RWANDA WATER RESOURCES BOARD (RWB)
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ANNUAL WATER STORAGE STATUS REPORT FOR 2022-2023

Rwanda Water Storage Status, August 2023

I. INTRODUCTION

Water storage refers to holding water in a contained area for a period of time. Water storage can be natural or artificial. Natural water storage occurs in all parts of the hydrologic cycle in which water is stored in the atmosphere, on the surface of the Earth, and below ground. Artificial water storage is done for a variety of reasons and is done on small and large scales. Water storage locations are commonly referred to as reservoirs.

Surface water storages include natural and artificial reservoirs, lakes, ponds and lagoons, also the bodies of water held behind weirs and dams.

Artificial water storage has, and will continue to have, a large role to play in both emerging and mature economies. The ability to store and manage water is pivotal to meet demand for different uses. Controlling water flows to deliver the preferred amount of water at the right time is essential in order to support efficient food and energy production and contribute to the flood control.

Rwanda has a relatively high average annual rainfall of 1,200 mm, making rain water harvesting (storage) an attractive alternative source of water to meet increasing demands for human needs, socio-economic development as well as environmental protection. Despite this, Rwanda is considered a water scarce nation due to limited storage capacity.

Over the past years, Rwanda has suffered of severe water shortages in different catchments, even though large amounts of water continue to annually flood out to sea from the country. The problem is that the sporadic, spatial and temporal distribution of precipitation rarely coincides with demand. Whether the demand is for natural processes or human needs, the only way water supply can match demand is through storage. The main water storage system being applied in Rwanda is the construction of dam which is defined as a barrier built across a watercourse for impounding water.

Natural variability in rainfall and temperature mean that in many places access to freshwater is already unpredictable. For many smallholder farmers, reliable access to water is the difference between plenty and famine. The classic response is to store water behind dams or in tanks or ponds when it is abundant and where it can be conserved for times of shortage. Water storage spurs economic growth and helps alleviate poverty by making water available when and where it is needed.

This report presents the Annual Water Storage Status of Rwanda for 2022-2023. The report describes all national surface water storages which include: Natural and Artificial water storages. Furthermore, the report indicates water storage projects in pipeline.

1.1 Need for Water Storage in Rwanda

Even though Rwanda has abundant water, but has insufficient water storage capacity. Inadequate storage leaves farmers vulnerable to the vagaries of climate. Rwandan farmers are heavily reliant on rain fed subsistence agriculture. The lack of storage infrastructure means farmers have limited ability to cope with droughts and floods. These limitations are estimated to cost the economy one-third of its growth potential. Investment in appropriate Water storage is an urgent option to increase agricultural productivity and to ensure that farmers have options for coping to the coming climate changes.

Water storages are designed and/or operated to provide services like electricity generation, water supply, flood and drought management, irrigation, fisheries, environmental services and recreational activities, etc. While these objectives (renewable and power services, water quantity management, ecosystem services, economic growth and local livelihoods) can conflict at times, they are also often complementary.

1.2 Advantages of water storage

Water is one of the most important things humans need for survival. Water storage is essential for meeting all of the domestic, agricultural, hydropower, industrial and other demands.

Advantages of water storages are summarized in the diagram below:

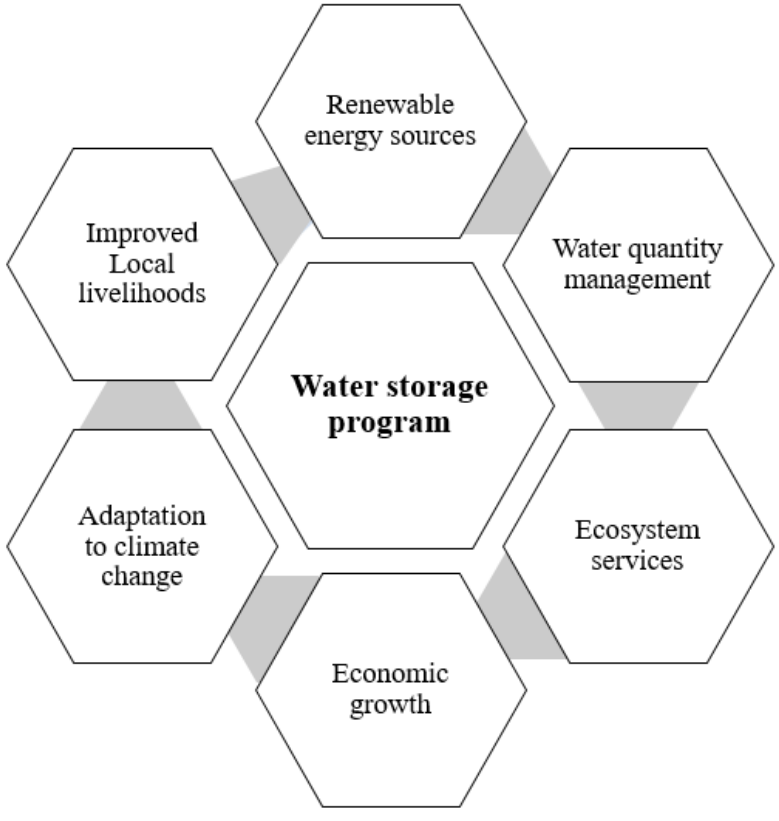

Figure 1: Diagram illustrating Water storage program and its importance

II. NATURAL WATER STORAGE

Each stage of the hydrologic cycle involves the storage of water. Water can be stored in the atmosphere, on the surface of the Earth, or underground. These water storage areas are most commonly known as reservoirs. Natural reservoirs include oceans, glaciers and ice sheets, groundwater, lakes, soil moisture, wetlands, living organisms, the atmosphere, and rivers.

Rwanda is situated in the region of Great Lakes and has many lakes bordering it. In total, Rwanda has nearly 40 lakes with an estimated storage capacity of 225.165 billion m^3. The major lakes of Rwanda include Kivu, Burera, Ruhondo, Muhazi, Rweru, Cyohoha,Sake, Kilimbi, Mirayi, Rumira, Kidogo, Mugesera, Nasho, Mpanga, Ihema, Mihindi, Rwampanga and Cyambwe.

Key information of major lakes in Rwanda are found in Annex 3 and their map is found on next page.

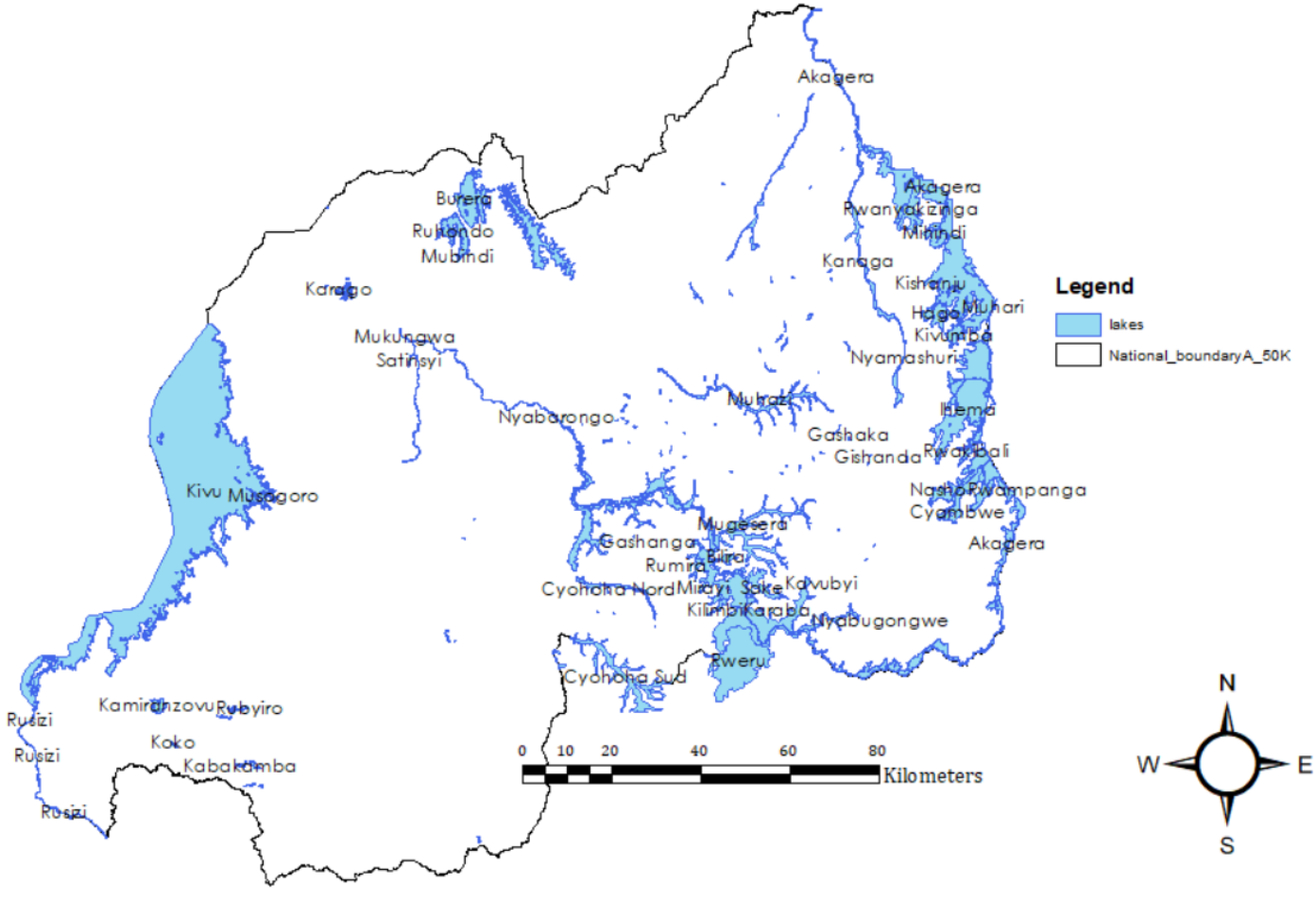

Figure 2: Major lakes of Rwanda

III. ARTIFICIAL WATER STORAGE

Man-made reservoirs, sometimes called artificial lakes, are important water sources in many countries around the world. In contrast to natural processes of lake formation, reservoirs are artificial, usually formed by constructing a dam across a river or by diverting a part of the river flow and storing the water in a reservoir. Upon completion of the dam, the river pools behind the dam and fills the artificially created basin. The stored water can be used for irrigation, drinking water after purification or to produce energy.

