support from the RNRA-IWRM.

Figure 27: Main institutional entities involved in water resources exploitation



2.12.5.2 WATER RESOURCES EXPLOITATION AND CONFLICT RESOLUTION

During the exploitation of a permit, it is needed to monitor if the actual operation more or less complies with the permitted operations. When there is abundance of resources the consequences of a deviation between actual and permitted operations does not interfere with exploitations elsewhere and reasonable deviations can be condoned. What shouldn't be allowed under any circumstance however, is that the water user deliberately provides wrong information on the actual abstractions. In the case of higher committed areas, all water users should comply quite strictly with the stipulations in their permits. In the case of conflict there are may be four levels of resolution identified as follows:

WATER MANAGEMENT AND CONFLICT RESOLUTION AT THE USER LEVEL (LEVEL 1)

The Water User has rights but also obligations: the permit holder should be explicitly aware that he has an obligation to provide correct information on his interventions in a timely manner as specified in the permit (water use data).

The first level of conflict resolution constitutes the negotiation: involved parties meet to reach a mutually acceptable solution. This solution does not imply participation of a third party, only the involved parties and their representatives participate. They present proposals to reach an agreement, in a private process. Indeed, it does not have a legal character; the decision is taken by the parts. Consequently, it is not compulsory to follow the found solution. This process involves only users who are in conflict

It is recommended that the operation conditions of all permits in a catchment are accessible to all Water Users that operate permits in a catchment: other water users/operators are a source of information on non-compliant operation of neighboring permits. This approach should however not lead to autonomous actions other than negotiations between permit holders.

WATER MANAGEMENT AND CONFLICT RESOLUTION BY THE LOCAL AUTHORITIES (LEVEL 2)

The second level involves the implication of the local authorities when the two belligerent parties are unable to find common ground. In this case, the Water/Environmental District Officer may occupy the position of facilitator. He/she will have several obligations during this process. The officer will assist in meeting design and help keep the meeting on track. He/she will clarify and accept communication from parties and frame a problem constructively based on the permitted interventions and the available resources. His/her principle role will be to suggest procedures for achieving agreement and summarise direction. However, the Water/Environmental officer must not judge or criticize; he/she will not push his/her own ideas.

WATER MANAGEMENT AND CONFLICT RESOLUTION BY CATCHMENT WATER MANAGEMENT OFFICES (LEVEL 3)

If the conflict cannot be solved by the local authorities, the next step is to try to find a solution by the Catchment Water Management Offices; the mediation may take the form of a specialized investigation where the catchment water management officer formulates an opinion if needed with support from RNRA-IWRM. For conflict resolution it is however required that both water users accept the opinion of the catchment water management offices. If such is not the case, the last resort is the Rwanda Water Authority.

CONFLICT RESOLUTION BY THE RWANDA WATER AUTHORITY (LEVEL 4)

If a conflict does not find a solution at the preceding three levels, it can be brought to the Rwanda Water Authority. This entity should make a full fledged investigation on the issue, typically involving the RNRA-IWRM on technical matters and local government on local matters. The Rwanda Water Authority has decision power on issues of water resources management.

2.12.5.3 WATER RESOURCES EXPLOITATION AND EXTREME CONDITIONS

In the case of extreme drought or other circumstances (drought, flood, other calamities), the Minister in charge of water (MINIRENA) has the responsibility to declare an emergency situation in order to safeguard livelihood of the general public and the natural resources including water resources and the environment.

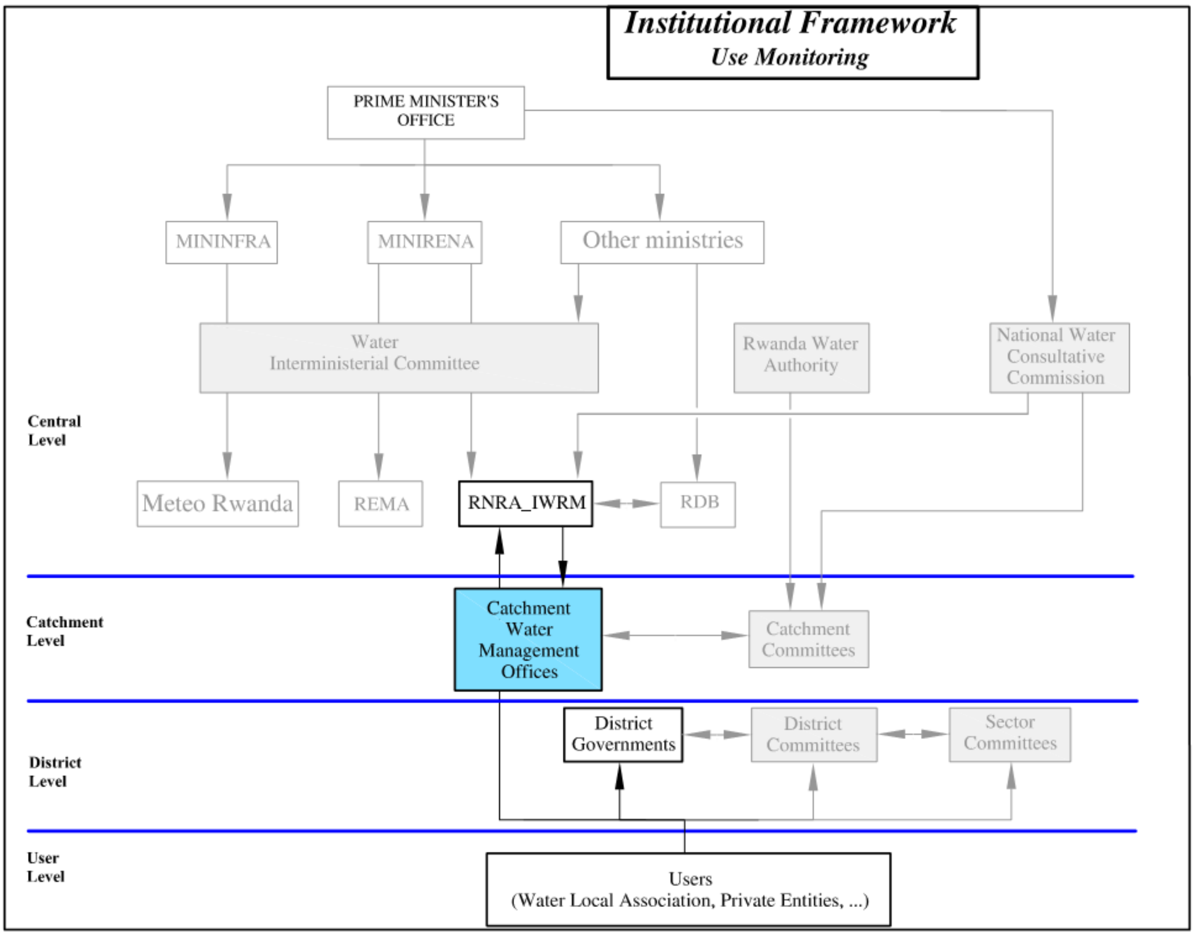
Consequently, the permit holder should be aware that the conditions of his/her permit can be adjusted in case of extreme conditions (when a water stress situation is declared for a specific duration for instance), erroneous issuance of a permit or improper exploitation of this and/or other permits

2.12.6 MONITORING OF USE INTERVENTIONS

Considering the multitude of interventions, it is not possible for government to keep track of water use. It is for this reason that the monitoring of use should be delegated to the user with an occasional control by a government entity which has the possibility to warn and ultimately apply a penalty in the case of inappropriate use. In this section, the Consultant will present the institutional functioning for monitoring water use data. As suggested above, water users are the major actors in this process, supported by water/environment district officers who will help them with data collection if needed. This function of the district agents could be taken over by Catchment Water Management officers, when this new entity becomes available in a catchment. Their mission is to collect (with users), interpret and analyze at the first step the data. Through the Water MIS, RNRA-IWRM will have to analyze this information, verify the collective water use data against water resources monitoring. If needed, this department will send a feedback to user and make occasional verification of correctness of information.

The entities involved in this function are indicated in the diagram below.

Figure 28: Main institutional entities involved in water use monitoring



2.12.6.1 Improving the current situation

Even with the current limited water use, there is a multitude of water users which are intervening as they please wherever they please: EWSA, Local Water Users associations, farmers' cooperatives, etc. Currently, the RNRA-IWRM monitors some use interventions and some users do monitor their own interventions but for the sole purpose of their internal management procedures (EWSA water supply for instance) and this information is not relayed to the RNRA-IWRM. There is an enormous amount of information which can be obtained if the proper monitoring of data is done by users themselves through the Water MIS, controlled by the RNRA-IWRM and decentralized offices.

In monitoring of water use for the purpose of potable water supply, EWSA is responsible for monitoring of water supply installations and their operation. To this effect EWSA operates a large database of water abstraction, production and network expansion, spanning several decades. It is obvious that the RNRA, which should keep track of the balance between available water resources and demand, is not informed on the actual use of the resource for purposes of drinking water supply. In order to correct this situation, EWSA should obtain water permits for its abstractions from ground and surface water resources for all piped water supply systems, and it should provide information on actual abstractions at e.g. a monthly interval for each of these systems.

For the monitoring of environmental demand, the main problem is the lack of knowledge on need and impact of environmental flow. Currently, RNRA-IWRM monitors the surface water resource at the major rivers and has the task to monitor underground water also. But this function should address water quantity and quality parameters and be extended onto these critical watersheds and wetlands. The issuance of authorizations and concessions by RNRA-IWRM is currently not operational and not based on an assessment of available resources, current use of those resources (for other than environmental demand) and projected demand (for other than environmental purposes).

Monitoring of industrial water use currently falls under the responsibility of EWSA which is normally based on monthly meter readings whereas monitoring of mining use is mostly the responsibility of the miner himself. This information is available but is not transferred to RNRA. For reasons of demand projection, it would however be useful if RNRA-IWRM could access such information. But for the time being, RNRA-IWRM does not seem to have the capacity to manage and analyze such information. The practical implementation of the water and environmental laws is required (permits for water abstraction and waste water disposal, improved communication with RNRA-IWRM, decentralized water management, compliance with EIA, etc.).

For the monitoring of agricultural use, the example of irrigation projects shows the importance of communication between users and the RNRA-IWRM. All irrigation projects should be declared (RWH pond irrigation, marshland rehabilitation, development of dam, abstraction from natural lake of river, abstraction from groundwater, and reuse of water from other sources (e.g. urban waste water,...)) prior to implementation which only should take place whence a permit is issued by RNRA-IWRM. Hence, as for other uses, the responsibility for the monitoring of water use and its communication to RNRA-IWRM, should be delegated to users. In this case, it means the private user or in most cases the cooperative managing the irrigation infrastructure. The WUA may be delegated to provide such information.

2.12.6.2 WORKLOAD OF WATER USE MONITORING

It will be the responsibility of water users themselves to complete and update their data through the Water MIS. The information elements to be collected at the frequency specified in the permit (as the case maybe from annual to monthly) are:

- Water users ID and permit ID (all permits)
- Start-and end date of the exploitation period (all permits)
- Realized volume of abstraction (flow and groundwater permit) or retention (storage permit) (only for authorization and concession permits)
- Operational status of the installations (all permits)
- Update on water use (all permits)
- Change of contact details of the owner (all permits)
- Change of operator or contact details of the operator (all permits)
- Realized return flow quantity, flow rate, calendar and water quality (for authorization and concession permits)

- Status of protection and mitigation measures and their impact (for authorization and concession permits only)
- Payments modalities (if any) of the permit

The data is collected directly in the Water MIS either by the water user or with the assistance from district staff or with the assistance from staff from the CMWO or directly from the RNRA-IWRM.

The RNRA-IWRM should collect, control, storage, analyze, interpret and update the water use data provided by the water users. The principal aim of this information is to see that permits are exploited within the framework of their specifications.

