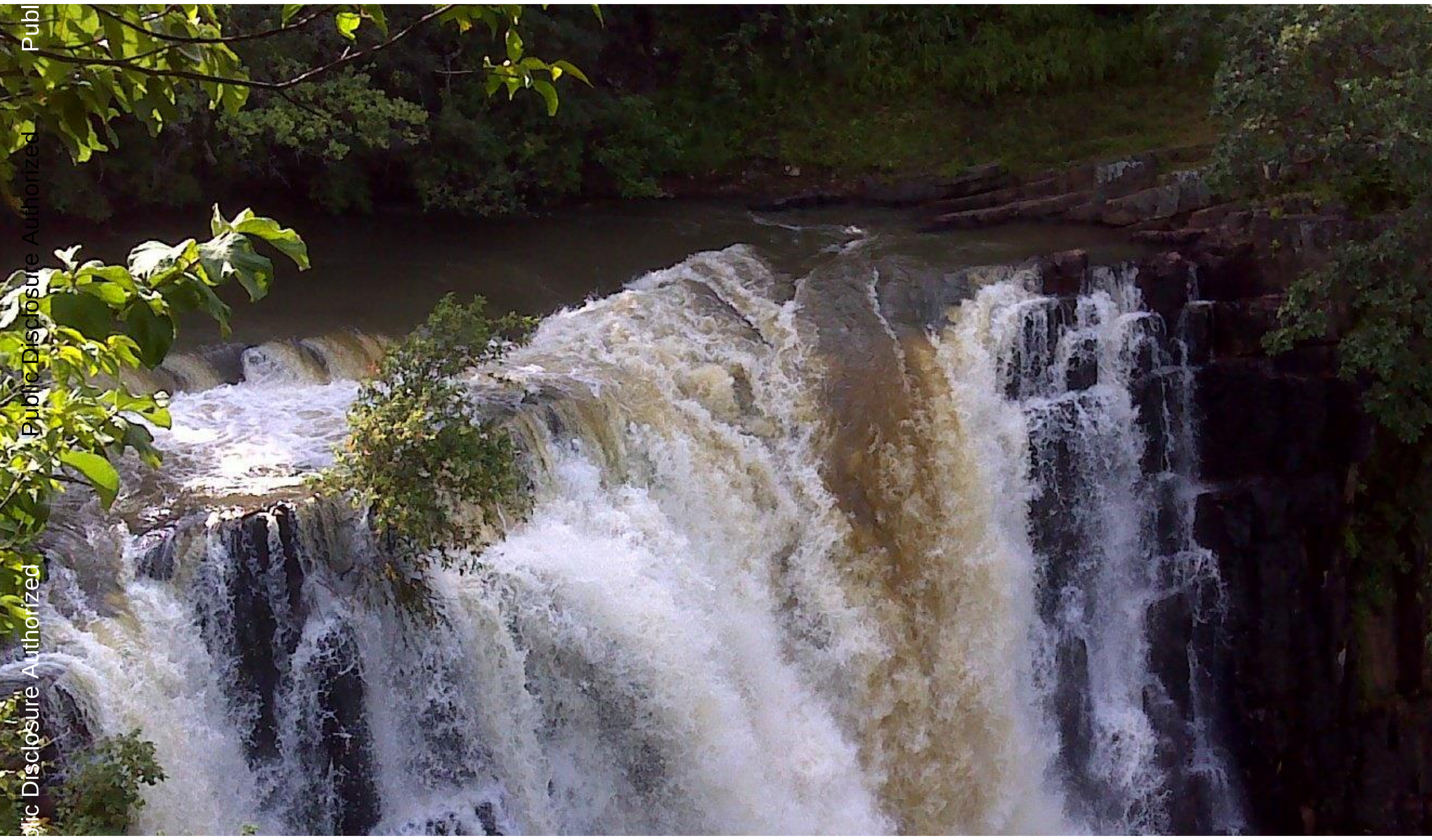
Phase 3 - Production of Validated Small Hydro Atlas

SMALL HYDRO MAPPING REPORT

Renewable Energy Resource Mapping: Small Hydro - Tanzania [P145271]