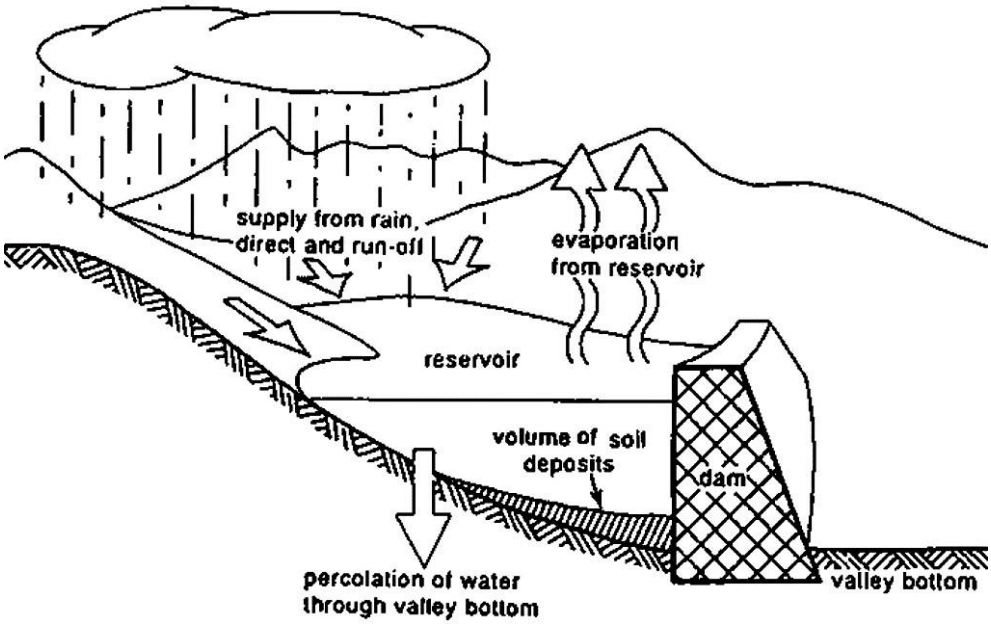

Figure 3: On-stream storage reservoir formed by a dam across a valley and its water cycle

In Rwanda, three main types of artificial storages are considered. These storages are:

a) Water ponds
b) Valley dams
c) Dams

Water ponds storages are mainly used for small scale irrigation, Valley dams for livestock watering and dams are used for Irrigation, hydropower generation and domestic water supply.

3.1 Water ponds

Irrigation is leading in consumptive water use in Rwanda, followed by domestic water use, and mining, industries, fish ponds and coffee washing stations. This is according to the report updating "Water Users and Uses Assessment in Rwanda".

Water shortage is one of major challenges faced by small farmers (mainly vegetable growers/ Horticulture Production) especially in the drought prone areas i.e Eastern province and Southern province (Amayaga region) of Rwanda. One of the few options for them is rainfall, but much of the water runs-off from its steep hills owing to the area's mountainous landscape.
As a result, farmers do not have enough water to irrigate their fields, above all, when rainfalls are limited, or during the dry seasons.

One of the solution is collecting storm water in the ponds before it reaches the fields and apply that water to fields (irrigation) by gravity or through solar-powered pumps. The system provides a constant source of water that is evenly distributed to all the fields, including those that are difficult to reach due to the hilly terrains.
The water ponds adopted in Rwanda are underground ponds with storage capacity in the range of 120 - 480 m^3 usually lined with black plastic dam sheet, to limit the loss through seepage. The water ponds are used mainly for small scale irrigation.

The following figure shows the typical water pond constructed for serving the small-scale irrigation.

Figure 4: Typical Water ponds found in Rwanda (lined with plastic sheeting)

Table 1: Storage capacity of water ponds in different district of Rwanda

No	District	Number of ponds of 120 m^3	Volume (m^3)	Number of pond of 250m^3	Volume (m^3)	Number of ponds of 480 m^3	Volume (m^3)	Total ponds	Total storage for ponds
1	Bugesera	183	21,960		7		15	183	21,982
2	Gakenke	8	960		0		0	8	960
3	Gasabo	27	3,240		0		0	27	3,240
4	Gatsibo	69	8,280		0		0	69	8,280
5	Gicumbi	17	2,040		0		0	17	2,040
6	Gisagara	17	2,040		0	14	6720	31	8,760
7	Huye	25	3,000		0	1	480	26	3,480
8	Kamonyi	12	1,440		0		0	12	1,440
9	Karongi	6	720		0		0	6	720
10	Kayonza	39	4,680		0	1	480	40	5,160
11	Kirehe	86	10,320	72	18000	14	6720	172	35,040
12	Muhanga	1	120		0		0	1	120
13	Ngoma	15	1,800		0		0	15	1,800
14	Ngororero	11	1,320		0		0	11	1,320
15	Nyamagabe	9	1,080		0		0	9	1,080

16	Nyanza	61	7,320		0	10	4800	71	12,120
17	Nyarugenge	1	120		0		0	1	120
18	Ruhango	50	6,000		0	10	4800	60	10,800
19	Rulindo	20	2,400		0		0	20	2,400
20	Rutsiro	1	120		0		0	1	120
21	Rwamagana	33	3,960					33	3,960
Total 1		**691**	**82,920**		**18007**	**50**	**24015**	**813**	**124,942**

3.2 Valley dams

Livestock plays an important economic and socio-cultural role among communities in Rwanda. Despite having undergone many changes including large scale losses and epidemics, livestock farming still contributes significantly to Rwanda's GDP.

According to the census of Nyagatare District of 2013 and the District Potentialities Assessment, the total number of households keeping cattle in five surveyed sectors (Nyagatare,
Karangazi, Rwimiyaga, Matimba and Rukomo) was 2,490 with a total cattle population of 198,613 (average stocking rate of 1.7 head/ha).

Valley dams are used for livestock water consumption and most of them are located in the eastern part of the country. They are constructed in the valley for collecting runoff. Today the improvement is being done on the reservoir area by lining it with clay to minimize the loss of water through seepage and hence taking the name of valley tanks.

Valley dams have been introduced in Eastern Zone of Rwanda to face water scarcity challenges for a significant number of cattle located in the drier Districts of Eastern Province namely Nyagatare, Gatsibo and Kayonza. The valley dams are mostly used for livestock watering. However, during dry seasons, some of them get dry and can't serve the purpose of storing water for livestock. This calls for rehabilitation and training of users for proper maintenance.

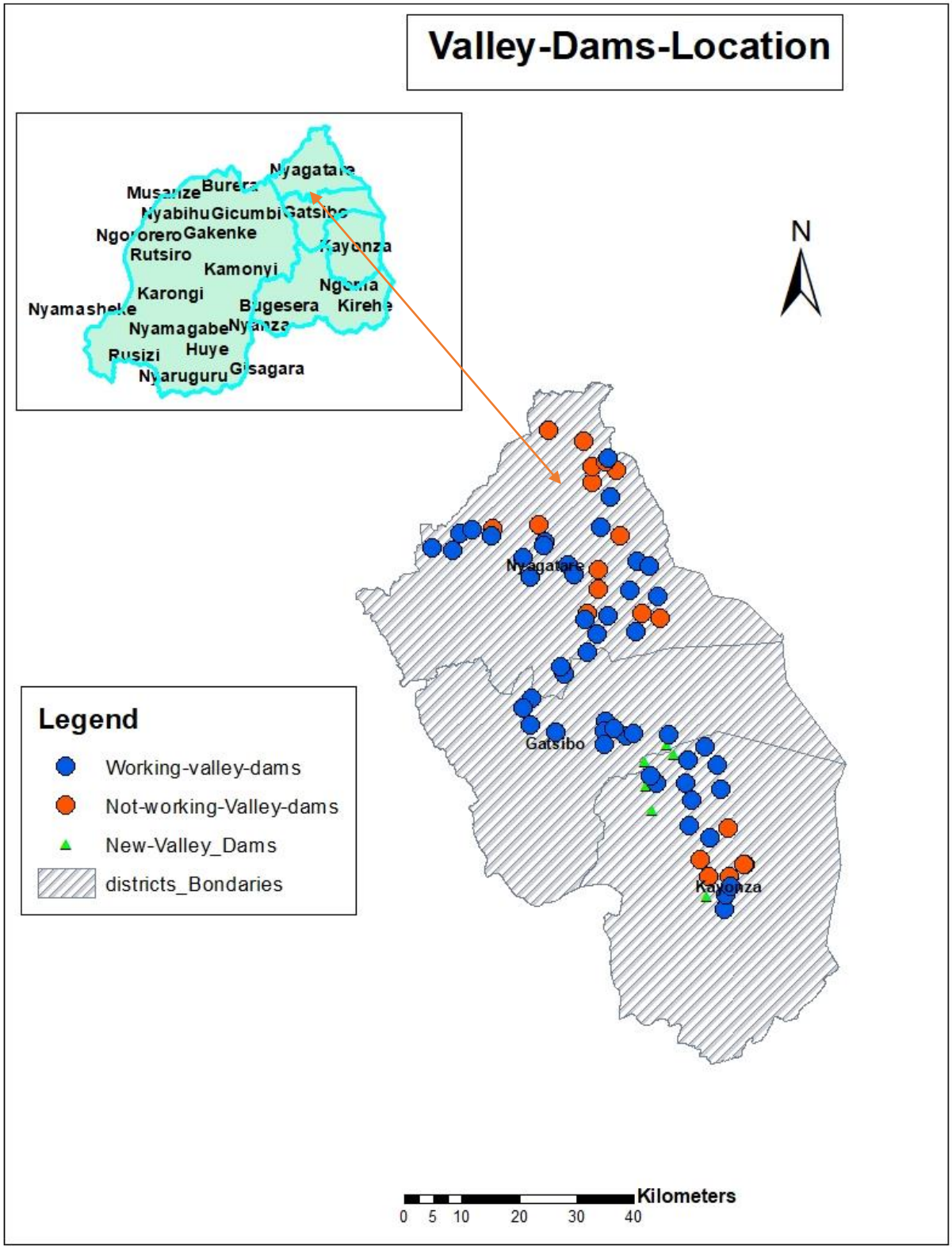

Figure 5: Map showing the location of different valley dams

A big number of valley dams is observed in Nyagatare District with 42 valley dams, followed by Kayonza with 28 valley dams while the low number is observed in Gatsibo with 12 valley dams. This may be driven by the need for livestock watering in Nyagatare where the big number of livestock is observed and the climate is much hot in Nyagatare and Kayonza Districts compared to Gatsibo District. Annex 2 provides more details regarding estimated volumes and location of existing valley dams.