The first step at the RNRA-IWRM office is the storage of these data in the data base/Water MIS, analysis of these collective water use data and then interpretation of collective water use data and verification against water resources monitoring. The storage should be made by the two Water Data and Information Management officers who have a technical competency for that. After the storage, the analysis and interpretation of these collective water use data should be made both by the Water Data and Information Management system unit (two officers) and the Water Permit administration (two officers), who should have the responsibility to verify against the permit data and information done by users. Water Permit administration officers are the competent officers to know the Water Permit Procedure and there are responsible, at the central level, to know what is asking from the water users.

After the storage and analysis of this information, the second step for the RNRA-IWRM is to check the quality control of these permit data and update it. The RNRA-IWRM should use the Water MIS as a communication and information collection platform and control the updates on the operational status of the declaration permits and more detailed and frequent update on the status of authorization and concession permits.

The RNRA-IWRM may verify the correctness of the information entered in the Water MIS and may demand assistance from the CMWO staff. When the actual water use deviates significantly from the permitted quantity, the owner may be contacted directly (or via the CMWO) in order to investigate this anomaly and, when needed and possible, take actions to prevent a recurrence. The return flows are compared with the abstracted volume, the water use, and the permitted return flows (in terms of quantity, calendar and water quality).

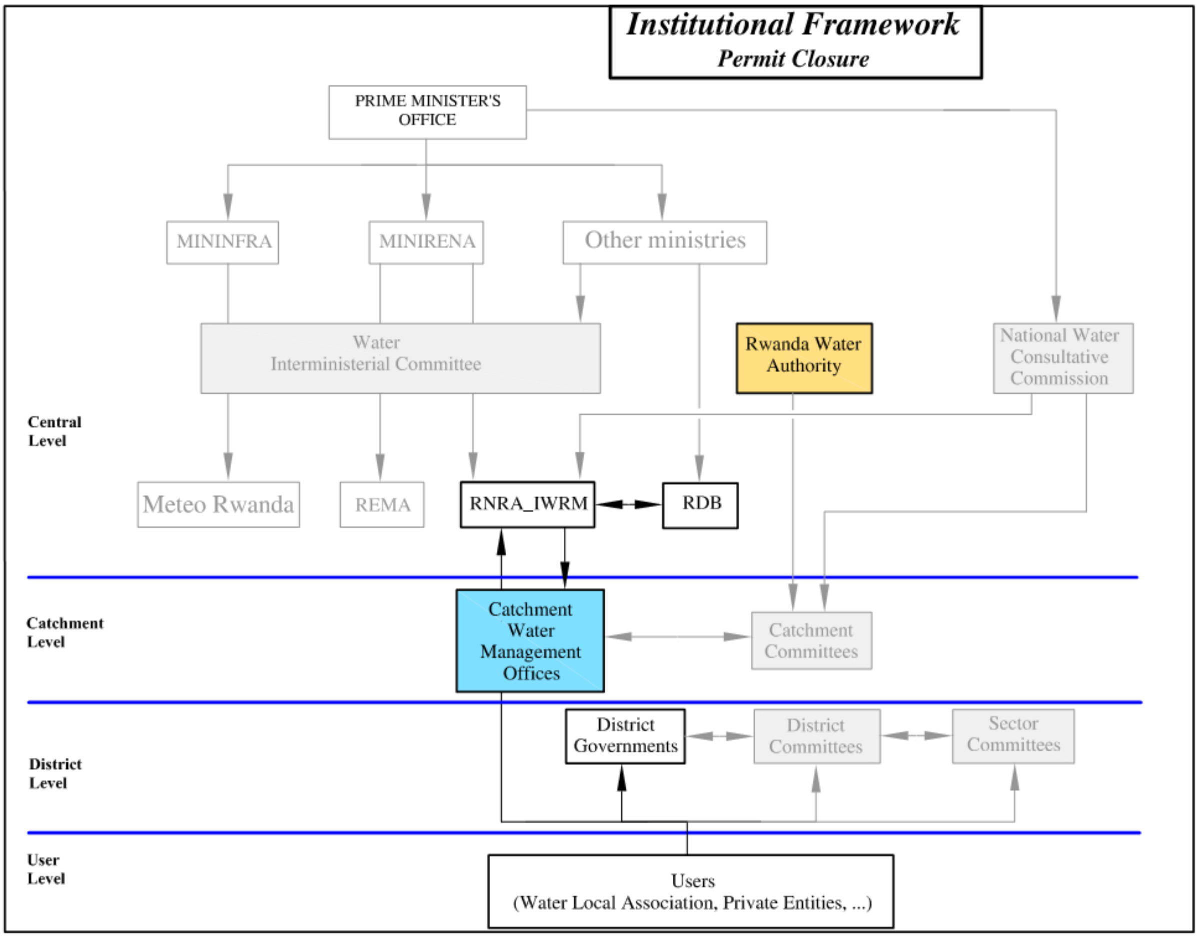
Even if he does not intervene in the monitoring of use, the Water Use Planning officer is responsible for the training of stakeholders. Consequently, he should also explain to the water users, through meetings with them on the field, the Water MIS concept and its importance for the IWRM.

The Consultant suggests a training of the full RNRA-IWRM's staff about the utilization of the Water MIS. For the monitoring of use interventions, the concerned staff (mentioned above) should know how to use the Water MIS (from the storage to the analysis) but should also know how to explain it to water users. Currently, the Water MIS is only used by Water Resource Monitoring officers. As the RNRA-IWRM works as a team, the Consultant suggests an internal training which could be made by the Water Resources Monitoring officers (four officers) to the whole staff. If necessary, they could request specific assistance from the Consultant's staff.

2.12.7 CLOSURE OF PERMIT FOR INTERVENTION IN NATURAL HYDROLOGICAL CYCLE

In the diagram below, we present the actors who intervene during the closure of a water permit.

Figure 29: Main institutional entities involved in the closure of a water permit



2.12.7.1 *MODALITIES FOR CLOSURE OR CONTINUATION OF A WATER PERMIT*

The closure of a water permit may be called for under one of the following situation, linked to its expiration of duration and choices of the actors:

- The permit duration is expired and the Registered Water User (RWU) does not request an extension of the permit duration
- The permit duration is not expired but the RWU has no interest in the further exploitation
- The permit is not yet expired but the RNRA-IWRM aspires to put an end to or substantially reduce the intervention

The closure of the permit could further be decided as a result of an inappropriate exploitation by the user, verified on the ground by the CMWOs and requested by the RNRA-IWRM and decided by the RWA.

The closure may also be the consequence of an erroneous assessment from the RNRA-IWRM or CMWOs (including erroneous field observations). In this case, the permit is temporary closed for further investigations, and compensation payment may be due to the disadvantaged user (case to be decided by the RWA).

However, before the expiration of the duration of the permit, there are different situations, linked to the needs of the RWU or the catchment situation, in order to continue the permit operation:

- If the RWU wishes to continue operating the installations under the same conditions, the RWU must request such extension prior to the expiration of the permit lifetime
- If the water resources in a catchment are moderately exploited there is not much benefit in the closure of permit so the continuation of the permit under the same conditions can be routinely approved. More or less standard approval of continuation of permit exploitation is also suggested for all declaration permits under all conditions. The duration of the new permit can be negotiated with the RWU.

When it is desirable that a permit (authorization or concession) be continued, even when unaltered or slightly altered, it is suggested that a new permit application procedure is started. This has advantages for keeping track of permitted use levels over time.

For the continuation of the permits there are particular situations for flow permits and groundwater permits in highly committed catchments and aquifers:

For the flow permits operated by commercial entities that wish to continue their operations in highly committed catchments, the RWU may look for alternative modes of water abstraction (e.g. daily or intra seasonal storage) or reductions of water demand through process improvements, water reuse options, etc.

For large capacity groundwater abstraction permits operated by commercial entities in highly committed aquifers, it is recommended that the “waiting list” of the aquifer is checked for primary use operations. When no such operations are recorded the permit may be continued under new conditions and for a limited period of time (not exceeding 5 years). If this time period is insufficient for a viable commercial exploitation, alternative water resources may be investigated by the RNRA-IWRM in cooperation with REMA and RDB, or the permit may be given for a longer time period.

2.12.7.2 ACTORS INVOLVED IN THE CLOSURE OF A WATER PERMIT

In the case of the closure of a permit, the water user will have to proceed as follows:

- Inform the RNRA-IWRM on his registered water user ID and the permit ID that will be closed
- The water user must realize any corrective measure for the closure of the permit that was defined upon the opening of the permit unless modified by the next point.
- Discuss any corrective measures that the user proposes for the closure (demobilization of equipment…) with the RNRA-IWRM or the CWMO officer. Likewise, the RNRA-IWRM or the CWMO officer in its place, could propose in its turn necessary corrective measures; however, if the user does not agree, he could request a revision at RWA. When a final decision has been reached, the user must implement them to a satisfying standard to the opinion of the RNRA-IWRM; if he/she fails, RNRA-IWRM may take to implement these works at the cost of the water user.

- Any outstanding payment of registration fees and the like must be paid by the RWU.
- When the permit is closed before its expiration by RNRA-IWRM, there should be a possibility for the user to oppose the discontinuation of the permit and the proposed compensation payments. As an administration could not arbitrate litigation between another administration and a user, this case could be deal with the Rwanda Water Authority (RWA) or a competent court if this new organ is not created.

The closure of the permit may happen when the permit is not yet expired but the RNRA-IWRM aspires to put an end to or substantially reduce the permitted intervention; the premature permit closure will be ground for compensation payments from the Government of Rwanda.

When the permit will not be continued, the RNRA-IWRM needs to analyze the data record of the permit (for the installed intervention equipment for abstraction and return flow, operation procedure, abstracted or stored volumes, return flow quantities and water quality, corrective and mitigation measures during operation, compliance of permit duration and payment of due fees…); it may proceed with a field visit, sometimes in association with REMA and RDB officers, to assess the current status of the intervention equipment and to estimate the impact from this equipment.

The RNRA-IWRM needs to estimate the impact of the closure of the permit on the hydrological situation in the catchment. The correct closure of the permit is finally registered in the Water MIS and kept for record.

2.13 TRANSITIONAL MECHANISM FOR ESSENTIAL CATCHMENT WATER MANAGEMENT SERVICES WITH DISTRICT TERRITORIAL AUTHORITY PRESERVED

2.13.1 INTRODUCTION

An institutional framework for IWRM compliant water management has been proposed in the preceding section 2.12. This framework is largely inspired by the 2008 Water Act which provides adequate guidelines for such IWRM compliant water management.

However, the guidelines defined in the Water Act do not provide for water management services at the catchment level. Where these services were found to be essential for IWRM, they are duly proposed in the institutional study under the format of (i) a catchment committee (a representative body where government administration and water user representatives from the districts that make up the catchment, can debate and ultimately decide upon water resources planning, - implementation and - exploitation issues at the catchment level), and (ii) a 'Catchment Water Management Office' that generates water management knowhow and advises representative bodies and water users in general on all matters pertaining to water management (planning, resources protection, intervention permits, resources development, resources exploitation, and monitoring of natural resources and interventions in the natural hydrological cycle).

Whereas the notion of catchment based water management is fully supported, the introduction of a catchment based water management level does not fit easily with the established modus operandi of decentralized government which operates above all through the districts as the custodians of land and water resources and as executives of financial processes for government interventions (project development and resources protection).

The implementation of a new layer of government superimposed on the district layer is obviously uncalled for and does not conform with the government intentions to provide effective services through a 'lean government' concept.

The purpose of this section is therefore to describe a minimal yet adequate institutional set up that abides by the command of the districts over their domain yet allows for the smooth integration and consideration of catchment based water management necessities in such command.

Prior to the proposition of such a structure in paragraph 2.13.5, we will briefly delve into the need for catchment based water management services in paragraph 2.13.2, into the current status of catchment based water management provisions (paragraph 2.13.3) and suggested approach for catchment planning studies (paragraph 2.13.4).