June 2018



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1	04/2015	Small Hydro Mapping report **Final Phase 1**	Pierre SMITS	Quentin GOOR
2	12/2017	Small Hydro Mapping report **update Phase 3 - Draft**	Quentin GOOR	Pierre SMITS
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ABBREVIATIONS AND ACRONYMS

AfDB	African Development Bank
ASTER GDEM	Advanced Spaceborne Thermal Emission and Reflection Radiometer Global Digital Elevation Model
CIF	Climate Investment Funds
CSOs	Civil Society Organisations
DfID	Department for International Development
EAPP	East African Power Pool
ESMAP	Energy Sector Management Assistance Program
EUEI	European Union Energy Initiative
EWURA	Energy and Water Utilities Regulatory Authority
FAO	Food and agricultural organization
FGDs	Focused Group Discussions
GoT	Government of Tanzania
GRDC	Global Runoff Data Centre
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit
GW	Gigawatt
GWh	Gigawatt hour
ICEIDA	Icelandic International Development Agency
IDA/GEF	International Development Agency / Global Environment Fund
IFC	International Finance Corporation
IPP	Independent Power Producers
JICA	Japan International cooperation Agency
Kfw/BGR	Kreditanstalt für Wiederaufbau
kW	Kilowatt
kWh	Kilowatt hour
MDBs	Multi-lateral Development Banks
MDGs	Millennium Development Goals
MEM	Ministry of Energy and Minerals
MNRT	Ministry of Natural Resources and Tourism
MW	Megawatt
MW	Mega Watt
MWh	Megawatt hour
PPP	Public-Private Partnership
PS	Permanent Secretary
REA	Rural Energy Agency
REF	Rural Energy Fund
SPPA	Small Power Purchase Agreements
SREP	Scaling Up Renewable Energy Program
SRTM	Shuttle Radar Topography Mission
SSA	Sub-Saharan Africa
TANESCO	Tanzania Electric Supply Company
TEDAP	Tanzania Energy Development and Access Project
ToRs	Terms of Reference
UNEP	United Nations Environment Program
WB	The World Bank
WBO	Water Basin Office
ZECO	Zanzibar Electricity Company Limited

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1 INTRODUCTION

1.1 BACKGROUND OF THE ESMAP PROGRAM

The Energy Sector Management Assistance Program (ESMAP), a global knowledge and technical assistance program administered by the World Bank and supported by 11 bilateral donors, has launched, in January 2013, an initiative that will support country-driven efforts to improve RE resource awareness, put in place appropriate policy frameworks for RE development, and provide 'open access' to resource and geospatial mapping data. It will also support the IRENA Solar and Wind Atlas by improving the data availability and quality that can be accessed through the atlas on a modular basis.

This "Renewable Energy Mapping: Small Hydro Tanzania" study, is part of a technical assistance project, ESMAP funded, being implemented by Africa Energy Practice 1 (AFTG1) of the World Bank in Tanzania (the 'Client') which aims at supporting resource mapping and geospatial planning for small hydro. It is being undertaken in close coordination with the Rural Energy Agency (REA) of Tanzania, the World Bank's primary Client country counterpart for this study.

The "Provision of Small Hydropower Resource Data and Mapping Services" IDA 8004801 Framework contract was signed 29th May 2013, while the specific contract " Renewable Energy Mapping: Small Hydro Tanzania", n. 7169139, is dated 4th November 2013.

1.2 OBJECTIVE OF THE STUDY

The objectives of the study are:

- To improve the quality and availability of information on Tanzania's small hydropower resources. The project will provide the GoT (Client) and commercial developers with ground-validated maps (at least 70+ sites up to 10 MW) that show the varying levels of hydro potential throughout the country, and highlight several sites most suited for small hydropower projects.
- To contribute to a detailed comprehensive assessment and to a geospatial planning framework of small-hydro resources in Tanzania; (ii) to verify the potential for the most promising sites and prioritized sites (~ 20 prioritized sites) to facilitate new small hydropower projects and ideally to guide private investments into the sector; and (iii) to increase the awareness and knowledge of the Client on RE potential.

The study is delivered in three phases:

- **PHASE 1:** Preliminary resource mapping based on satellite and site visits.
- **PHASE 2:** Ground-based data collection.
- **PHASE 3:** Production of validated resource atlas that combines satellite and ground-based data.