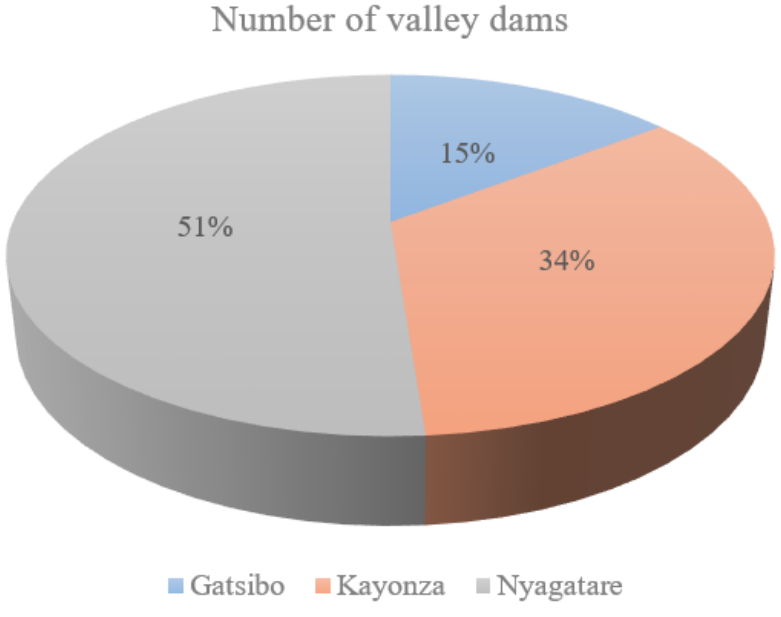

Figure 6: Distribution of valley dams per District

Out of 77 valley dams found in Rwanda, 20 of them are not operating i.e., are dry while 49 remaining are still operating, and the coordinates of the remaining 8 were not found. However, some of the operating ones need quick maintenance. In general, all valley dams in Gatsibo district are operating whereas Nyagatare district has the highest number of dried dams.

Generally main problems faced by existing valley dams include:

- Lack of regular maintenance and poor management
- Invasion of Papyrus and water Hyacinth
- Overtopping
- Destruction caused by cattle
- Unknown boundary of valley dams' area

Figure 7: Gikobwa Valley dam located in Gatsibo district (left) and a dry valley dam in Nyagatare (right)

3.3 Dams

Dams are barriers (structures) constructed to impound (store) water for various purposes. Usually dams are commonly used for flood control, human water supply, irrigation, livestock water supply, energy generation, containment of mine tailings, recreation, or pollution control. Many dams fulfill a combination of the above functions. In Rwanda, the majority of dams are for irrigation and most of them are earth dams.

3.3.1. Distribution of Dams per uses

Among 50 dams identified in Rwanda only 2 are used for hydropower (Nyabarongo 1 HP/concrete gravity dam and Rukarara dam), 2 are used for water supply (Kadahokwa and AIDR dams), 1 is used for irrigation and water supply (Rugeramigozi 1 dam). 45 remaining dams are for irrigation water supply either for marshland and hillside irrigation.

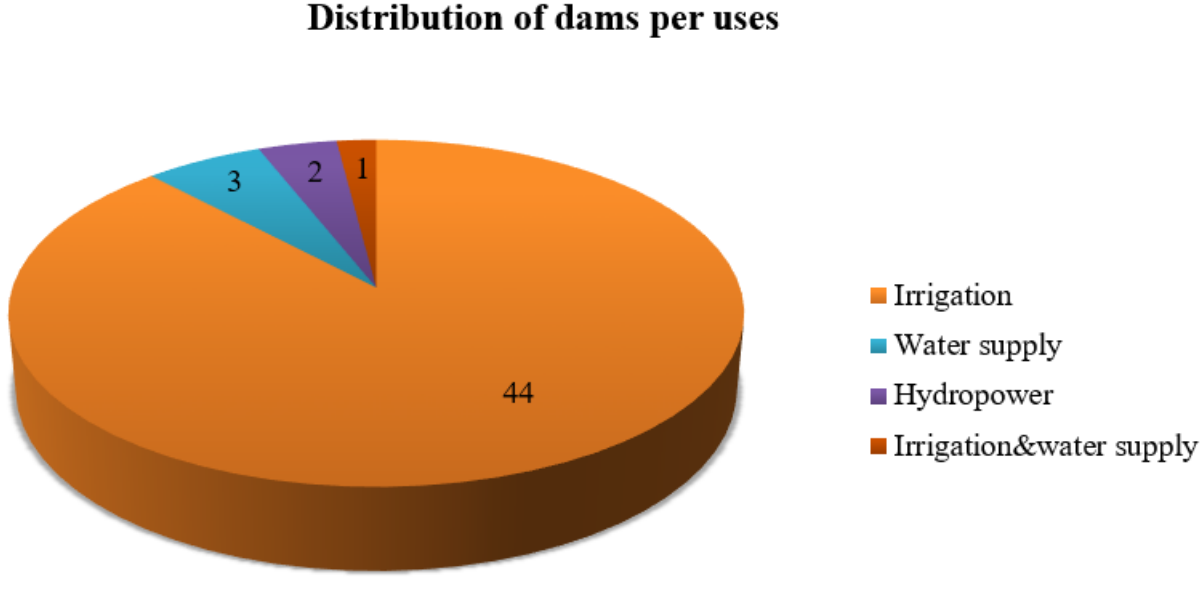

Figure 8: Distribution of Dams per uses

3.3.2. Distribution of dams per district

More than the half of all existing dams in Rwanda are located in the districts of Eastern province. This might be linked to prolonged droughts that usually hit this province. In that province and in the whole country, Kayonza has 7 dams in total; the highest number of dams compared to other districts. All 28 dams found in the districts of Eastern province are used for agricultural water supply (Irrigation). The districts of southern province follow with 18 dams in total.