2.13.2 THE NEED FOR CATCHMENT BASED WATER MANAGEMENT SERVICES

Recall the five essential water management functions as follows:

1. strategy development
2. planning of resources protection and - development
3. implementation of resources development (and protection works)
4. exploitation of resources development
5. monitoring of water resources in the natural hydrological cycle and in an, in principle, unlimited number of user intervention cycles.

We will discuss whether these five functions must be provided at catchment level or if they can possibly be provided at a different level (national/central, district, or otherwise)

STRATEGY DEVELOPMENT is typically a prerogative that is exercised at ministerial level under which a ministry defines in what way and with what means it will organize its water management activities. The Water Interministerial committee has been proposed to synchronize and align these strategies (avoiding redundancies and promoting cooperation) hence strategy development is not decided upon at catchment level. Strategy development does not require intervention at catchment level.

On the contrary, **PLANNING** of resources protection and resources development is only possible at the catchment level. It is easy to see that the district and catchment domains do not in the least align (district boundaries are often waterways which are the central pathway of the catchment). In fact, the domain of each and every district in Rwanda is located in at least two catchments (Rusizi) whereas for most of them the number of catchments varies between 3 and 5 or even more. Conversely, the area of each of the catchments in Rwanda comprises at least three districts (Rusizi again) but typically the number of districts in a catchment varies between 5 and 12.

Planning of water resources development can only be done when the available (surface and groundwater) resources are known. With the results of the current NWRMP study, these resources are now known at the catchment level and the allocation of resources development between the districts need to be negotiated at the level of the catchment.

The planning function can be presented in a Catchment Master Plan. A description of the Catchment Master Plan is presented in the table of contents section under the 'list of terms'. The planning function can only be successfully handled at the catchment level.

When the planning of resources development has been developed in a concerted manner at the catchment level (dividing the cake between the districts), the actual **IMPLEMENTATION OF RESOURCES DEVELOPMENT** (when such implementation is financed by government) can be done under the supervision of the district, provided that such implementation is in agreement with the overall resources development plan defined for the catchment.

In fact, whether de developer is government, or a private entity that wishes to invest and operated in a district makes no difference. Any water resources development activity:

- needs to be in agreement with the planned interventions in a catchment,
- requires a water permit under different regimes (declaration for minor intervention, authorization for any intervention with significant impact on natural resources and standing water users, and concession for major interventions with regional implications) and intervention modes (currently three as there are (i) direct abstraction of water from surface water, (ii) retention of surface waters behind a dam, and (iii) pumping of water from groundwater).
- requires approval from the local authority (district/sector).

The water resources development activities with an expected significant impact (authorization or concession regime) also require an EIA. It is suggested that the permit application process and the EIA study be aligned.

Provided that the envisaged intervention in the natural hydrological cycle is permitted and in conformity with the planned developments, the implementation function can be successfully handled by the districts and there is no absolute need for a catchment based supervision.

The **EXPLOITATION OF THE DEVELOPED RESOURCES** needs to be in accordance with the issued water permit that should describe in detail the rights and obligations of the water user on the one hand and the government of Rwanda on the other hand. Whereas it is possible that suitably trained district staff supervises the exploitation of developed resources (a pumping station in a river or lake, a dam on a river or water course, a borehole (with hand pump or motorized)) in lowly committed catchments (demand at 5 to 10 % of the average renewable resources), this option becomes unworkable for highly committed catchments (already at say 15% of the average renewable resources). For the highly committed catchments under conditions of stress (hence every dry season), the control and guidance of permit exploitation through a number of (partial) districts that make up a catchment, becomes totally ineffective.

For highly committed catchments (Muvumba is the first catchment in Rwanda approaching this status) it becomes essential to define a set of objective rules for operational water management under conditions of water stress that are implemented throughout the catchment. This set of rules can be presented as the Catchment Water Management Plan. A description of the Catchment Water Management Plan is presented in the table of contents section under the 'list of terms'

In conclusion, when water resources management becomes demanding, the catchment is the only suitable intervention platform for water resources exploitation. This stated, it is conceivable that district technical staff participates in the operation of the Catchment Water Management Plan, provided that they are suitably trained and informed on the stipulations of the individual permits and the set of rules (the Catchment Water Management Plan),.

The last essential water management function is the **MONITORING OF WATER RESOURCES** in the natural hydrological cycle and in an, in principle, unlimited number **OF USER INTERVENTION** cycles.

This resources monitoring function can only be meaningfully defined at the catchment level. The monitoring of user interventions is an exhaustive task which is proposed to be implemented by the water users themselves with support, supervision and control from relevant authorities. It is very well conceivable that district technical staff when suitably trained and informed, participates in the monitoring of especially major water users (exploiting a permit under an authorization of concession regime), and provides support and guidance for all water users.

In conclusion, the catchment level is fundamental to the water resources development planning function (function 2), for the rational exploitation of resources in highly committed catchment (function 4), and for monitoring of natural resources (function 5). In fact, the catchment level is indispensable for each function that deals with catchment resources,. This does not necessarily mean that a new and autonomous authority is required; the aspired functionality may very well be provided by means of communication and negotiation between lower tier entities that make up the catchment. A proposition is presented in section 2.13.5.

2.13.3 CURRENT STATUS OF CATCHMENT BASED WATER MANAGEMENT PROVISIONS IN RWANDA

There are currently no institutional entities in Rwanda that manage water resources or otherwise operate at the catchment level.

This study presents a Catchment Master Plan for each catchment. Each plan presents the renewable surface - and groundwater resources, an estimate of current water use through developed resources, demand projections for 2012, 2020, 2030, and 2040 for the essential water demand categories (in short water supply, industrial and mining water demand, livestock, irrigation, hydropower and environmental requirements) adjusted to the available resources, main issues and prospects and a cost estimate of government investment requirements over the entire planning period. Where transfers from upstream to downstream catchments are required and possible, these transfers have been quantified with the anticipated date that such transfer may be called upon.

As they are based on a reasonably accurate assessment of monthly renewable resources and estimate of future monthly demand for each catchment, these Catchment Master Plan are useful documents that may serve as a first outline of catchment based water resources development plans. However they have been developed within the context of the National Water Resources Master Plan and are not sufficiently detailed on local resources and demand nor did they allow for comprehensive stakeholder involvement.

EWSA has initiated catchment based water supply plans for the Eastern Province[25], the Akanyaru catchment (NAKN), and the upper Nyabarongo catchment (NNYU).

It is commendable that EWSA adopts such catchment based approach, yet the drawback is that they, as per their mandate, focus on potable water supply for urban and rural areas with

[25] this first attempt was associated to the Eastern Province but this administrative domain covers all of the lower Akagera catchment (NAKL) as well as some additional areas in parts of Upper Akagera (NAKU) and Muvumba catchments (NMUV)

some associated industrial demand. EWSA does not necessarily consider other demand categories as there are the major ones irrigation and environment as well as a series of smaller demand categories e.g. hydropower, energy, fisheries, livestock, etc.

Hence, there is need for a comprehensive approach that is outlined in the following paragraph.

2.13.4 PROPOSED APPROACH FOR IMPROVED CATCHMENT PLANNING

The proposed approach for improved catchment planning should combine the results of the catchment master plans with the approach so far implemented by EWSA while extending to all demand categories.

The catchment based approach should comprise an exhaustive identification and assessment of water use and demand areas and required monthly service volume (comprising rural and urban potable water demand with due allowance for future growth, industrial demand with all subcategories (mining, energy, agro industrial, etc.), irrigation demand, fisheries and livestock, environmental demand for normal and reserved areas, etc.). This exhaustive identification should be build on the awareness on current use and demand, on development plans available at sector and district levels (District Development Plans) and on stakeholder involvement (through the sector and district committees). Great care should be taken that the district and sector data are allocated to the proper catchment and not randomly duplicated in the 'wrong' catchment.

These demand investigations should be presented in a GIS database clearly highlighting current primary and commercial use, current demand (current level of services plus non developed primary and commercial use ventures), and future demand projections (future projected level of services and viable commercial water use ventures for which renewable resources are long term available).

The demand investigations should be completed with the identification of supply locations and zoning of adequate least cost services (spring - borehole - gravity pipeline - pumped pipeline - rainwater harvesting - the combination of pico hydropower to carry natural spring water to elevated hills) considering exploitation and investment costs (in this order) for all demand categories. For highly committed catchments or highly committed parts of a catchment, a ranking of priorities between demand categories should be defined. Indicatively, primary use categories - potable water supply, livestock, environment - should be give (partial) priority over commercial use categories. Further ranking of priorities between commercial users can be based on costs and consequences (to the commercial operator, civil society and the environment) of non or partial supply.

The supply zoning exercise should apply GIS software with a reasonably accurate digital terrain model that allows for the automatic identification of areas that can be serviced from a specific source (spring, dam site, reservoirs, etc.). This concept has been applied at a smaller scale for the identification of irrigation command area from reservoir sites for the Feasibility study for the development project for modern large scale agriculture around lake Nasho (2 500 ha). "*Réalisation de l'Etude de faisabilité du Projet de Développement d'une Agriculture Moderne à Grande Echelle autour du lac NASHO dans les Districts de Kirehe et Kayonza (Province de l'Est)" by SHER Ingénieurs Conseils s.a. - February 2011 for Minagri - LWH.*

A catchment planning exercise of this depth cannot be delegated to EWSA as it far exceeds its mandate. RNRA-IWRM seems to be the entity in charge of such investigation which may likely require the services of an experienced consulting engineer.

2.13.5 Proposed transitional structure for catchment based water management provisions and 'lean' government arrangements

On catchment based water management services

From the previous paragraphs it is clear that the functions of water resources development planning, water resources exploitation and water resources monitoring can only be meaningfully implemented when exercised at the catchment level.

As the government of Rwanda operates its development policy and associated financial dealings through the districts, it is counterproductive to create a superimposed institutional layer. However, there is an evident need to provide part of the essential water management services at catchment level.

The aspired IWRM compliant institutional structure proposed in section 2.12 presents two new entities at the catchment level which are the 'Catchment Committees' and the 'Catchment Water Management Offices'.

> The 'catchment committee' was proposed as a representative body of covered[26] district authorities, district technicians involved in matters related to water (water supply, sanitation, health, business development, irrigation, environment, etc.) and representatives of water users (same listing) to debate and formulate a joint opinion on the planned development, implementation and exploitation of the common resource.
>
> The 'catchment water management office' was proposed as a decentralized office of the RNRA-IWRM division operational in each of the nine catchments. Their role is to support the catchment committee as well as district and sector committees on all water related matters with adequate information and technical investigations and opinions on any water issues within the catchment area, to develop a medium to long term catchment master plan in cooperation with the covered districts and with representatives of all water users in the area, to ensure that the water matters of each DDP are coherent and realistic with respect to the catchment master plan and the DDPs of the further districts located in the catchment, to develop a catchment water management plan in cooperation with the covered districts and with representatives of all water users in the area to effectively manage conditions of water scarcity (or excess), to support adequate water resources monitoring in the catchment area and to interpret and signal any irregular results, to support and verify water use monitoring by water users and to interpret and signal any irregular results, to provide support to actual and prospective water users on any water management matters.

Even when government funds would be amply available a full scale implementation if this structure is not realistic for a short or medium term implementation. Considering the complexity of the issues at hand, it is proposed to start a **single pilot in the Muvumba catchment**. The following approach is proposed as a transition mechanism and a learning experience:

[26] Meaning that the district is partly or (exceptionally) almost totally located within (covered by) the catchment area.