1.3 SCOPE OF THE REPORT

The first version of the Small Hydro Mapping Report was delivered at the end of Phase 1 (April 2015). It presented the preliminary prioritization process and recommendations for data gap mitigation (hydrology, geology, socio-environment, topography). The first version of that report included maps created from GIS layers, a training and capacity building program and a revised Technical, Financial Proposals for Phase 2 and 3 alongside an Delivery Plan for ground-based hydrological monitoring and site investigations during Phase 2.

The final version of the Small Hydro Mapping Report is delivered in the context of Phase 3 (December 2017). It presents the methodological approach, describes the activities undertaken and the key results achieved. The Small Hydro Mapping Report was written in close interaction with the Small Hydropower Resource Atlas of Tanzania, also delivered at the end of Phase 3.

All the activities, results and deliverables from the Study were presented and debated during the final workshop that was held in Dar Es Salaam on December 14, 2018. The list of participants is presented in Appendix 8.

Table 1 presents an overview of the 11 deliverables produced during the three phases of the Study, summarized in the final version of the **Small Hydro Mapping Report**.

Table 1. Overview of the 11 deliverables of the Study

N°	TITLE OF THE DELIVERABLE	DESCRIPTION
PHASE 1 : Initial scoping and mapping		
1	*Small Hydro Mapping Report – Interim Output*	This report presents the preliminary prioritization process and recommendations for data gap mitigation (hydrology, geology, socio-environment, topography). The first version of that report included maps created from GIS layers, a training and capacity building program and a revised Technical, Financial Proposals for Phase 2 and 3 alongside an Delivery Plan for ground-based hydrological monitoring and site investigations during Phase 2.
2	*Site Visits Report – Existing Sites*	This report gives detailed information on the 11 existing sites visited by SHER.
3	*Site Visits Report – Potential Sites*	This report gives detailed information on the 85 potential sites visited by SHER.
PHASE 2 : Ground-based data collection		
4	*Site Investigations Report*	This report aims at providing an overview, at reconnaissance level, of the top 20 prioritized potential small hydropower sites in Tanzania.
5	*Prefeasibility Study of the Muyovosi hydroelectric project (SF187)*	Detailed prefeasibility report.
6	*Prefeasibility Study of the Luegere hydroelectric project (SF022)*	Detailed prefeasibility report.
7	*Prefeasibility Study of the Muhuwesi hydroelectric project (SF266)*	Detailed prefeasibility report.
8	*Prefeasibility Study of the Samvya hydroelectric project (SF217)*	Detailed prefeasibility report.
PHASE 3 : Production of a validated Atlas of the hydropower resource combining spatial data and field measurements		
9	*Small Hydro Mapping Report – Final Output*	The final version of the Small Hydro Mapping Report was delivered in the context of Phase 3 (December 2017). It presents the methodological approach, describes the activities undertaken and the results achieved.
10	*Atlas of the Hydropower Resource of Tanzania*	This report is a document that contains all the information directly or indirectly related to hydropower and collected during Phase 1 and Phase 2 of this Study. The information has been compiled and processed in a Geographic Information System (GIS) and is presented as thematic maps, tables, graphs and various illustrations.
11	*Geographical Information System (GIS)*	The GIS has been designed to meet the compatibility and standardization requirements defined in the terms of reference. It contains all the data presented in the Atlas of the Hydropower Resource, including the spatial database of potential hydropower sites.