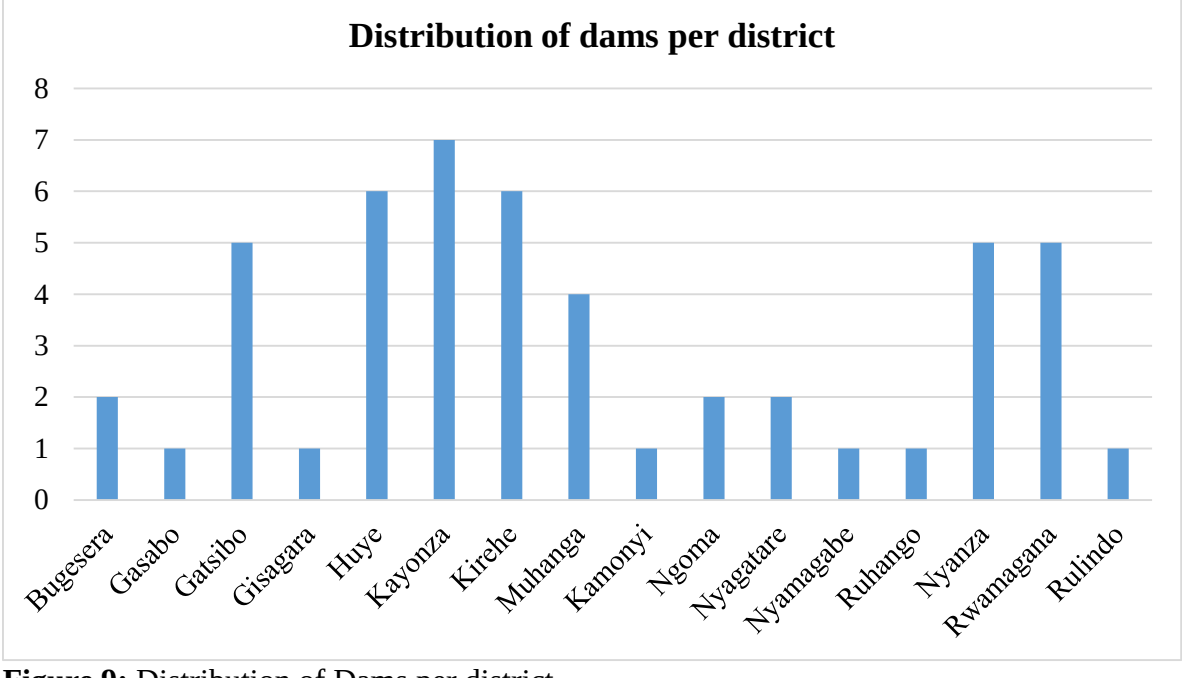

Figure 9: Distribution of Dams per district

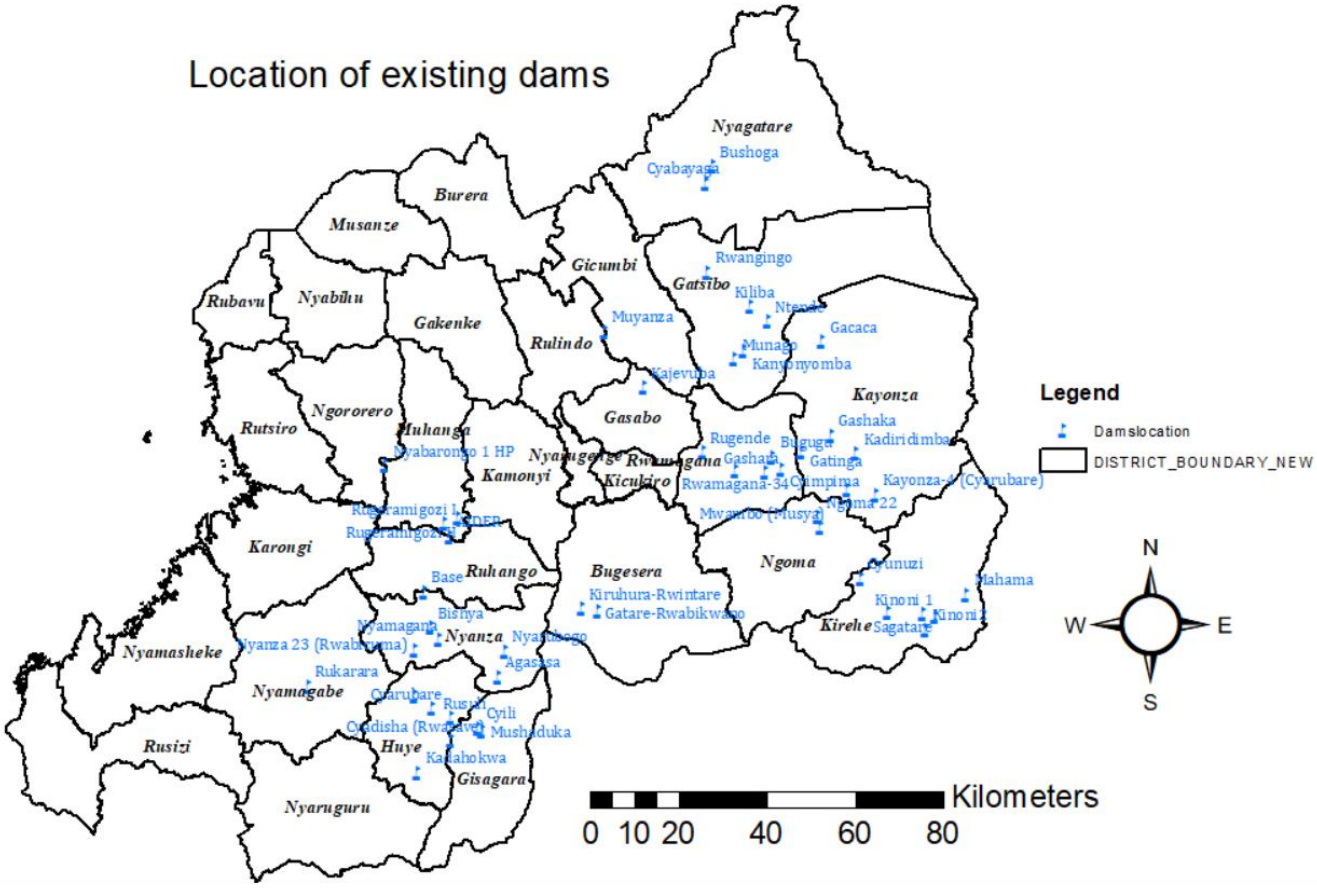

Figure 10: Map showing the location of existing dams in Rwanda

3.3.3. Storage Capacity (m^3) of existing dams

The diagram below shows the storage capacity of existing dams. Nyabarongo Concrete dam (Nyabarongo HPP) has the highest storage capacity with 35MCM followed by Rwinkwavu and Rwangingo dams which have estimated capacities of 4.2 MCM and 3.75 MCM respectively.

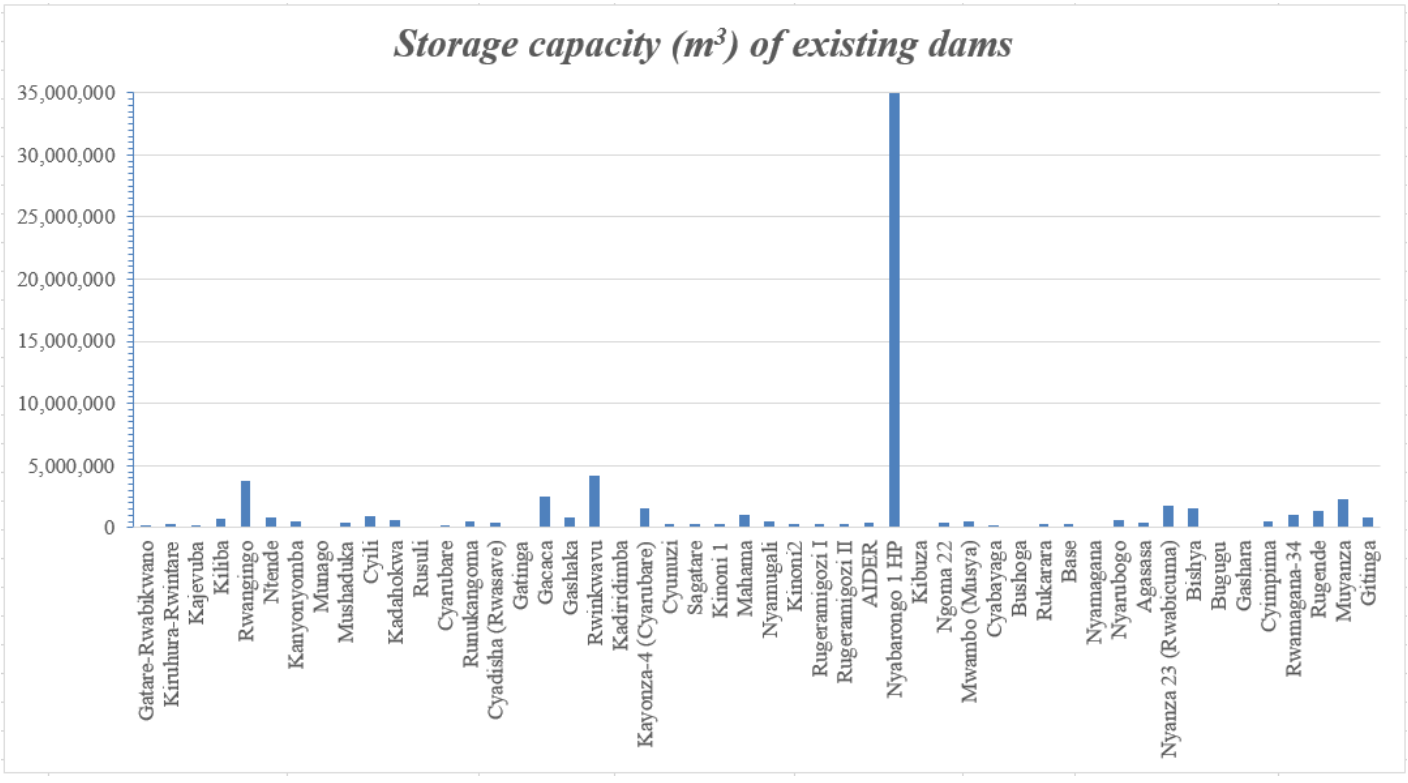

Figure 11: Storage Capacity of existing dams

Figure 12: View of Rwinkwavu embankment dam

Figure 13: View of Gashara embankment dam and its spillway structure

Annex 1 provides more details regarding estimated volumes and location of existing dams.

IV. WATER STORAGE PROJECTS IN PIPELINE

This section covers dam projects in pipeline; meaning dam projects being developed and their implementation (construction) will happen in the future or has started but not yet completed. It includes dam projects for domestic water supply (under WASAC), Multipurpose dam projects such as Muvumba dam (under RWB), dam projects for irrigation water supply (under RAB), dams for hydropower generation (under REG/EDCL) and transboundary dam projects.

4.1 Nyabarongo II HPP

The Nyabarongo II Multipurpose Dam, is a multipurpose dam under construction across the Nyabarongo River in Rwanda. This dam is located at -1.861525^{o} and 29.892083^{o}, in the boundaries between Northern province and Southern province of Rwanda (between Kamonyi and Gakenke districts).

The dam will measure 59 metres high and 363 metres long, creating a reservoir with storage capacity of 803,000,000 cubic meters. The reservoir is also expected to provide irrigation water to an estimated 20,000 hectares of land, downstream of the dam site. In addition, the dam will host Nyabarongo II Hydroelectric Power Station, with installed generating capacity of 43.5 megawatts (3 turbines with 14.5 MW each).

The dam has a crest elevation of 1,414 m with a crest width of 8.00m. The upstream dam slope ratio is 1:2.0, the downstream dam slope ratio is 1:1.8. In order to enhance the stability of the upstream and downstream dam slopes, a stabilizing fill is set at the upstream dam toe, with theberm elevation of 1380.00m; a spoil area is set between the upstream cofferdam and the stabilizing fill, with a platform top elevation of 1,372.00m; and a stabilizing fill is also set at the downstream dam toe, with the berm elevation of 1,382.50m.

The dam site is about 20.5 km away from Kigali City and has a catchment area of 6500 km^2. The average annual discharge (flow of Nyabarongo river) at the dam site is 80.7 m^3/s. The dam reservoir is stretching over a distance of 67km long between 5 districts: Gakenke, Kamonyi, Muhanga, Ngororero and Nyabihu.

Figure 14: Nyabarongo II Multipurpose Dam artistic impression (Final dam outlook)

4.2 Muvumba Multipurpose Dam

The Government of Rwanda has received financing from the African Development Bank for Muvumba Multipurpose Water Resources Development Program (MMWRDP) and the program is being implemented in Nyagatare District by Rwanda Water Resources Board.

The planned Muvumba Multipurpose dam site is located upstream of Nyagatare, in North-Eastern Rwanda in Gatunda, Karama and Rukomo sectors. This dam is expected to secure stable water resources for agricultural, hydropower and domestic water supply in the district and in particular, provide water supply for Nyagatare, Karangazi and Rwimiyaga sectors, and water for irrigation and livestock watering in Musheli, Rwempasha, Tabagwe, Nyagatare, Rukomo, Rwimiyaga and Gatunda sectors.

The proposed dam will have a height of 39m and gross storage of 54.77 million cubic meters. The command area of the irrigation scheme is estimated at 8,820 ha covering Tabagwe, Gatunda, Karama, Rukomo, Nayagatare, Rwempasha, Musheri and Rwimiyaga sectors. It is possible to upgrade the installed capacity to 1000kW and the system generates an annual firm energy of 5.19GWh (90 percent dependable) and Average Energy 6.94GWh. The program is envisaged to supply water of approximately 50,000m^3 /day for people in Karangazi, Rwimiyaga and Nyagatare sectors in addition to livestock use.