- The duties of the catchment water management office for the soon to be highly committed catchment of Muvumba, will be provided by two staff members of the RNRA-IWRM division. Preferably these staff members will be a hydrologist (bachelors or possibly masters) and a business oriented professional (BBA or possibly MBA). These staff members are based in the offices of the RNRA - IWRM but they will frequently visit the Muvumba catchment area notably the districts of Nyagatare (935 km² representing 54% of the district domain and 58 % of the catchment area), of Gicumbi (455 km² represents 56% of the district domain and 28 % of the catchment area) and Gatsibo (152 km² represents 12 % of the district domain and 10 % of the catchment area)[27]. These staff members will be full time available for the provision of government water management services in the Muvumba catchment. When deemed necessary, consultancy support services for the formulation of detailed catchment master plan, catchment water management plan, formulation of water permits in the catchment area, the implementation of resources monitoring stations, or any other provisions, will be provided.
- Sector Committees are implemented in those sectors that are located within the Muvumba catchment area. They collect information and debate issues of water resources planning, development, exploitation and monitoring within their domain. The RNRA - IWRM staff members will support these committees in the identification of participants, information provision, preparation and conduct of their meetings and any other requirements that may come up.
- Three District Committees are implemented (Nyagatare, Gicumbi and Gatsibo) covering the domain within the Muvumba catchment. They collect information and debate issues of water resources planning, development, exploitation and monitoring within their domain. The RNRA - IWRM staff members will support these committees in the identification of participants, information provision, preparation and conduct of their meetings and any other requirements that may come up.
- A single Catchment Committees is implemented for the Muvumba catchment. The RNRA - IWRM staff members will support this committee in the identification of participants, information provision, preparation and conduct of their meetings and any other requirements that may come up. They debate issues of water resources planning, development, exploitation and monitoring within their domain.

As a starting arrangement, the institutional structure proposed in the NWRMP study will thus only be implemented in the catchment of Muvumba exclusive of a decentralized Catchment Water Management Office. The full services of this office will however be provided by two staff members of the RNRA-IWRM with consultancy services in support (for processing of detailed catchment master plan, water management plan, permit investigations, etc.). The full services have been specified under the 'catchment water management office' heading earlier in this paragraph.

It should be expected that such a pilot water management structure will require at least two years to take hold and deliver first results.

When this pilot is successful (adequate water management services are provided by government) in the above proposed format, it can be extended to other catchments. It is

[27] The district of Burera covers 56 km² in the Muvumba catchment which represents 3% of the catchment and 12% of the district. The Rulindo district covers 4 km² in this catchment. For reasons of simplicity, it is suggested that this be ignored for the time being.

suggested that the pilot water management structure be thoroughly evaluated before being extended to other catchments. Such evaluation may likely provide recommendations for adjustments of the institutional structure, level of intervention and the procedures.

Depending on the actual workload of the RNRA-IWRM staff involved in the catchment services and the tasks delegated to consultants, it may be possible that two RNRA-IWRM staff members are in charge of three catchments. If this proofs to be a workable format, the final stage would see six RNRA-IWRM staff members handling decentralized water management services for the total nine catchment in Rwanda. The logical grouping could be:

- central area with Upper Nyabarongo, Mukungwa and Lower Nyabarongo
- western and southern area with Kivu, Rusizi and Akanyaru
- eastern area with upper and lower Akagera and Muvumba catchments

ON LEAN GOVERNMENT STRUCTURE

Further to this practical approach for the introduction of catchment based water management functions at the decentralized level (the districts), there is increased emphasis on **lean and efficient government institutions**. In this light it may be assumed that the institutional structure as depicted in the 2008 water act would probably be leaner these days. A reduction of the proposed institutional structure would be possible along the following lines:

- committees are representative bodies that convene a few times per year to discuss and decide or recommend. There is little benefit in the cancellation of these entities and we suggest that they all be maintained as presented in the general institutional framework of Figure 22. This applies for the Water Interministerial Committee for especially strategy alignment at central level and for the series of Catchment -, District - and Sector Committees that assure stakeholder participation as well as communication and alignment of resources use planning, development and exploitation across the sectors and districts of a catchment.
- if two new permanent structures at central level is considered too costly (Rwanda Water Authority and National Water Consultative Commission), it is suggested that the two be merged to Rwanda Water Authority (an ombudsman function for all matters related to water: planning, development, exploitation including highest instance of conflict resolution) to also provide the specific function of the National Water Consultative commission (approval of national and regional permits).
- it has been stated previously in this paragraph that the Catchment Water Management Offices, do not need to be autonomous offices but can be decentralized antenna's of the RNRA-IWRM under which auspices they are bound to provide water management services and it may proof possible that experienced RNRA-IWRM staff members provide these services for a group of catchments. These 'field' services to water users and decentralized committees are crucially important for information exchange, planning, resources development and exploitation, as well as support for resources monitoring.

In practical terms this means that the existing institutional framework is essentially maintained with improved communication and cooperation on data exchange between government entities and between government and water users.

The RWA would be the only truly new institution, and the RNRA-IWRM provides part of its services at the decentralized catchment level through catchment water management antenna.

There is little prospect for the provision of adequate water management services without resources and use analysis and communication at catchment level and without the convening committees at decentralized level.

2.13.6 COMPLEMENTARY MEASURES

Essential complementary measures are:

- application of the water permit system
- development of a system of accredited consultants for the study of permit applications.

The Water Permit System developed and proposed in this Master Plan has been launched for its nationwide implementation during the 2014 World Water Day. It should be realized that there is a very substantial backlog to process the permits of standing water use.

Indicatively, the number of declaration permits (negligible impact comprising all protected springs, boreholes, gravity water supply systems, etc.) may be of the order of some 50,000 or substantially more. The number of authorizations and concessions (significant impact; larger water supply systems with pumped surface water abstractions, irrigation projects, hydropower, surface dams, pumped groundwater abstractions, etc.) may be of the order of some 1,000 or substantially more (estimate a minimum of 30 per district or 100 per catchment).

Obviously the RNRA-IWRM does not have the manpower to handle such a backlog. It is suggested that consultancy services are provided to close this gap. In line with what has been proposed in this section, it is suggested that this will be done firstly in the Muvumba catchment.

It is also suggested to develop a system of consultant accreditation for the handling of water user permit applications (similar to the accreditation system of REMA for EIA studies). The accreditation should consider the types of permits (surface water direct abstraction, storage permit, groundwater abstraction permit and used water disposal permit) as the hydrological investigations necessary for each permit type are very different (base flow, monthly - annual flow probability, hydro-geology and water quality aspects).

2.14 ROAD MAP FOR THE IMPLEMENTATION OF THE INSTITUTIONAL STRUCTURE FOR IWRM

This section presents a road map for establishing an effective institutional structure for Integrated Water Resources Management. First, the basic issues are identified that follow from the review of the water sector in previous sections of this chapter. Discussions with key stakeholders of these basic issues and the requirements of the Water Law and Water Policy have led to the definition of priorities for the NWRMP. Strategic guidance will be developed for the achievement of these priorities. In accordance with these strategic considerations, near term, medium term and long-term measures are identified.

2.14.1 BASIC ISSUES

Previous sections indicate that progress in water resources management is still insufficient, particularly as it relates to planning and coordinated development, management, and comprehensive monitoring of resources and particularly water use. This lag of progress is related to two interdependent root causes:

Lack of adequate budgets. The overall water resources management tasks have been seriously under-funded for many years. The funding of these tasks will have to increase substantially to enable the responsible organizations to fulfill the responsibilities assigned to them in the Water Law.

Institutional deficiencies. Insufficient staffing (referring to posts being filled, the staff member's experience and adequate training), and insufficient cooperation and data exchange among the various water sector organizations is a major issue that is contributing to performance shortfalls in overall water resources management. The cooperation between RNRA-IWRM and other governmental agencies involved in management (notably RDB, REMA, MeteoRwanda) at central level and district and users at decentralized level, can and should be improved.

2.14.2 ACTION PLAN FOR A WORKABLE INSTITUTIONAL STRUCTURE FOR THE WATER SECTOR

The analysis of the current and required institutional structure in the preceding sections has permitted to identify a number of necessary actions for the improvement of the institutional structure. The actions are ordered for near, medium and long term implementation.

The action plan at near, medium and long term is presented in the table below

table 54: Road map for the improvement of the institutional structure for IWRM.

Priorities	Subject	Near Term (2014 ~)	Medium Term (2015 - 2020)	Long Term (2020 +)
Monitoring of Water Resources	Rainfall	1. Cooperation on data exchange between MeteoRwanda and RNRA-IWRM on rainfall and meteorological data is specified and implemented	Continuation of 1.	Continuation of 1.
	Surface Water	2. Training of RNRA-IWRM officers on the Water MIS	Continuation and extension of 2.	Continuation and extension of 2.
		3. Implementation of the National Water Resources Monitoring Network comprising 8 stations that are equipped with direct data transfer to RNRA and automatic water level and velocity measurement and 5 stations for flood warning on large rivers. (Total of 13 stations)	Continuation of 3.	Continuation of 3.
		4. Implementation of the Hydrometric Network comprising 28 stations on rivers in Rwanda and 12 limnimetric stations on major lakes and wetlands	Continuation of 4.	Continuation of 4.
		5. Implementation of the Impact Monitoring Network comprising 10 stations equipped with piezometers with low	Continuation of 5	Continuation of 5

Priorities	Subject	Near Term (2014 ~)	Medium Term (2015 - 2020)	Long Term (2020 +)
		maintenance cost that are used to investigate emergent issues, impacts and that are shifted after the investigation		
	Groundwater	6. Awareness campaign for major users about IWRM and collaboration with them through Water permit system (especially EWSA) 7. Equip RNRA-IWRM with tools for controlling major users and implement control of major users	Continuation of 7.	Continuation of 7
Strategy	Institutions	8. Establishment of the Water Interministerial Committee (WIC) including secretariat	Operation of WIC	Operation of WIC
	Guidance Documents	9. Prepare second National policy on protection, planning, use and management of water resources for its operation in 2015 -2020.	10. Operate second National policy on protection, planning, use and management of water resources. (start in 2015 -2020) 11. Prepare third National policy on protection, planning, use and management of water resources.	
Planning	Institutions	12. a- Establishment of the National Water Consultative Commission (NWCC) including secretariat or -b- integrate the functionality with RWA or -c- allow for ad hoc solutions for controversial water development works. 13. Establishment of Catchment	Continue as per 12-a, 12-b or 12-c. Operate, evaluate and adjust	Continue as per 12-a, 12-b or 12-c. Consider decentralized CWMO

Priorities	Subject	Near Term (2014 ~)	Medium Term (2015 - 2020)	Long Term (2020 +)
		Water Management functionality for Muvumba catchment within RNRA-IWRM offices preferably in the format of a "one-stop-center" for information, permit application including access to Water MIS	Muvumba Water Management Office functionality and extent on other catchments as needed;	services financed through water permit administration fees, or remain with catchment services at RNRA-IWRM offices
		14. Establishment of Catchment Committees in Muvumba catchment (CC)	Operation of existing CCs and establishment of new CCs as needed	Operation of existing CCs and establishment of new CCs as needed
		15. Establishment of District and Sector Committees in districts in Muvumba catchment (DC and SC)	Operation of existing DCs and SCs and establishment of new ones as needed	Operation of existing DCs and SCs and establishment of new ones as needed
		16. Training of RNRA-IWRM staff on issues of planning and support of CC, DC and SCs.	Continue training of staff as required	Continue training of staff as required
	Planning products	17. National Water Resources Master Plan finalized, published, distributed and available for download through Water MIS.	NWRMP used and updated as required	NWRMP used and updated as required
		18. Indicative Catchment Master Plans improved at catchment level by RNRA-IWRM with full user involvement through CC, DC and SC as well as sector service providers for drinking water supply (EWSA) and the irrigation sector (Minagri - Irrigation Task Force.	Catchment Master Plans used, improved and updated as required	Catchment Master Plans used, improved and updated as required
	Financial Aspects	19. In cooperation with MINECOFIN, MINIRENA undertakes an assessment of the financial aspects of water management	Implement and where needed improve the financial mechanisms	Continue using the financial mechanisms elaborated under 19.

Priorities	Subject	Near Term (2014 ~)	Medium Term (2015 - 2020)	Long Term (2020 +)
		services. This will include the following activities: ○ Financial analysis of the operations of all agencies involved in water management (budgeting, costing, sourcing of funding). ○ Design a financing structure for the operations of all agencies by means of tariffs, licenses, fees and tax- based revenue sources to meet water resource management needs. Development of water should remain affordable and institutions should be paid for their services (management of water, not water).	elaborated under 19.	
Implementation of Resources Development Works	Institutions	20. -a- Establish the Rwanda Water Authority or -b- provide for ad hoc solutions for any conflict and resolution on water resources development issues (civil court staff with special training). 21. Training of all RNRA-IWRM staff (including staff in charge at catchment level) in all aspects of Water Management; Water MIS, Water Permit system, water permit including user's rights and obligations, EIA, etc.. This training may include visits to neighboring countries (Uganda) to adopt successes and avoid pitfalls.	Continue operation of RWA Continue training of staff as required	Continue operation of RWA Continue training of staff as required

Priorities	Subject	Near Term (2014 ~)	Medium Term (2015 - 2020)	Long Term (2020 +)
		22. Training of RDB and REMA staff involved in EIA applications and monitoring, in Water Permit application and monitoring.	Repeat training as needed	Repeat training as needed
		23. Education of CC, DC, SC and all water users on water resources management through sessions with RNRA-IWRM catchment staff and documents available from the Water MIS and other web sources.	Update educational material and continue education of committee members, water users and the general public as required.	Update educational material and continue education of committee members, water users and the general public as required.
		24. Establish a list of accredited consultants for hydrological studies of surface and groundwater abstractions and surface water storage works (similar to the EIA accredited consultants of REMA)	Keep the list of accredited consultants up to date and keep track of the quality of their studies.	Keep the list of accredited consultants up to date and keep track of the quality of their studies.
		25. Implement a nationwide public awareness campaign on all matters related to water management, the role of RNRA-IWRM, the new institutions and their respective roles, the water permit system, the rights and obligations of the general public and registered water users in particular	Repeat public awareness campaign if so required	
	Water Management products	26. Finalize and implement water permits system for i) direct abstraction from surface water, ii) storage of surface water, iii) direct abstraction from groundwater.	Continue using the permit system specified under 26 30. Finalize and implement water permits for iv) used water disposal and v) miscellaneous interventions	Continue using the comprehensive permit system specified under 26 and 30.
		27. Finalize and implement the hydrological viability check on all permits	Finalize and implement the	Continue using the hydrological

Priorities	Subject	Near Term (2014 ~)	Medium Term (2015 - 2020)	Long Term (2020 +)
		at catchment level 1 28. process and implement the hydrological viability check on all permits at catchment level 1	hydrological viability check on all permits at catchment level 3 (or smaller)	viability check at catchment level 3 (or smaller)
		29. Implement the Water MIS for continued resources monitoring and analysis, the registration of water permits, the registration of water use and the analysis and interpretation of water balances per catchment	Continue using the Water MIS for state of the art water management services	Continue using the Water MIS for state of the art water management services
	Environmental Impact Assessment	31. Fine tune the work flow of water permit and EIA assuring that the EIA study and approval are based on the proper intervention volume and capacities, the implementation, operation and closure of the intervention. 32. Fine tune the monitoring of the EIA (by REMA) and the water permit (by RNRA-IWRM, its catchment staff and users) to avoid redundancy and contradictions.		
		33. Update the EIA application process (by RDB (conflict of interest!) or preferably REMA) and finalize the Water permit application procedure (RNRA-IWRM)	Continue using updated EIA application process	Continue using updated EIA application process
		34. Update the EIA compliance monitoring (REMA) and finalize the Water permit monitoring process (RNRA-IWRM)	Continue using updated EIA compliance monitoring	Continue using updated EIA compliance monitoring

Priorities	Subject	Near Term (2014 ~)	Medium Term (2015 - 2020)	Long Term (2020 +)
Exploitation of Resources Development Works	Institutions	35. Training of selected RNRA-IWRM staff (notably staff in catchment planning but not exclusively) in all practical aspects of water resources management under normal and extreme conditions, including professional handling of conflict resolution	Repeat training as required	Repeat training as required
		36. Similar training of RWA (or a civil court) by international experts and legal specialists	Repeat training as required	Repeat training as required
		37. Similar training of CC, DC and SC on aspects of practical water management and conflict resolution.	Repeat training as required	Repeat training as required
		38. Catchment wide public awareness campaign on water management issues	Continue campaign as required	Continue campaign as required
	Handling of water management issues	39. Definition of water management principles for Muvumba catchment under i) normal conditions, ii) conditions of highly committed catchment, and iii) extreme conditions: ○ Prioritization of water uses (primary use versus commercial use, added principles, e.g. character and quantity of losses from non-use, etc.) ○ Handling of the different permit types (direct abstraction, storage, groundwater (or lake)) ○ Environmental protection and ecological water use	Update definitions as required and extend process to other catchments	Update definitions as required and extend process to other catchments

Priorities	Subject	Near Term (2014 ~)	Medium Term (2015 - 2020)	Long Term (2020 +)
		○ temporary suspension of permits ○ water user own information and inspection of actual water use; handling of deliberately false information ○ handling of non permitted interventions ○ handling of other water users' or general public complaints on water use. ○ predefine handling of special conditions (drought, flood) for specified domains areas,		
		40. Implementation of water management principles under i) normal conditions, ii) conditions of highly committed catchment, and iii) extreme conditions by RWU, SC, DC, CC, RNRA-IWRM catchment staff, RWA or civil court; it may be considered to delegate the water management services to a specialized service provider.	Continue implementation and adjust processes if needed only after evaluation of extreme conditions that didn't work out properly.	Continue implementation and adjust processes if needed only after evaluation of extreme conditions that didn't work out properly.
		41. Implement an awareness campaign of the general public on practical issues of water management; water use proxies, do's and don'ts, opportunities, public access to permit data, etc. These campaigns should be 'catchment - wide'.	Replicate, adjust, repeat awareness campaigns on catchments as needed	Replicate, adjust, repeat awareness campaigns on catchments as needed
	Water use monitoring	42. Elaborate water use proxies (energy demand (diesel or cashpower), energy production (hydropower), water level in	RNRA-IWRM or its catchment staff may continue working and improving this important issue.	RNRA-IWRM or its catchment staff may continue working and improving this important issue.

Priorities	Subject	Near Term (2014 ~)	Medium Term (2015 - 2020)	Long Term (2020 +)
		reservoir, actually irrigated area, number of standposts on water supply system, etc. in order to facillitate water use monitoring and the appraisal of monitoring results.		
		43. Define water use reporting obligation very explicitly in the water permit (especially authorization and concession)	Repeat as required.	Repeat as required.
		44. Water users report water use data as per their permit (mostly in case of authorization and concession; declaration is generally free except for operational status).	Replicate, adjust, repeat awareness campaigns on catchments as needed	Replicate, adjust, repeat awareness campaigns on catchments as needed
		45. Registered water use data should be regularly verified (by RNRA-IWRM catchment staff) as being realistic and more or less coherent with permitted quantities. If not, communication with RWU and possible site inspection. Correct use data should be registered, analyzed and interpreted against domain water balance, resources data, etc. in order to: i) improve new permit contracts, ii) update catchment water balances, iii) adjust and refine resources monitoring, iv) update catchment master plans, etc.	Continue water use monitoring exercise including analysis and interpretation of data of improved water management	Continue water use monitoring exercise including analysis and interpretation of data of improved water management
	Permit closure	46. Finalize the process of water permit closure with special emphasis on the restitution of conditions prior to the intervention based on permit specifications and current conditions, implicating EWSA	Update if required	

Priorities	Subject	Near Term (2014 ~)	Medium Term (2015 - 2020)	Long Term (2020 +)
		and RDB. 47. apply the permit closure process including the registration of the permit closure in the Water MIS	Repeat as required.	Repeat as required.

2.15 ROAD MAP FOR THE IMPLEMENTATION OF THE LEGAL STRUCTURE FOR IWRM

The legal structure for the implementation of IWRM is a work in progress. Indeed, the overall concept and the different elements that have been defined are up to date and adequate, yet, inconsistencies have been found and a number of necessary institutions and entities have not yet been identified or identified but not yet defined. Hence, changes, additions and improvements are required. The anticipated result is a leaner but stronger, coherent and consistent legal framework, which puts more emphasis on the use of instruments for implementing the principles set out in the laws.

The suggested changes as required for the final IWRM compliant institutional structure, are presented in the table below. Most of these changes will not be needed when the transitional institutional structure as described in paragraph 2.13 is opted for.

table 55: Road map for improvement and completion of the legal structure for IWRM.

Institution	Law/Article	Suggested change
The Water Interministerial Committee	The Water Law establishes the Water Interministerial Committee at the **article 18**: "*There shall be established in the Prime Minister's office a Water Interministerial Committee composed of ministerial department representatives concerned with water in their domain and whose supervision shall be by a Director in the ministry of water. It shall be consulted on all legislative drafts/Bills regarding planning in the water domain elaborated at the national level, as well as on matters of national, regional or international level.*"	A Prime Minister's order determining the organization, functioning and composition of the National Water Consultative Commission should be enshrined. The Consultant proposes some suggestions for its composition, missions and organization as well as the creation of a Technical Coordination Commission which will coordinate work between institutions
The National Water Consultative Commission	The Water Law establishes the NWCC at the **article 16** : "*There shall be established a National Water Consultative Commission composed of:* *1° Representatives of Government;*	The Consultant suggests its modification as follows: Replace: "*There shall be established a National Water Consultative Commission composed of:* *1° Representatives of Government;*

	2° Representatives of various public and private water users. *The Minister chairs the Commission's meetings. The structure, the functioning and the composition of the commission are fixed by the order of the Prime Minister. The National Water Commission shall be consulted on the following matters:* *1° planning projects in the water domain elaborated to the national level or the big hydrographic basin level and on the revision of these projects;* *2° projects of water supplying, planning, management and transfer of water from basin to basin, with national character as well as in the big projects of the same category of provincial character;* *3° any water related issue, in case the Minister deems it necessary.*	*2° Representatives of various public and private water users.* " By: "*There shall be established a National Water Consultative Commission composed of representatives of decentralized governments and representatives of various public and private water users.*"
	The **Prime Minister's order n°143/03 of 24/05/2013** determining the organization, functioning and composition of the National Water Consultative Commission	The Consultant suggests some modifications of this Prime Minister's orders : Chapter II : Article 3 : Composition of the NWCC : The NWCC shall be composed of representatives of decentralized government and representatives of various public and private water users. Hence, the Commission may comprise members, who represent industry, middle class, farmers, workers, fishermen, consumers, environmental protection associations, water leisure activities, cities and villages, water and sanitation operators. Consequently, the NWCC could be formed by: ➢ a College of decentralized authorities: representatives of districts

		➢ a College of civil society: * socio-economical field * associative field ▪ Environmental issue ▪ Gender issue ▪ Human rights and rights of minorities ▪ Religious entities * operator
Rwanda Water Authority	**Article 17**: Rwanda Water Authority A special Law shall determine powers, responsibilities, organization and the functioning of the National Water authority.	
Catchment level	There is nothing in the Water Law about the Catchment level.	After "The article 19 : boundaries of hydrographic basins", the Consultants proposes the formulation of a new article (article 20) about the Surface Water Catchments division : Article 20 : Surface Water Catchments division : "*Rwanda consists of nine surface water catchments. The delimitation and the denomination of surface water catchments are determined by the law."* The Consultant suggests also a Ministerial Order determining the main characteristics and management visions in the Surface Water Catchments in Rwanda
Catchment Water Management Offices (CMWO)	There is nothing in the Water Law about decentralized entities of the RNRA-IWRM at the Catchment level.	The Consultant proposes the creation of the CMWOs in the Water Law : In the Water Law, after the article (20), article (21) : Article 21: Catchment Water Management Offices