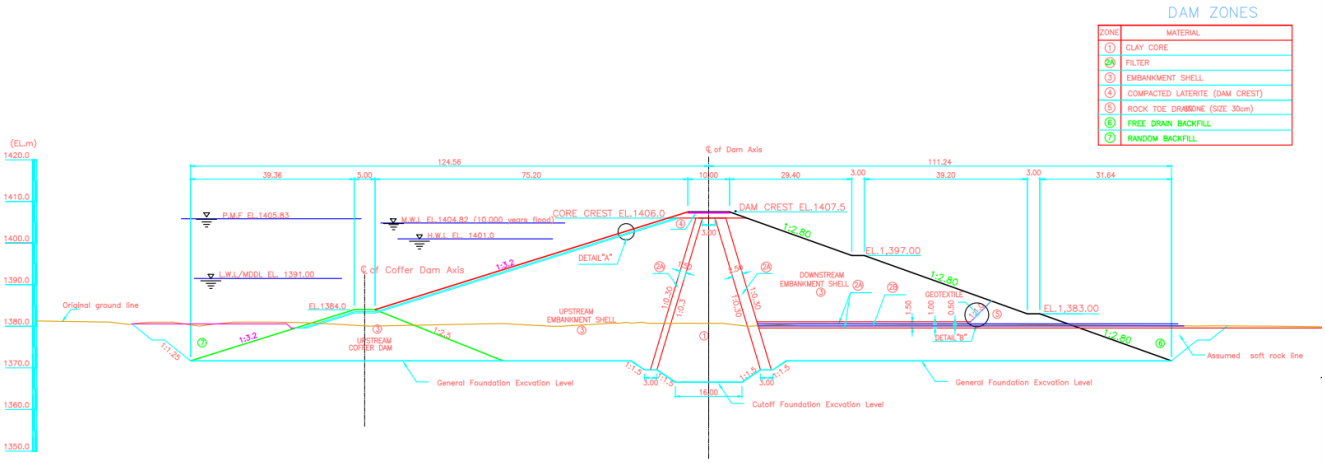

Figure 15: Muvumba Multipurpose dam cross section

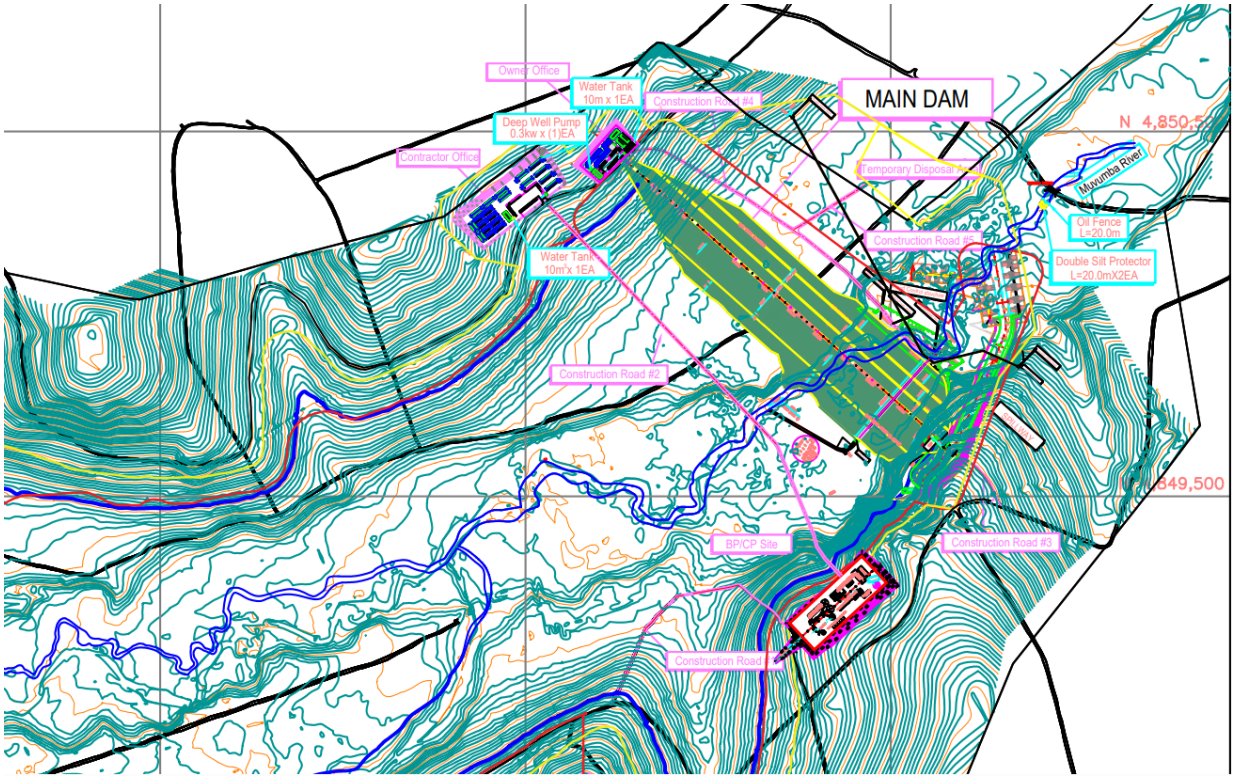

Figure 16: Plan view of Muvumba Multipurpose dam

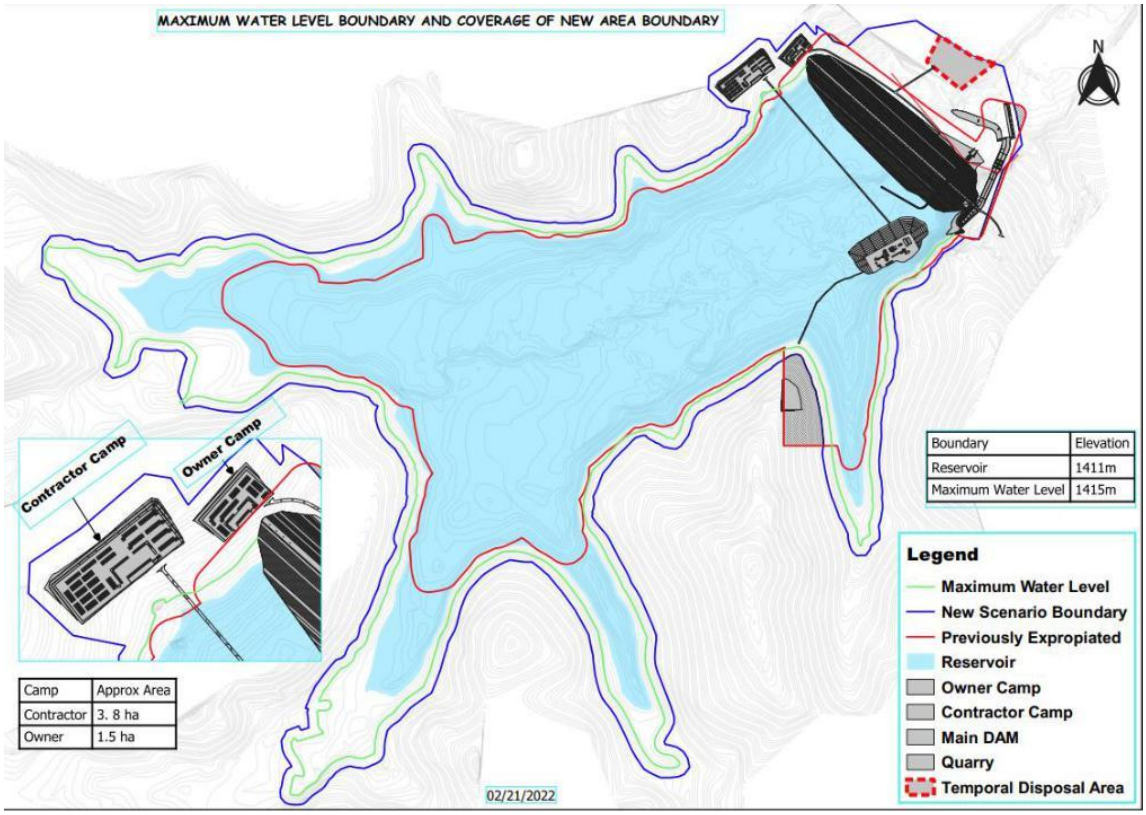

Figure 17: Plan view of Muvumba Multipurpose dam

4.3 Akanyaru Multipurpose dam

The proposed Akanyaru dam project is situated at 2° 46' 35.4" South and 29° 49' 10.32" East, along the transboundary Akanyaru River which defines the border between the Southern Province of Rwanda and Burundi's Ngozi Province (at the trans-boundary Akanyaru River). Akanyaru River is part of the Kagera River basin that forms part of the Lake Victoria Basin. The proposed project is located

The site is located in Gisagara District which is one of the 8 Districts that make up the southern province of Rwanda, in Kyimana Village, Mukindo Sector and it borders the Republic of Burundi to the south.

Akanyaru multipurpose dam is planned to be used for power generation, water supply and irrigation. Its pre-feasibility and FS with DD is under Nile Basin Initiative for shared benefits of Burundi and Rwanda.

The project envisages a 52m high dam with water storage capacity of 333 million cubic metres. The project is expected to generate 14.5 MW hydropower producing 127 GWh of energy per year which is enough to supply energy to about 141,111 households with 846,000 people. The dam will irrigate 12,474 ha supporting 24,948 farmers and provide food for about 124,740 people and supply water to 614,200 people from the two countries.

The dam site has an estimated annual average inflow of 739.2 Mm^3/year. The reservoir volume and area as well as people to be affected by this planned dam are indicated in the table below:

Dam name	**Reservoir Capacity Mm^3**	**Reservoir Area (km^2)**	**Catchment Area (km^2)**	**Potential number of people to be relocated**
Akanyaru	333.9	14.9	1727.79	8450

The project also includes restoration of degraded watersheds upstream of the dam. This project, classified under agriculture, hydropower, natural resources, watershed management and water supply sectors was identified in 2012 by Rwanda and Burundi with support from NELSAP-CU. NELSAP-CU undertook the detailed identification studies in 2012 with financing from a Sweden-Norway grant.
In 2016 NELSAP-CU prepared a Project Concept Note and did a full proposal in March 2018 for funding from the AfDB NEPAD-IPPF. The Akanyaru project is part of the Nile River Basin investment programmes prioritised by Burundi and Rwanda.

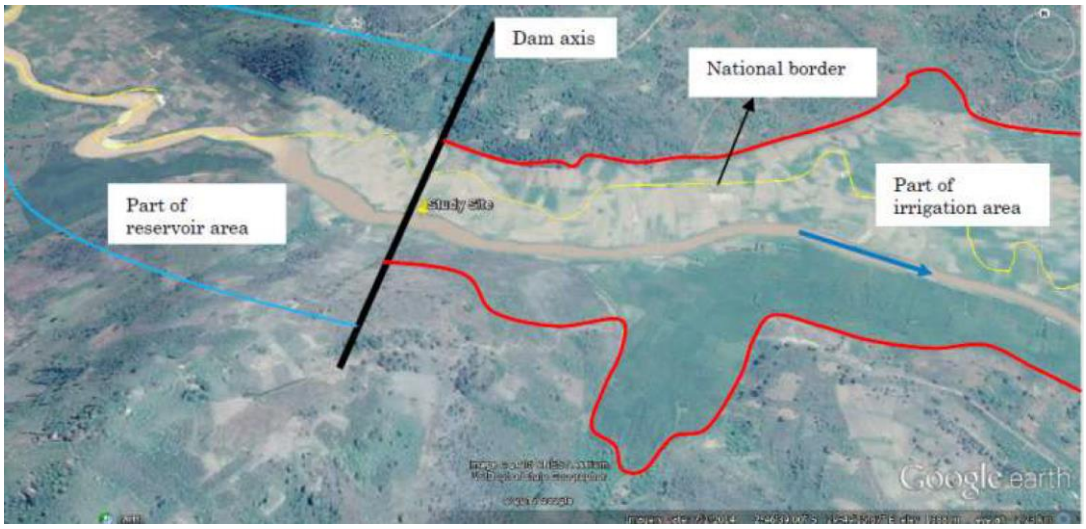

Figure 18: Proposed Akanyaru multipurpose dam axis location

4.4 Rusizi III Dam

The Ruzizi III is a 147MW hydropower project being developed on the Ruzizi River that flows along the borders of the Democratic Republic of Congo (the DRC), Burundi, and Rwanda.