		There shall be established one Catchment Water Management Office (CWMO) per Surface Water Catchment. These CWMO are decentralized entities of the RNRA-IWRM and serve as a link with the population. They are under the supervision of the RNRA-IWRM. Their main functions are to develop and implement catchment master plans, be a link between the RNRA-IWRM, the Catchment Committees and the community served by the Catchment and control the water resources uses. The organization and functioning of the CMWO shall be determined by Ministerial Order. The Consultant suggests the enshrinement of a Ministerial Order determining the organization, functioning and composition of the Catchment Water Management Offices.
Catchment Committees	There is nothing in the Water Law about Catchment Committees.	The Consultant proposes the creation of the Catchment Committees In the Water Law, after the article (21), article (22) : Article 22: Catchment Committees There shall be established one Catchment Committee (CC) per Surface Water Catchment. These CCs are interdistrict committees. They are under the supervision of the Rwanda Water Authority. They are composed of : ➢ A College of representative of district authorities located in the catchment: ➢ A College of civil society at the local sector and some representatives in cross-cutting issues concerning water uses The Committee shall be assisted by an Executive Secretary. The organization and functioning of the committees shall be

		determined by Ministerial Order. The Consultant suggests the enshrinement of a Ministerial Order determining the organization, functioning and composition of the Catchment Committees.
District Committees	The Water Law defines District Committees at the **article 20 and 21**. The Ministerial Order nº005/16.01 of 24/05/2013 determining the organization and functioning of hydrographic basin committees.	The Consultant proposes to modify the Water Law and suppress this ministerial order.
	Article 20: District Committees for hydrographic basins There shall be established a basin district committee composed of: 1° administrations' representatives concerned by water; 2° elected representatives of the local decentralized communities; 3° representatives of the different categories of water users. The Committee may in its work use competent people in the water domain. The basin committee holds meetings in the premises of a district or in any other place indicated by the beneficiary entities. The Committee shall be assisted by an Executive Secretary. The organization and functioning of the committees shall be determined by Ministerial Order.	Article 23 : District Committees There shall be established a district committee at the district level which will participate in the elaboration and apply the catchment master plan in their territory, elaborated at catchment level. It shall be composed of : 1° Representatives of the elected members at the decentralized level: "representatives of committees for hydrographic basins at Sector level" 2°Representatives of the different water users organizations: "representative of National Women Council at District level", "a representative of the National Youth Council at the District level", " two (2) representatives of farmers at District level", "a representative of water user organizations in the field of agriculture at District level", "a representative of water users in domestic activities at the District level", "two (2) representatives of non-government organizations operating in the field of water in the District" and "a representative of the Private Sector at the District level".

		The district committee holds meetings in the premises of a district or in any other place indicated by the beneficiary entities. The Committee shall be assisted by an Executive Secretary. The organization and functioning of the committees shall be determined by Ministerial Order.
	Article 21: The basin committee mission The basin committee shall be charged with: 1° to propose the initial version of the master plan and management of the basin waters as provided for in this Law. 2° to propose the delimitation, if necessary, of under-basins and the designation of the aquifer for which an integrated management of the water resource must be done; 3° to formulate orientations and proposals concerning the planning and management of the waters of under-basins or aquifer; 4° to formulate propositions of arbitration or solution in case of conflict of water uses; 5° to formulate opinions on all technical or financial questions that is submitted to it by the administration. 6° to value the relevance and the feasibility of basin organisms, to prepare their setting up in the event that it would be judged necessary.	The consultant proposes to suppress this article. The district committee should not legally be empowered for producing catchment master plan because it has different territorial boundaries. As the district committee has only an advisory function, it shall participate and apply the catchment master plan in its territory, elaborated at RNRA-IWRM and catchment level.
	The Ministerial Order nº005/16.01 of 24/05/2013 determining the organization and functioning of hydrographic basin committees.	The Consultant suggests a new Ministerial Order determining the organization and functioning of district committees, following the Consultant's propositions
Sector Committees	The Water Law defines Sector Committees at the **article 22 and 23**.	

	The Ministerial Order nº005/16.01 of 24/05/2013 determining the organization and functioning of hydrographic basin committees.	
	Article 22: Basin committee at the sector level There shall be established a committee for the management of a small basin or aquifer at the level of the administrative decentralized authority of the district to which it is connected. Where it is deemed necessary, sub-basin or hydrographic basin committee at the sector level. The structure and functioning of this committee shall be the same as set out for the basin committee at the district level.	The consultant suggests to replace this article by the following text. **Article 22** : Sector Committees There shall be established a committee at the sector level which will participate in the elaboration and apply the catchment master plan in their territory, elaborated at catchment level. The sector committee is composed of local water associations for a public participation at the decentralized scale.
	Article 23: Responsibilities of committees at sector level The Sector committee shall have the following responsibilities: 1° to propose the initial version of the local master plan; 2° to fix management procedures for the under-basin waters or the aquifer, provided for under this Law; 3° to formulate at its level propositions and opinions.	The consultant proposes to modify this article. The sector committee is not legally empowered for producing catchment master plan.
	The Ministerial Order nº005/16.01 of 24/05/2013 determining the organization and functioning of hydrographic basin committees.	The Consultant proposes a Ministerial order determining the organization and functioning of sector committees
Catchment Water Management Plans	**Article 30**: Hydrographic basin master plan and their management In each hydrographic or aquifer correspondent to a hydrographic unit or coherent hydrogeologic, a diagram of waters planning and management fixes the general objectives of water resources integrated management as well	The Consultant proposes to replace these two articles by only one, based on surface water catchment areas and not hydrographic or sub-basin areas : Article 31 : Catchment Water Management Plans

	as the aquatic ecosystems. It shall be established for a five (5) years period by the basin committee in conditions provided for by this Law and is approved by the administrative authority. The arrangements must be compatible with arrangements of the planning national diagram and waters management. Programs and administrative decisions in the water domain must be either compatible or made compatible with diagram arrangements of waters planning and management.	In *each surface catchment*, a diagram of waters planning and management fixes the general objectives of water resources integrated management as well as the aquatic ecosystems. It shall be developed by the Catchment Water Management offices for a *six (6) years period* in conditions provided for by this Law with remarks and comments from the Catchment committees and the National Water Consultative Commission. Its implementation at the decentralized level is done by the district and sector committees. The arrangements must be compatible with arrangements of the planning national diagram and waters management. Programs and administrative decisions in the water domain must be either compatible or made compatible with diagram arrangements of waters planning and management.
	Article 31: Management of sub-basins and aquifer In sub-basins or aquifer correspondent to a hydrographic unit or coherent geological hydrographic, a local diagram of planning and management of waters can be instituted by the committee of sub-basin or aquifer according to the same modes that the diagram of waters planning and management and to specify its objectives. It is approved by the decentralized administrative authority territorially competent.	
Regimes of water use	**Chapter V "Regimes of Water Use" of the Water Law**	The consultant presents some suggestions for modification and completion of this chapter.
	Article 33: Declaration regime Operations submitted to the declaration regime are those operations susceptible not to present any serious dangers for health and public security and not to have impacts limited on the out-flow of waters, on the resource, on the quantitative and qualitative point of view, as well as on the diversity of the aquatic environment.	Article 33 : Declaration regime Interventions submitted to the declaration regime are those interventions susceptible not to present any serious dangers for health and public security and that are unlikely to have a major impact on the natural hydrological cycle or on other water uses. The declaration can be operated without much supervision or control from water management authorities.
	Article 34: Authorisation regime Are submitted to the authorization regime, operations susceptible to present	Article 34 : Authorization regime Are submitted to the authorization regime, interventions that

	dangers for health and the public security, to be harmful to the waters free out-flow, to reduce the water resource, to attack its quality of water or the aquatic environment diversity.	are susceptible to present dangers for health and the public security and to have some significant impact on the natural hydrological cycle or on other water uses. The authorization requires regular supervision and control from water management authorities.
	Article 35: Concession regime The following activities shall be submitted to the concession regime: 1° operations and activities that are susceptible to present serious dangers to health and public security; 2° activities which may highly interfere with the free water flow; 3° activities which may reduce both water quality and quantity; 4° activities which may considerably increase the risk of flooding; 5° activities which may seriously endanger the aquatic life; 6° operations of water use presenting a general interest character or approved by relevant authority.	Article 35 : Concession regime The concession is intended for interventions that are expected to have major impact on the natural hydrogeological cycle and or on other water uses. The concession requires frequent and in depth supervision and control from water management authorities.
Intervention types for water uses	There is nothing in the water law about intervention types	The consultant suggests a new article, at the beginning of the "Chapter VI : Particular Provisions" Article 48 : Interventions types in the natural hydrological cycle There are five different types of interventions in the natural hydrological cycle:

		i) abstraction of surface water from a water course, river or lake ii) retention of surface water in a reservoir for later user iii) abstraction of groundwater from an aquifer iv) release of used water in the natural hydrological cycle v) miscellaneous interventions that do not involve the abstraction of release of water per se but which are likely to have some impact on the natural flow
	Ministerial order n°002/16.01 of 24/05/2013 determining the procedure for declaration, authorization and concession for the utilization of water	The consultant proposes the suppression of this ministerial order in order to replace it by a new one, more precise and complete and based on the proposed Water Permit procedure Ministerial order determining the permit types and procedures for the water permit system.

KNOWLEDGE TRANSFER AND CAPACITY BUILDING

Knowledge transfer and capacity building (task 2_5) are identified as an intermittent task during the exploratory phase (concluded in May 2013) and as a 'continuous' task near the end of the Master Plan preparation phase (concluded in January 2014). In effect, a series of training sessions was organized during the month of November 2013.

The entire study and its productions fall under the heading of knowledge transfer and capacity building. It is factual to mention that especially knowledge transfer is a two way street; RNRA staff may benefit from the knowledge and expertise of the consultants staff but in a similar way, the consultant's staff benefit from complementary experience, knowledge and expertise of the client's staff members.

During the Master Plan study, capacity building is an issue which is mostly directed to the benefit of especially the RNRA-IWRM. Upon completion of the Master Plan study and pending the installation of further entities involved in water management services as identified in the Master Plan study, further training and capacity building efforts will be required. The next two paragraphs will summarize what has been done so far in the field of knowledge transfer and capacity building, and what is still required.

2.16 ACTIVITIES UNDERTAKEN DURING THE STUDY

The mechanisms for knowledge transfer and capacity building that have been implemented during the course of the Master Plan study are:

- delivery of study results (several technical notes and formal reports);
    - inception report
    - technical note on Catchment division
    - technical note on Nyabugogo Flooding (several versions plus presentations)
    - technical note on special program
    - exploratory phase report plus annexes
    - paper on water permit procedure
    - Catchment Master Plan reports (9 pcs, one for each catchment)
    - Water MIS technical specifications and software requirements
    - Water MIS Installation and Deployment Manual
    - Water MIS Resources Balances User Manual
    - Water MIS Geoserver User Manual
    - Water MIS Permit System User Manual
    - Master Plan main report (with annexes)
- workshops with presentation and discussion of study results;
    - inception report workshop (with 6 presentations)

  - first and second progress report workshop (the second workshop was internal to RNRA-IWRM; 8 plus 1 presentations)
  - exploratory phase report workshop (with 6 presentations)
  - master plan report workshop (with 5 presentations)
- cooperation between the consultant and the client during field work. The fieldwork has been concentrated during the exploratory phase; the main fields of investigation are specified below and mostly all field work has been done with client's staff participation:
  - examination of all hydrological stations and reporting
  - discharge measurements at selected hydrological stations and reporting
  - infiltration measurements at selected sites and reporting
  - installation and monitoring of data loggers for flow measurement at selected small catchments
  - installation and monitoring of data loggers for groundwater stages at selected aquifers
  - ground- and surface water sampling at selected locations for purposes of water quality investigations and age-dating of groundwater
- regular meetings took place between the consultant staff (team leader and others) and client staff (DDG and others) when required for monitoring of study progress and alignment of the study with clients expectations
- the preparation of an e-learning platform for matters related to water resources and their use (Hydraccess) has been installed recently;
- dedicated training of consultant staff on specific issues, notably those related to the operation of the different modules of the Water MIS (implemented during the month of November 2013)
  - Water MIS technical specifications
  - water resources module : structure and introduction
  - water resources module : end user overview of functions, administration and user management
  - water resources module: synchronization and importation of data
  - water resources module: other content management (stations, sensors, time series, ...)
  - water balances: structure and introduction
  - permit system: structure and introduction (including training on hydrological viability test)
  - permit system: administration and user management
  - permit system: content management from application up to permit closure
  - Hydraccess: introduction on use and capabilities
  - GeoServer: introduction on use and capabilities

- worksessions and training with RNRA-ICT department staff on hosting and other technical issues including installation and deployment of the different server based modules: Water Resources Module, Water Balances Module, Permit System, Geoserver.

Notwithstanding this dedicated training on the Water MIS for its exploitation and maintenance, it is unlikely that this comprehensive but once - off training will suffice for the smooth implementation and operation of the Water MIS. This requirement is considered in the next paragraph.

2.17 FURTHER KNOWLEDGE TRANSFER AND CAPACITY BUILDING REQUIREMENTS

Upon completion of the study, further knowledge transfer and capacity building will be required for the existing RNRA-IWRM division as well as for new entities and the general public. Without knowledge on staff availability and their capabilities it is not possible to formulate a tailor made training program. We will here suffice with a listing of the likely training and briefing requirements for the different institutional entities involved in the IWRM operations.

- RNRA-IWRM
    - continued support of selected staff members in charge of the operation of the system with the exploitation of the Water MIS including support for the finalization of the Water Permit procedure as suggested by the consultant, data exchange with MeteoRwanda, the development of proxies for estimating water use, and other notions.
    - continued support in data resources preparation, processing and interpretation for the establishment of water resources balances and availability.
    - (independent) support for the installation, operation and exploitation of fully automated hydrometric equipment
    - continued support for the operation of short term hydrometric stations with dataloggers at small catchments, data collection and interpretation
    - continued support for the installation and operation of groundwater stages monitoring stations, data collection and interpretation
    - continued support with the development of the permit procedures per intervention type
    - dedicated consultancy for the formulation of waste water disposal permits (in combination with RURA/REMA and possibly other institutions)
    - training on customer service for all aspects related to water permits, initiation, exploitation and closure
    - training on completeness check of permit applications
    - training on hydrological viability check of permit applications at level 1 catchment
    - dedicated consultancy for the development of hydrological viability check of permit application at level 3 catchment

  - support for the development of dedicated water management procedures at catchment level especially in case of scarcity of resources or excess demand (in cooperation with CWMO staff)
  - dedicated consultancy and research for the development of adequate environmental flow criteria in large and small catchments

- RNRA-ICT
  - continued support with the maintenance of the different software solutions (specifically Drupal, Xataface and GeoServer)
  - support for putting the online Water MIS modules into production environment (deployment of solutions at BSC, after acquisition of adequate hosting package)
  - continued support with the disaster recovery (if needed)

- WIC (Water Interministerial Committee)
  - briefing of WIC members on aim and procedures of the WIC with special emphasis on aspects of synchronization of IWRM strategy development; this may be provided by RNRA-IWRM (secretariat)
  - briefing of WIC members on interministerial procedural alignment (for water permit and EIA applications between IWRM - RDB - REMA), data exchange (rainfall between MeteoRwanda and IWRM) and planning alignment (rainwater harvesting, hydropower with water supply, etc.)

- RWA
  - briefing of RWA staff on aim and procedures of the RWA with special emphasis on aspects of planning documents approval and synchronization between catchments and districts, verification and approval of water resources development and exploitation aspects, highest level of water sector conflict resolution

- NWCC
  - Briefing of NWCC members and employees on aim and procedures of the NWCC with special emphasis on planning and the evaluation of large permits

- CWMO (if decided that these entities will be implemented in at least one or several catchments)
  - comprehensive training on aspects of catchment water resources planning
  - dedicated training on all aspects of water management with major emphasis on
    - planning

        - permit application, operation and closure as per the finally decided procedures
        - aspects of resources development
        - aspects of resources exploitation
        - hands-on water management procedures on normal and extreme hydrological conditions in combination with normal and highly committed natural resources with due consideration of the resources environment and the intervention methods, prioritization between users, etc.
        - aspects of permit exploitation monitoring
    - training of staff in aspects of conflict management and customer service

- CC (if decided that these entities will be implemented in at least one or several catchments)
    - briefing of CC members on aim and procedures of the CC with special emphasis on aspects of synchronization of IWRM water resources planning procedures, resources development and operational water management procedures development; this may be provided by RNRA-CWMO staff

- DC
    - Same as for CC with training provided by RNRA-WMO staff preferably in combined sessions.

- SC
    - Same as for CC and DC with training provided by RNRA-WMO staff preferably in combined sessions.

- general public and water users (including government related water users, EWSA, Districts, etc.)
    - awareness campaign on the aspects of IWRM with specific emphasis on the permit procedure (when finalized IWRM), the notion of a registered water user, the notion of public information on issued water permits, and the nature of the rights and obligations of water users related to the exploitation of their permits.
    - briefing of (new) aspiring water users on the user registration process, the permit application process, the permit intervention types and regimes, the permit holder's rights and obligations according to the permit including the obligation to provide truthful information, public access to permitted interventions, etc.

- RDB and REMA
    - briefing for the alignment of water permit and EIA application and monitoring exercise.

- accredited consultants and consultancy bureaus for permit application handling
    - training and accreditation of selected and qualified service providers for the assessment of surface water abstraction permits and the handling of large scale direct abstraction permits for RWUs (hydrological modeling)
    - training and accreditation of selected and qualified service providers in the assessment of surface water storage permits and the handling of large scale direct abstraction permits for RWUs (hydrological modeling)
    - training and accreditation of selected and qualified service providers in the assessment of groundwater abstraction permits and the handling of large scale direct abstraction permits for RWUs (groundwater modeling)
    - upon development of a full set of procedures for handling of waste water disposal permits, training and accreditation of selected and qualified service providers in the assessment of groundwater abstraction permits and the handling of large scale direct abstraction permits for RWUs (water quality modeling)

3 Cross cutting issues (gender, ICT, environment, sustainable development)

The cross cutting issues as there are the environment, sustainability, capacity building and information technology are very much core to the entire study and these issues are dealt with extensively in the Exploratory Phase Report and this Master Plan Report. A further discussion of these issues is not needed.

For the issue of gender however this is very different because none of the tasks identified for the National Water Resources Master Plan study does address this issue. It is nonetheless very significant especially where it concerns primary water use at the family level, but it stretches effortlessly beyond this level when it involves the 'one cow - one poor family' program (Minagri -RAB), the availability of water for the small vegetable garden within the family 'rugo' with a direct impact on food security, food supply and household income, fair and equitable access to water for commercial (agricultural) water use, and the prevention or at the very least the control of pollution of natural resources.

Hence, where it is evident that women play a crucial role in the 'provision, management and safeguarding of water' (with reference to the 1992 Dublin conference water principles), it looks as if this role is still predominantly played as water user at the household level and the question remains as to how their expertise and demands can be heard when water management decisions at higher echelons are to be taken.

A first suggested step would be to examine existing documentation on the assessment of the role of women in water management at all levels (strategy, planning, implementation, exploitation, monitoring) and for all resources and uses. This examination shouldn't be limited to the role and position of just women (gender in the strictest sense) but should be extended to other specific social groups according to age (children, elders) or other relevant characteristics e.g. occupation, level of education, sensory or physical disabilities, etc.

A logical point of entry would be the Ministry of Gender and Family Promotion (Migeprof) and its operational structures (National Gender Cluster), as well as international organizations (GWP Gender strategy; UN Women) and NGOs active in this field. Where it is quite unlikely that the existing documentation would be exhaustive over the full breadth of the water sector, it is probably worthwhile to complement this documentation study with a study of the access to and involvement in the entire water management sector of gender and further relevant social groups. Such a study could also include a structured assessments of the different group's opinions and needs across the management levels and resources use in which they are involved, the disadvantages (or better still the quantified costs) of the non involvement or inequity of access in the water sector, and a strategic action plan. Pending the results of the investigations, this action plan could comprise for instance:

- a quota system for representatives of social groups for WUAs (if legally possible), for sector -, district - and catchment councils, positive discrimination for equally qualified women for the CWMOs and different water management offices at the national level;
- restrictions on children's chores for water collection during school hours;
- wheel chair access for public water supply and sanitation facilities (at least in urban areas, school grounds, etc.)

- support (financial, technical or otherwise as needed and 'fair') for disadvantaged groups in the development of commercial water related ventures
- awareness campaign on the issue
- etc.

Mainstreaming of the gender issue (as a genteelism for disadvantaged groups) in IWRM requires a dedicated and comprehensive investigation of the relevant groups (the listing above is probably incomplete), their issues and the realization of a tailor-made action plan to address those issues.

4 SUMMARY AND PRINCIPAL CONCLUSIONS AND RECOMMENDATIONS

In essence, this report on the National Water Resources Master Plan of Rwanda contains three core products: i) the Master Plan, ii) the Water MIS, and iii) the institutional and legal road maps. These products may be used to transform the current, at times chaotic and rather ineffective water management procedures which still work out because of very low use levels, towards state of the art integrated water management capability that makes optimum use of available (land and water) resources as a means for development and poverty reduction.

The **Master Plan** is a comparison of the available renewable resources with water demand from primary use (essentially water supply to sustain livelihood and the environment) and from numerous water using commercial ventures in different categories (industrial, mining, fisheries, livestock, irrigation, hydropower, navigation, recreation, etc.). Based on existing population data, growth projections thereof and identified development opportunities, water balances (water resources - water demand equilibriums) for the current situation and for 2020, 2030 and 2040 future dates have been estimated for nine catchments throughout Rwanda (see chapter 1.5 and Figure 1 for details on the nine catchments).

The findings per catchment are as follows:

- the Lake Kivu catchment (CKIV) belongs to the Congo river basin and the catchment area is formed by all land that drains into Lake Kivu. The water balance is expected to remain in surplus beyond the 2040 date. Key issues are: high rainfall, development of potable water supply with a gradual shift from rural to urban demand over the planning period, protection of land and water resources, rainfed agriculture, potential for small hydropower development, limited scope for irrigation development as lake waters are in principle less suitable for irrigation development;
- the Rusizi River catchment (CRUS) belongs to the Congo river basin and the catchment is formed by all land that drains in to the Rusizi River. The river catchment comprises territory in the DRC and Burundi. The water balance is expected to remain in surplus beyond the 2040 date. As most demand is located along the Rubyiro river, the resources of this tributary (CRUS_2) are already extended. Key issues are similar to the ones listed for CKIV. It is suggested to investigate the use of Rusizi river water for rice production in the Bugarama valley.
- the upper Nyabarongo River catchment (NNYU) belongs to the Nile river basin and the catchment is formed by all land draining into the Nyabarongo river upstream of its confluence with the Mukungwa River. The water balance is expected to remain in surplus beyond the 2040 date. Key issues are: high rainfall, significant and stable surface flow, large groundwater reserves, surplus resources for downstream catchments, development of potable water supply shifting from predominantly rural to predominantly urban supply over the planning period, protection of land and water resources, rainfed agriculture production, dam construction, irrigation development, significant small hydropower potential (run of river).
- the Mukungwa River catchment (NMUK) belongs to the Nile river basin and the catchment is formed by all land draining into the Mukungwa River upstream of its confluence with the Nyabarongo River. The water balance is expected to remain in surplus beyond the 2040 planning date. Key issues are: high rainfall, significant and stable surface flow, natural springs, surplus resources for downstream catchments,

development of potable water supply shifting from predominantly rural to predominantly urban supply over the planning period, protection of land and water resources, rainfed agriculture production, significant small hydropower potential (run of river).