Ruzizi III regional hydropower plant project entails the construction of a run-of-river dam (on the Ruzizi River between DRC and Rwanda downstream from the Ruzizi II hydropower dam), a 147 MW power plant and a distribution station. Burundi's current total capacity will double, while Rwanda's will increase by half. DRC's share will contribute to raising supply in the Eastern region currently not connected to the interconnected network, while also significantly reducing the percentage of energy of thermal origin.

It is the first privately financed project in sub-Saharan Africa that will utilise a common regional water resource to generate power that will be shared equally between three countries.

Rusizi III Hydropower (145MW) construction project is supported by the World Bank, EU, AfDB among others with an expected investment capital of $450 million and is expected to be completed by 2024. The project is being developed under CEPGL umbrella for Rwanda, Burundi and DRC. Rusizi III hydropower project planned to generate 147MW and the power output will be shared among the three partner states with Rwanda getting 47MW and the rest being shared between Burundi and DRC.

The project consists of 105m long dam crest whose height is 20.5m, 2.28km Headrace Tunnel and a surface power station with 3*50 MW Francis Units. The reservoir will have a storage capacity of 1.9 million cubic metres.

The Project will be constructed and owned as a public-private partnership (PPP) among the Republic of Burundi, the Democratic Republic of the Congo (DRC), and the Republic of Rwanda (together as the Contracting States) and REL. It is an Independent Power Project (IPP) based on a Build, Own, Operate, Transfer ("BOOT") structure and underpinned by a 25-year concession agreement and Power Purchase Agreements (PPAs). It will also reduce the local communities' dependence on wood fuel and charcoal; a major threat to the countries' forests and biodiversity. Availability of the renewable power will support efforts to extend electrification to the region.

4.5 Warufu Dam

Warufu dam was proposed upstream of the Karehe village. The reservoir had a total volume a total storage volume of app 25.0 million m^3 is required to ensure the irrigation of the 2,500 ha command area at an acceptable level of reliability along with the water supply of Nyagahanga, Ngarama and Gatsibo Sectors and the release of water from the dam for either environmental purposes or supplementary irrigation to the downstream irrigation projects. This includes the dead storage volume of app 2.4 million m^3 dedicated for reservoir siltation.

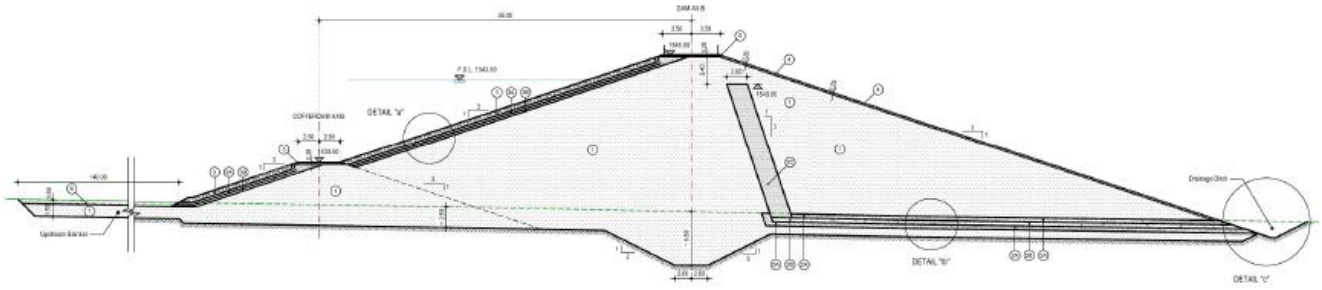

Figure 19: Typical cross-section of the embankment dam

The construction of the dam and reservoir near the village could also supply with drinking water, the inhabitants, considering the erection of a water treatment plant. It could also support irrigation with some minimum pumping to the nearby suitable areas. Developing fisheries in the lake will also increase food security and help the population with a better income.

The crest elevation is set at elevation 1546.60m. Taking into account that the lower elevation in the valley is app 1526.6m, the maximum dam height from ground level is 19.9m and only in the narrow strip of the riverbed it increases to app 21m.

4.6 Bakokwe Dam

The planned Kagaga Water Supply System aims to increase the access to clean water in some Sectors of Muhanga, Kamonyi, and Ruhango District. Muhanga and Kamonyi, located at the center of the country, are some of the areas with a high economic development as well as estate development, especially along the Kigali-Muhanga Road. Ruhango, which borders both Muhanga and Kamonyi, is also located at the center of the country and has water scarcity.

The specific area targeted with the proposed project covers an area of approx. 594.5 km^2 with an approximate total population of 323,464 inhabitants as of the year 2012, and a projected population of 394,639 in 2020.

The Kagaga Water Supply System comprises a dam on Bakokwe River (Bakokwe dam), a water treatment system located in the vicinity of the dam, storage tanks and distributions system as its main components. The proposed Bakokwe Dam will be a zoned embankment dam located on the Bakowe River, just downstream of confluence between Kagaga River and Makurungwe River in Muhanga District, Rwanda.

Bakokwe Dam is 16m high and is therefore classified as a large dam under the International Commission on Large Dams classification. Moreover, it is located in an area of high seismic activity, with fault lines being detected under the dam axis as per the geophysical survey.

Table 2: Summary of Dam Component

General description	
Dam Name:	Bakokwe Dam
Source:	Bakowe River, just downstream of confluence between Kagaga River and Makurungwe River in Muhanga District, Rwanda
Purpose:	Water Supply
Dam Type:	Zoned Embankment
1. CATCHMENT	
Catchment Area:	50.4km^2
Altitude at dam site:	1665 m.a.s.l.
Mean annual rainfall:	1,200 – 1,400 mm
2. RESERVOIR	
Fetch:	1.4km
Depth:	12m
Capacity:	2.4 million m^3
3. EMBANKMENT	
Crest Length:	195m
Crest height:	16m

Crest width:	7m
Upstream slope:	1:2.5
Downstream slope:	1:2.5
Freeboard:	4m
Upstream Slope protection:	Dumped Riprap
Downstream slope protection:	Grassing
4. FOUNDATION	
General Soil Type:	Rock
5. SPILLWAY	
Type:	Side channel spillway with ogee crest acting as sill
Total Length of side channel:	160m
Width at sill (ogee crest length):	35m
Width of side channel:	8m
6. DRAW OFF SYSTEM	
Height of Stand pipe:	10m
Pipe Diameter:	1000mm
Height of tower:	16m

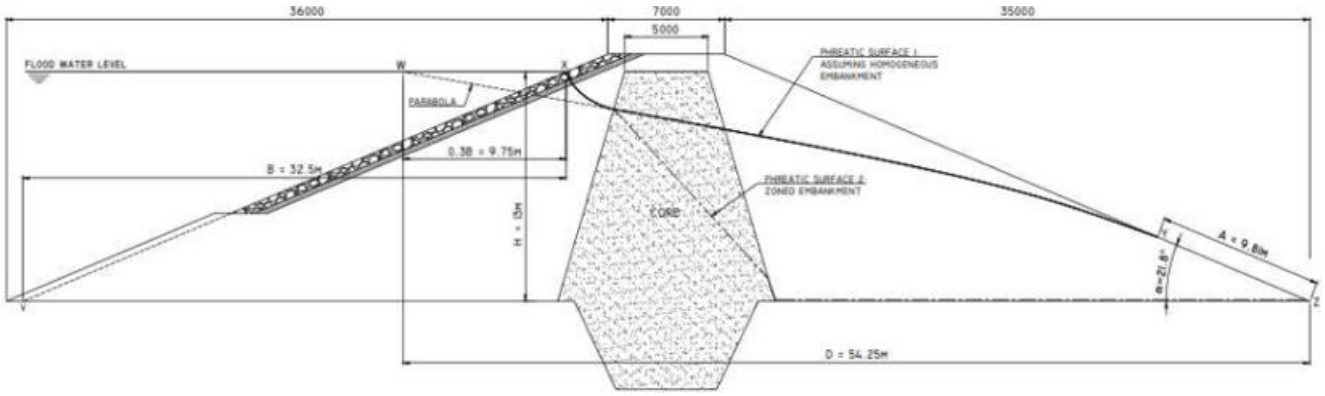

Figure 20: Bakokwe dam cross section

V. Total Annual Water Storage Status

The water storage status presented in this report is composed of: Natural Storage (lakes) and Artificial Storage (Water ponds, Valley dams and dams). The annual water storage in Rwanda for the fiscal year 2022/2023 is estimated at **225.25 billion cubic meters.**

The Natural Storage (lakes) makes 99.96% of the total storage while the Artificial Storage (Water ponds, Valley dams and dams) makes 0.04%. More details are provided in the table below:

Table 3: Annual Water Storage Status

SN	Water Storage type	Total estimated storage capacity (m^3)	Natural Storage (m^3)	Artificial Storage (m^3)
1	Water ponds	124,942		
2	Valley dams	11,071,370		
3	Dams	72,563,300		
4	Lakes	225,165,037,327		
	Total water storage	**225,246,491,699**	**225,165,037,327**	**83,759,612**

VI. CHALLENGES & RECOMMENDATIONS

6.1 Challenges

- Reservoir sedimentation has become a significant problem within existing water storage infrastructures. Sediment deposition in reservoirs limits the active life of reservoirs by reducing reservoir storage capacity for irrigation, water supply, hydropower and flood risk reduction. Sedimentation also impacts dam outlets, water intakes, water quality, etc. This can be minimized by controlling erosion in the catchments areas of the dams;

- The lack of buffer zones is another issue observed in many existing dams. This is a big issue that need to be discussed at high level for water resources protection;

- Most of Irrigation dams are managed by local farmers with limited technical knowledge;
- Ponds lined with plastic sheeting are facing the issue of missing the sheeting for replacement;
- Valley dams need to be properly managed and rehabilitated

6.2 Recommendations

Water storage development in Rwanda is key to adaptation to climate change. Therefore, its implementation requires the collaboration of different institutions, stakeholders using water and the Ministry of Environment having water resources in its attribution.

Therefore, we recommend the following:

- Recognize, quantify and optimize all benefits and value created at reservoirs for all multi-purpose water users;
- To incorporate flexibility options for design and operation of reservoir to be able to adapt to the evolution of social & environmental requirements, climate change, etc.;
- Put in place state regulations on water storage development (dams and water structures are long term investments and highly capitalistic);
- Highlight the role of water storage for climate mitigation & adaptation;
- Address mitigation of sedimentation issue by involving different stakeholders;
- Customize water storage models to local context according to strong and best practices;

ANNEX 1: Water Storage, Irrigation, Water supply and Hydropower Dams

No	Name	X	Y	Z(m)	Districts	Dam type	Dam height (m)	Storage capacity (m^3)	Use
1	Gatare-Rwabikwano	507393	4747300		Bugesera	Earth fill	4	150,000	Irrigation
2	Kiruhura-Rwintare	503673	4747754		Bugesera	Earth fill	4	300,000	Irrigation
3	Kajevuba	517702	4797746	1436	Gasabo	Earth fill	5	180,000	Irrigation
4	Kiliba	541992	4816195	1418	Gatsibo	Earth fill	8.5	700,000	Irrigation
5	Rwangingo	532244	4823872	1415	Gatsibo	Earth fill	10	3,750,000	Irrigation
6	Ntende	545787	4812731	1389	Gatsibo	Earth fill	4.5	800,000	Irrigation
7	Kanyonyomba	540558	4806141	1486	Gatsibo	Earth fill	9	550,000	Irrigation
8	Munago	538437	4804209	1509	Gatsibo	Earth fill	5	120,000	Irrigation
9	Mushaduka	481292	4719925	1500	Gisagara	Earth fill	13.7	450,000	Irrigation
10	Cyili	480400	4720750	1419	Huye	Earth fill	9.5	950,000	Irrigation
11	Kadahokwa	466499	4710621	1727	Huye	Earth fill	18	600,000	Water supply
12	Rusuli	474175	4723063	1642	Huye	Earth fill	6	200 000	Irrigation
13	Cyarubare	469776	4725108	1630	Huye	Earth fill	4	150,000	Irrigation
14	Runukangoma	465968	4727931	1575	Huye	Earth fill		500,000	Irrigation
15	Cyadisha (Rwasave)	474185	4717776	1679	Huye, Gisagara	Earth fill		450,000	Irrigation
16	Gatinga	553702	4783278	1407	Kayonza	Earth fill		1,500,000	Irrigation
17	Gacaca	558214	4808265	1359	Kayonza	Earth fill	9.5	2,500,000	Irrigation
18	Gashaka	560355	4787047	1472	Kayonza	Earth fill	4	850,000	Irrigation
19	Rwinkwavu	563870	4774584	1416	Kayonza	Earth fill	9.5	4,200,000	Irrigation
20	Kadiridimba	565646	4782893	1358	Kayonza	Earth fill		50,000	Irrigation
21	Kayonza-4 (Cyarubare)	570245	4773527	1451	Kayonza	Earth fill	9.5	1,600,000	Irrigation
22	Cyunuzi	566910	4754555	1367	Kirehe	Earth fill	7	319,300	Irrigation
23	Sagatare	573227	4746772	1405	Kirehe	Earth fill	6.5	282,000	Irrigation
24	Kinoni 1	581029	4746531	1438	Kirehe	Earth fill		250,000	Irrigation
25	Mahama	590742	4750927	1312	Kirehe	Earth fill		1,000,000	Irrigation
26	Nyamugali	583796	4746054	1375	Kirehe	Earth fill	13.7	550,000	Irrigation
27	Kinoni2	581684	4743043	1362	Kirehe	Earth fill		300,000	Irrigation
28	Rugeramigozi I	472586	4766929	1800	Muhanga	Earth fill	6	270,000	Irrigation&water supply
29	Rugeramigozi II	475848	4768273	1816	Muhanga	Earth fill		260,000	Irrigation
30	AIDER	473784	4764078	1758	Muhanga	Earth fill	9	400,000	Water supply
31	Nyabarongo 1 HP	459243	4780182	1503	Muhanga, Ngororero	Concrete gravity	44.5	35,000,000	Hydropower
32	Kibuza				Kamonyi	Earth fill		65,000	Irrigation
33	Ngoma 22	557265	4768481	1378	Ngoma	Earth fill	7	450,000	Irrigation
34	Mwambo (Musya)	557680	4766008	1379	Ngoma	Earth fill		530,000	Irrigation
35	Cyabayaga	531747	4844056		Nyagatare	Earth fill		200,000	Irrigation
36	Bushoga	533261	4847900		Nyagatare	Earth fill	4	120,000	Irrigation

No	Name	X	Y	Z(m)	Districts	Dam type	Dam height (m)	Storage capacity (m^3)	Use
37	Rukarara	441788	4730247		Nyamagabe	Concrete gravity	12	260,000	Hydropower
38	Base	467950	4751637	1616	Ruhango	Earth fill	9	250,000	Irrigation
39	Nyamagana	471528	4740792	1744	Nyanza	Earth fill	4	60,000	Irrigation
40	Nyarubogo	486403	4738201	1386	Nyanza	Earth fill	9	600,000	Irrigation
41	Agasasa	484730	4732391	1432	Nyanza	Earth fill	10	374,000	Irrigation
42	Nyanza 23 (Rwabicuma)	465922	4738404	1607	Nyanza	Earth fill	19	1,820,000	Irrigation
43	Bishya	469542	4743450		Nyanza	Earth fill	11	1,600,000	Water supply
44	Bugugu	546986	4782121	1393	Rwamagana	Earth fill		576,000	Irrigation
45	Gashara	545334	4778514	1372	Rwamagana	Earth fill	13	637,000	Irrigation
46	Cyimpima	549116	4779304	1368	Rwamagana	Earth fill	9	540,000	Irrigation
47	Rwamagana-34	538681	4779049	1397	Rwamagana	Earth fill	14	1,000,000	Irrigation
48	Rugende	531199	4783106	1387	Rwamagana, Gasabo	Earth fill	13.5	1,350,000	Irrigation
49	Muyanza	508870	4810454		Rulindo	Earth fill	26	2,300,000	Irrigation
50	Gitinga				Kayonza	Earth fill		850,000	Irrigation
	Total 2							**72,563,300**	

ANNEX 2: Valley Dams, their estimated volumes and their location

No	Name	District	X	Y	Storage in m^3	Sector	Cell	Village	Year of construction
1	Ndago 1	Kayonza	572155	4791992	50,000	Mwili	Kageyo	Ndago	2017
2	Rugeyo	Kayonza	572361	4794520	50,000	Mwili	Kageyo	Rugeyo	
3	Kageyo	Kayonza	573345	4796072	3,500,000	Mwili	Kageyo	Rwisirabo 1	2007
4	Rwisirabo 2	Kayonza	575794	4799747	50,000	Mwili	Kageyo	Rwisirabo 2	
5	Rwisirabo2 (dam sheet)	Kayonza	575616	4799790	50,000	Mwili	Kageyo	Rwisirabo 2	
6	Rwisirabo 1	Kayonza	572999	4797748	50,000	Mwili	Kageyo	Rwisirabo 1	
7	Sabasengo	Kayonza	572868	4806153	50,000	Mwili	Kageyo	Gatindo	
8	Buhabwa	Kayonza	560353	4813945	109,980	Murundi	Buhabwa	Buhabwa	1999by CDC
9	Cyamburara	Kayonza	559325	4815210	53,460	Murundi	Buhabwa	Cyamburana	2000
10	Kwa Karamba	Kayonza	565444	4814078	50,000	Murundi	Buhabwa	Gakoma	2017
11	Gakoma 1/ Kwa Karugenge	Kayonza	566523	4811051	55,000	Murundi	Buhabwa	Gakoma	2017
12	Ku Cya musenyeri	Kayonza	565859	4817957	3,465,000	Murundi	Buhabwa	Gakoma	
13	Mucucu/Kwa Makanika	Kayonza	570863	4817089	50,000	Murundi	Buhabwa	Gakoma	2017
14	Kwa Sekimondo	Kayonza	568841	4820387	50,000	Murundi	Buhabwa	Gakoma	2017
15	Mu giperefe	Kayonza	569599	4804570	50,000	Gahini	Kahi	Nyamiyaga	
16	Byimana	Kayonza	568024	4800681	50,000	Gahini	Kahi	Nyamiyaga	
17	Kiyanja	Kayonza	569554	4797740	50,000	Gahini	Kahi	Tsima	2000
18	Rukore	Kayonza	566007	4806668	50,000	Gahini	Kahi	Rukore	2001
19	Gapfubyi	Kayonza	571480	4813017	50,000	Gahini	Kahi	Nyamiyaga	2001
20	Simbwa	Gatsibo	538616	4828793	50,000	Kabarore	Simbwa	Simbwa	2012 by

									MINADEF
21	Kibondo	Gatsibo	537044	4827217	50,000	Kabarore	Simbwa	Kibondo	
22	Gatoki	Gatsibo	538282	4824258	50,000	Kabarore	Kabeza	Gatoki	
23	Nyabikiri(kwa sakure)	Gatsibo	551427	4824758	50,000	Kabarore	Nyabikiri	Kinyeganyege	2012 by PEDERECIU
24	Kwa busungu	Gatsibo	551235	4823105	50,000	Rwimbogo	Nyamatete	Kidugudu	2012 by PEDERECIU
25	Kwa mutini	Gatsibo	551312	4820854	50,000	Rwimbogo	Nyamatete	Rwiminazi	2012 by PEDERECIU
26	Kwa murekwa	Gatsibo	554969	4822217	50,000	Rwimbogo	Ndama	Ndama1	
27	Munini	Gatsibo	556422	4822733	50,000	Rwimbogo	Mumimi	Munini	PEDERECIU
28	Gikobwa	Gatsibo	562389	4822482	50,000	Rwimbogo	Munini	Gikobwa	PEDERECIU
29	Kwa cyangwate	Gatsibo	552919	4823478	50,000	Rwimbogo	Rwikiniro	Ndama1	
30	Kwa sosi	Gatsibo	542827	4822853	50,000	Kabarore	Nyabikiri	Kabeza	
31	Gatebe 1	Nyagatare	223036	9852634	50,000	Rwimiyaga	Kirebe	Gatebe 1	2017 by Reserve force
32	Gatebe 2	Nyagatare	225170	9851795	50,000	Rwimiyaga	karushuga	Karushuga	2016
33	Rusa	Nyagatare	220151	9857226	50,000	Rwimiyaga	Kirebe	Musenyi	2005 by Amizero. A
34	Rukundo	Nyagatare	216748	9858688	50,000	Rwimiyaga	Gacundezi	Kirebe	2008
35	Bwera	Nyagatare	218463	9863987	50,000	Rwimiyaga	Kirebe	Kirebe	
36	Rubira	Nyagatare	219545	9868647	50,000	Rwimiyaga	Rutungo	Rubira	2005
37	Kwa Rugondo/ Agatindo	Nyagatare	218067	9870659	50,000	Rwimiyaga	Rutungo	Rubira	