- The lower Nyabarongo River catchment (NNYL) belongs to the Nile river basin and the catchment is formed by all land draining into the Nyabarongo river from its confluence with the Mukungwa River down to its confluence with the Akanyaru River. The water balance is expected to remain in equilibrium up to the 2040 planning date by optimizing irrigation development (reduction of high lift command area). Key issues are: medium rainfall, significant and stable surface flow, development of potable water supply in rural and urban areas (Kigali), protection of land and water resources, rainfed agriculture, dam construction for flow regulation and significant irrigation development (marshland, dam, hill side, groundwater), Muhazi Lake management for irrigation and flow regulation, small hydropower.
- The Akanyaru River catchment (NAKN) belongs to the Nile River basin and the catchment is formed by all land draining into the Akanyaru river up till its confluence with the Nyabarongo River which is the starting point of the Akagera River. The river catchment comprises significant territory in Burundi. The catchment resources will soon be stretched but water balance can maintain equilibrium up to 2040 planning date when significantly reducing and optimizing irrigation development. Key issues are: medium rainfall, significant but less stable surface flow in extensive marshland, development of water supply shifting from rural to urban predominance, protection of land and water resources with wetland vulnerability (Akanyaru peat marshland and Cyohoha lakes), rainfed agriculture, essential dam construction for flow regulation and limited irrigation development (marshland, dam, groundwater irrigation), further development of hill side irrigation must be barred, small hydropower development
- The upper Akagera River catchment (NAKU) belongs to the Nile River basin and the catchment is formed by all land draining into the Akagera river from its start at the confluence of the Nyabarongo and Akanyaru rivers up to the Rusumo Falls. The river catchment comprises significant territory in Burundi and Tanzania. In order to maintain equilibrium, the water balance requires a transfer of dry season water resources from upstream catchments (NNYU and NMUK) by 2040. Key issues are: medium rainfall, significant surface flow from upstream and lateral catchments in extensive marshlands and lakes, high evaporation losses from marshland and lakes, protection of land and water resources, development of water supply for rural and urban areas (Kigali), rainfed agriculture, optimized irrigation development (marshland and dam irrigation), hill side irrigation restricted to lower lift command area (<50 m).
- The lower Akagera River catchment (NAKL) belongs to the Nile River basin and the catchment is formed by all land draining into the Akagera river downstream of Rusumo Falls up to the confluence with the Muvumba River. The river catchment comprises territory in Tanzania. In order to maintain equilibrium, the water balance requires a transfer of dry season water resources from upstream catchments (NNYU and NMUK) by 2040. Key issues are: low rainfall, significant but non perennial surface flow in tributaries, significant evaporation losses from marshland and lakes, significant and accessible groundwater resources, protection of land and water resources with partly poor soils, demand of predominantly rural water supply,

national wildlife park, livestock water demand, irrigation development optimized for marshland- dam and groundwater irrigation, hill side irrigation restricted to lower lift command area (<50 m).

- The Muvumba River catchment (NMUV) belongs to the Nile River basin and the catchment is formed by all land draining into this river and its tributary the Mulindi. The catchment is transboundary with Uganda and flow patterns are complicated. The catchment's resources are currently stretched and a transfer from upstream catchments is not practically possible. In order to maintain long term water balance equilibrium there is need for significant dam development and optimization / restriction of irrigation development. Key issues are: low rainfall, significant but less stable surface flow, protection of land and water resources with partly poor soils, demand of predominantly rural water supply, livestock water demand, irrigation development optimized for marshland and dam irrigation, further development of hill side irrigation should be banned

In addition to the key issues identified for each particular catchment, a number of nationwide development opportunities are proposed as follows:

- the substantial shift from rural to urban water supply is expected to center around the current major urban centers (a list of 17) plus a number of emerging urban centers; EWSA should consider these centers as such and extend its list of urban centers to comprise at least part of the 118 identified emerging urban centers
- rainwater harvesting in high density urban centers may help solve a number of issues; research for viable technical solutions is recommended
- rainwater harvesting for livestock water is a tested approach in some high rainfall areas and may likely proof profitable in lower rainfall areas; it is recommended to optimize and promote this approach
- the development of pico hydropower (which is difficult to profitably develop for communal purposes) for high lift of protected natural springs may proof a viable technical solution for water supply in areas that are difficult to service by means of gravity water supply systems. This is recommended for inclusion in water supply master planning at catchment level.

For the planning period up to 2020, the government related investment costs associated with the Master plan vary according to the scenario from 2.3 to 2.6 trillion RWF (~ 2.5 to 3 billion euro) with most of the investment required for rural water supply and the irrigation sector and slightly over 10% each for urban water supply and other investments.

Slightly increased investment amounts (+ 5 to 10% according to the demand scenario) are required for the planning period from 2020 to 2030, with a significant increase of the investment for urban water supply and sanitation against a reduction of the investment for rural water supply. The investment in the irrigation sector increases to about 50% of overall investment.

The final planning period sees a substantial increase in investment (up to 4.1, 5 or 5,6 trillion RWF according to the growth scenario) which is related to reinvestment for expired water supply facilities after 10 to 30 years. Investment for urban water supply further increases to about a third of the overall investment.

Contrary to the Master Plan study which is a static planning tool that may eventually be updated, the **Water MIS** is a dynamic water resources management tool which is conceived for the collection, analysis and interpretation of water related data with the aim to facilitate appropriate water management decisions. The idea is that new data are continuously fed into the system, analyzed and interpreted with the result that the water management decisions are made on the basis of up to date data.

The Water MIS consists of three modules as follows:

- the water resources module; this module can store water resources data time series on rainfall, surface flow stages quantity and quality, groundwater stages and quality, evaporation data, etc. The data in this module are analyzed and interpreted to be used for water balances. A first set of such interpreted data has been prepared through the current Master Plan study. With additional resources data (longer time series, higher spatial resolution, new parameters) the interpretation of water resources data can improve and the interpreted data adjusted;
- the water use and demand module; this module holds interpreted and projected demand data for current and future times as has been prepared in the current Master Plan study. A further very important part of this module is the Permit system. It facilitates the water permit application process, it allows to register the essential information of a water permit (user, description of resource domain, permitted intervention from abstraction through to restitution), and to register the actual intervention quantities and capacities realized.
- the balances module: this module holds the creation of water balances at the catchment level between interpreted resources data and processed and interpreted demand data for current or future dates. A further option is the balance between interpreted resources data and water use according to issued permits or between resources data and water use data declared by the water users.

The system is accessible through the web for data feeding by water management staff or registered water users (RWU).

The Water MIS is a pilot system and is still relatively limited; it is only handling data at a spatial resolution of the level 1 catchment (nine units each about 1,500 to 3,000 km^2), it is not (and it will not be) an alert system, the permit application process handles only part of the suggested permit types (direct abstraction from surface waters, surface water storage, and groundwater abstractions), and most of the system is 'manual'. However, it consists of modules and is therefore easily updateable and it allows for very easy data exchange between water managers and water users.

The successful operation of the Water MIS depends on a number of factors that need to be addressed:

- in the sphere of personnel and users, there is need for:
  - further support of RNRA-IWRM staff including ICT department
  - installation and support of decentralized RNRA-IWRM staff
  - support of water users in the use of the system
- in the sphere of data and data processing, there is need for:
  - data exchange between government entities (MeteoRwanda, and other with RNRA-IWRM

- restore hydrological stations basic data, discharge measurements, rating curves water quality data, groundwater data, small catchment data
- make the permit system operational for three intervention types and start registering water users
- provide additional training in data handling, analysis and interpretation

Further facilities are needed in the spheres of software and hardware (Microsoft Office licenses for Access database system, decentralized access to the Internet, final installation of the system with dedicated RNRA/ICT server, web hosting package, backup solutions, network access by IWRM, etc.)

The third essential product is the **institutional and legal road map**. Rwanda has made a definite choice for the implementation of integrated water resources management for the sustainable development and protection of its water resources. The 2008 Water Act is entirely geared toward that approach defining a mostly adequate institutional structure for the essential functions water Management functions (the institutional structure is schematically depicted in Figure 22: water management framework in Rwanda):

- water resources management strategy definition; the newly proposed Water Inter-ministerial Committee is a not yet operational platform for synchronizing the different strategies of the many ministries involved in water. The current status of strategy definition between government entities is mostly adequate and coherent
- water resources planning; this function has been identified as weak due to mostly lacking vertical (central to decentralized) and horizontal (between water use sectors) coordination. The water act has identified Minirena with the RNRA-IWRM department as the pivotal entity for the development of planning products (for instance NWRMP). For major projects the National Water Consultative Commission is identified as a platform for review and discussion thus providing essential horizontal coordination. For the mobilization of the decentralized knowledge, district and sector committees are foreseen. A major problem with this scheme is that the district and catchment domains do not in the least align with the result that planning at district level is a void exercise because of the lack of awareness on available resources and he inability to optimize scarce resources allocation. For this to be corrected it is absolutely essential that an additional coordination layer at catchment level be created. The consultant recommends on the one hand the representative body the Catchment Committee (one for each catchment) where District and Sector Committees can synchronize their planning aspirations, with on the other hand the Catchment Water Management Office (one for each catchment) under the auspices of the RNRA-IWRM that can provide professional support. The Rwanda Water Authority is identified in the Water Act and can supervise and coordinate the planning products at the catchment level
- Water resources development: due to the weakness of the planning function, the development function is affected. The core of the solution is the implementation of a permit system under control of the RNRA-IWRM. A permit system is an essential tool for monitoring of water use which can be delegated to the multitude of water users with the prerequisite that the RNRA-IWRM is capable of collecting, verifying and interpreting the data. In order to realize this feat, it is essential that the RNRA-

IWRM delegates staff in the catchments to assist and guide aspiring and established water users; a further reason to install the Catchment Water Management Offices.

- Water resources exploitation: the actual interventions of water users in the natural hydrological cycle is currently largely unknown which makes water resources management virtually impossible. The pillars for changing this are as follows:
    - successful implementation of the permit system between the professionals of the RNRA-IWRM (including their staff on the ground at the nine CWMOs) and the registered water users
    - definition of operational water management principles considering resources and use variations (normal and extreme hydrology and normal and high commitment of resources), prioritization of water uses between primary and commercial use, different intervention and permit types, environment as a water user, etc.
    - implementation of the operational water management principles under guidance of the CWMO staff and with supervision of RWA
    - handling of conflicts at different levels (user, district, catchment, national) implicating different mediators (users themselves, district government, CWMO, RWA)

The responsibilities and functions of the different entities have been reviewed and where needed strengthened. Along the way there will be need for training and education whether it is professional permanent staff (CWMO, RWA, NWCC, RNRA-IWRM), elected and/or non permanent committee members (SC, DC, CC, etc.) or whether it is the general public. A substantial public awareness campaign on all matters relating to the water sector reform is mandatory.

A transitional institutional structure combining catchment water resources assessment with district domain authority has also been proposed which can be implemented immediately in highly committed catchments (Muvumba).

The legal road map reviews the existing legal instruments and lists a number of suggestions to modify the current boundaries of existing and newly proposed institutional entities.

The study completes with a brief review in chapter 0 of the current status of **knowledge transfer and capacity building** and the proposition of further requirements in that field for all essential operators involved in IWRM, followed by a brief discussion on **cross cutting issues** in chapter 3 with the main emphasis on the mainstreaming of the gender issue in IWRM where it is noted that gender is a substitute for disadvantaged groups.