38	Rutungo	Nyagatare	217544	9869982	50,000	Rwimiyaga	Rutungo		1997
39	Gashwenu	Nyagatare	215279	9866451	50,000	Rwimiyaga	Ntoma		
40	Rugaga	Nyagatare	215181	9869232	50,000	Matimba	Bwera	Rugoga	
41	Bwera	Nyagatare	213692	9873707	50,000	Matimba	Bwera	Bwera	
42	Musheri	Nyagatare	207690	9875528	50,000	Musheri	Kibirizi	Kibirizi	1995
43	Nkuna	Nyagatare	214492	9836855	50,000	Karangazi	Rubagabaga	Nkuna	2007
44	Nyagashanga	Nyagatare	216206	9839949	50,000	Karangazi	Nyagashanga	Kabare	1998
45	Rwabiharamba	Nyagatare	217943	9843226	50,000	Karangazi	Ndama	Rwabiharamba	
46	Kanyange 2	Nyagatare	222844	9840291	50,000	Karangazi	Nyamirama	Akayange2	2016
47	Akayange	Nyagatare	227139	9842780	50,000	Karangazi	Ndama	Akayange	2017by RDB
48	Akayange(kwa semana)	Nyagatare	226691	9846463	40,000	Karangazi	Ndama	Akayange	2017
49	Akayange(kwa musoni)	Nyagatare	224065	9843664	50,000	Karangazi	Ndama	Akayange	
50	Akayange(kwa turagara)	Nyagatare	221958	9847647	50,000	Karangazi	Ndama	Akayange	2017
51	Byimana	Nyagatare	216240	9847787	50,000	Karangazi	Kamate	Kigazi	
52	Kamate	Nyagatare	216420	9851120	45,000	Karangazi	Kamate	Kamate	
53	Kwa Ndereya	Nyagatare	214352	9843664	50,000	Karangazi	Ndama	Rwabiharamba	
54	Kwa Kayumba	Nyagatare	213938	9842561	50,000	Karangazi	Ndama	Ndama	
55	Ruziranyenzi	Nyagatare	209685	9834310	50,000	Karangazi	Musenyi	Ruzirznyenzi	

56	Rundiro(Kwa kagarama)	Nyagatare	210339	9832919	50,000	Karangazi	Karama	Rundiro	2000
57	Kwa Kayigiro	Nyagatare	197853	9858311	50,000	Tabagwe	Gitengure	Kayigiro	2000
58	Bitibyoma(kwa karekezi)	Nyagatare	197581	9857091	50,000	Tabagwe	Gitengure	Bitibyoma	2004 by PEDE RECIU
59	Nyagasigati(kida kamirwa)	Nyagatare	194290	9858125	50,000	Tabagwe	Gitengure	Nyagasigati	PEDE RECIU
60	Kangoma	Nyagatare	192169	9857616	50,000	Tabagwe	Nyabitekeri	Kangoma	
61	Mutozo	Nyagatare	190837	9854628	50,000	Tabagwe	Nkoma	Mutozo	1999
62	Kabusunzu	Nyagatare	187366	9854914	50,000	Tabagwe	Nyagatoma	Kabutongo	
63	Gihorobwa	Nyagatare	203129	9853365	50,000	Nyagatare	Rutaraka	Gihorobwa	2000
64	Rutaraka	Nyagatare	204380	9849915	50,000	Nyagatare	Rutaraka	Rutaraka	
65	Kamagire	Nyagatare	211020	9852055	50,000	Nyagatare	Kamagire	Kamagire	2003 by PEDE RECIU
66	Rwakigeli	Nyagatare	212091	9850374	50,000	Nyagatare	Ryabega	Murongero	
67	Mugari	Nyagatare	206732	9855405	50,000	Nyagatare	Rutaraka	Mugari	
68	Burumba	Nyagatare	206925	9855979	50,000	Nyagatare	Baringa	Burumba	
69	Kabare	Nyagatare	205894	9858949	50,000	Nyagatare	Nsheke cell	Nyageza	
70	kamiramigezi	Nyagatare			73,130				
71	Gikobwa	Gatsibo			60,000				
72	Mucucu (Nyirinkwaya)	Kayonza			45,000				
73	Mucucu (taremwa)	Kayonza			38,000				
74	Gakoma (kwa Murekezi	Kayonza			65,000				
75	Gisunzu (kageyo)	Kayonza			50,000				

76	Valley dam yo kuri RDB	Nyagatare			50,000				
77	Akayange (kwa Bugabo)	Nyagatare			45,000				
78	Gatindo	Kayonza	239154.21 m E	9806065.66 m S	110,500	Mwiri	Nyamugari		
79	Rugalika	Kayonza	225650.43 m E	9809266.40 m S	82,600	Murundi	Buhabwa		
80	Bikoki	Kayonza	242045.31mE	9799722.14m S	51,250	Mwiri	Kageyo		
81	Murundi	Kayonza	224654.00mE	9813579.00m S	18,150	Murundi	Buhabwa		
82	Kigarama	Kayonza	235261.00m E	9794138.00m S	14,300	Gahini/Mwiri	Nyamugali		
	Total				**11,071,370**				

ANNEX 3: Key information of major lakes in Rwanda

No	Type	Name	Location	Area m^2	Average Depth (m)	Total Volume (m^3)
1	Lake	Karago	-1°37'38.28", 29°30'48.24"	1003163.93	5	5015819.649
2	Lake	Ntosho	-1°38'29.86", 29°31'33.78"	235303.6096	4	941214.4383
3	Lake	Bihinga	-1°36'52.56", 29°31'36.12"	204339.1163	5	1021695.582
4	Lake	Nyirakigugu	-1°37'12.51", 29°29'7.26"	155085.3432	4	620341.3727
5	Lake	Kishanju	-1.6029°, 30.711°	598569.6259	4	2394278.504
6	Lake	Muhari	-1°39'53.28", 30°47'12.12"	846137.0451	4	3384548.18
7	Lake	kidogo	-2°10'6.31", 30°13'36.26"	671374.1109	3.5	2349809.388
8	Lake	murambya	-1.7753°, 30.7686°	1240145.434	4	4960581.738
9	Lake	Murambi	-1.7909°, 30.7655°	524087.9242	5	2620439.621
10	Lake	Kivumba	-1°42'51.48", 30°45'24.48"	11202626.62	4	44810506.5
11	Lake	Hago	-1°40'16.32", 30°43'5.52"	17871953.05	5	89359765.27
12	Lake	Mugesera	-2° 6'12.52", 30°19'7.08"	44325011.45	2.8	98,000,000
13	Lake	Gashanga	-2°8'35.99", 30°14'20"	1772827.23	3	5318481.69
14	Lake	Bilira	-2.175º, 30.2947º	5473955.696	6	32843734.17
15	Lake	Sake	-2°13'46.56", 30°21'36".	16311884.37	5	81559421.85
16	Lake	Mirayi	-2°13'43.68", 30°14'49.56"	2720020.636	3	8160061.909
17	Lake	Ihema	-1°51'47.78", 30°47'3.08"	92622558.16	5	325,000,000
18	Lake	Cyambwe	-2°2'22.92", 30°45'52.2"	22759797.77	6	136558786.6
19	Lake	Mihindi	-1°31'10.2", 30°43'9.12"	10476026.54	5	52380132.72
20	Lake	Muhazi	-1°52'4.77", 30°22'30.41"	35439908.56		330,000,000
21	Lake	Ruhondo	-1.517º, 29.739º	26601180.61		868,300,000

22	Lake	Gishanda	- 1°58'24.08", 30°39'35.24"	292605.2741	5	1463026.371
23	Lake	Rwakibali	-1°57'31.95", 30°47'0.16"	3406910.728	5	17,600,000
24	Lake	shakani	-1°51'51.94", 30°44'38.27"	2045633.791	4	8182535.163
25	Lake	Nasho	-2°2'38.04", 30°44'24.72"	12723775.17	4	37,400,000
26	Lake	Rwampanga	-2°2'40.56", 30°48'30.6"	10142174.6	6	60853047.6
27	Lake	Rwanyakizinga	-1°28'0.01", 30°40'1.99"	22617508.52	5	113087542.6
28	Lake	Kanaga	- 1°59'39.76", 30°46'48.58"	435568.8614	5	2177844.307
29	Lake	Cyohoha Nord	-2°15'0", 30°7'59.98"	1879638.967	5	9398194.833
30	Lake	Rumira	- 2°11'1.92", 30°14'17.25"	5158171.536	3	15474514.61
31	Lake	Kilimbi	-2°15'14.76", 30°16'22.44"	2692706.497	3	8078119.491
32	Lake	Gaharwa	-2°16'1.2", 30°16'49.8	3660051.911	3	10980155.73
33	Lake	Rweru	- 2°22'52.59", 30°19'13.75"	126158712.8	2.1	42000000
34	Lake	Cyohoha Sud	- 2°25'20.52", 30° 5'39.15"	55939618.82	5	95000000
35	Lake	Kivu	-2° 2'41.62"S, 29°11'8.58"	1010595675	220	2.22331E+11
36	Lake	Burera	-1°26'32.27", 29°46'17.60"	53320627.85		311,900,000
37	Lake	Nyabugongwe	-2°18'6.01", 30°29'4.99"	323030.2142	5	1615151.071
38	Lake	Karaba	-2°16'46.29", 30°21'51.63"	247796.7571	5	1238983.786
39	Lake	Nyakabingo	-2°14'50.52", 30°20'52.01"	135262.8823	5	676314.4117
40	Lake	Nyakabingo	-2°15'40.00", 30°21'18.88"	252740.6657	5	1263703.328
		Total 4				**225,165,037,327**