1.4 OVERALL APPROACH AND CHALLENGES

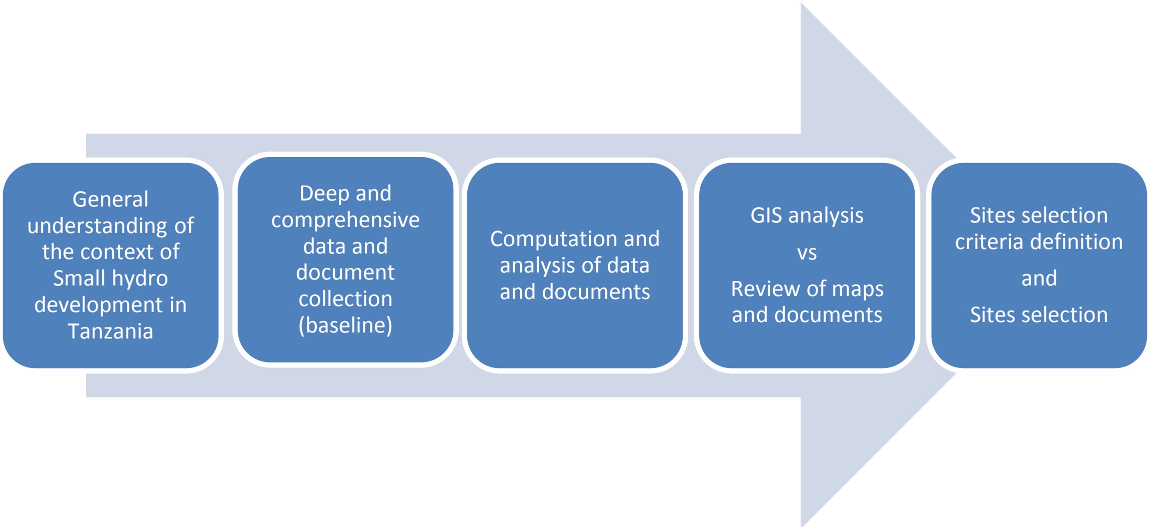
Our approach considers that the knowledge of SHPP potential in Tanzania will be elevated using two sources of information:

(i) The existing literature consisting of existing studies, lists of georeferenced sites, maps, etc. and

(ii) Additional information from our in-house potential hydropower site identification tool (SiteFinder) that relies on a digital elevation model (DEM) and a hydrological model. This tool has the objective to screen the area of interest (catchment, country, region, etc.) to identify potential river stretches that are likely to be relevant for hydropower development.

Hence, the Consultant has adopted the following approach to achieve the objectives of the study:

Figure 1. Overview of the delivery approach



The following chapters of this report present a comprehensive description of the various steps of the Study.

<u>Note</u>: Following the Inception Phase (corresponding to the first step in the above chart) and based on a request from REA, it was decided to add 20 potential sites to the list of 50+ promising sites to be visited during the field campaign (Site Visits - Phase 2). The World Bank has also extended to scope of work of the Consultant by adding four prefeasibility studies of potential hydropower projects. The Addendum to the Contract was signed on September 16, 2014 and the 20 additional field visits were undertaken between October 2014 and January 2015. The four pre-feasibility studies were carried out during phase 2 between October and December 2017.

2 ELECTRICITY SECTOR IN TANZANIA

2.1 INSTITUTIONAL FRAMEWORK

2.1.1 Actors

The main Government stakeholders in the Tanzanian Electricity Sector are the following: The Ministry responsible for "electricity matters" (as it is designated in the Electricity Act, 2008), the Energy and Water Utilities Regulatory Authority established under EWURA Act, Chapter 414, the Rural Energy Agency established under Part IV of the Rural Energy Act, 2005, and the utility TANESCO. Other Ministries also have a role in the energy sector activities such as the Ministry of Environment.

Ministry responsible of the energy sector

According to the Electricity Act, 2008, **the Minister of Energy and Minerals** is responsible for (i) "the development and review of the Government policies in the electricity supply industry;" (ii) the elaboration of "policies, plans and strategies for development of the electricity subsector", (iii) the reorganization and restructuring of the electricity supply industry with a view to attracting private sector and other participation ; (iv) through the Rural Energy Agency (as created by this Act), the preparation of the Rural Electrification Plan and Strategy and the promotion of rural electrification; (v) the establishment of import and export of electricity.

Regulation

The Energy and Water Utilities Regulatory Authority (commonly designated as EWURA), as created by the Electricity Act, 2008: (i) awards licenses to entities undertaking a licensed activity; (ii) approves and enforces tariffs and fees charged by licensees; (iii) approves licensees' terms and conditions of electricity supply; and (iv) approves initiation of the procurement of new electricity supply installations.

Under the 2008 Act, the following activities require a license as stated in section 8 (1) of the Electricity Act No. 10 of 2008 which shall be issued by EWURA: a) Generation; b) Transmission; c) Distribution; d) Supply; e) System operation; f) Cross border trade in electricity; g) Physical and financial electricity trade; and h) Electricity installations.

EWURA is charged to (i) protect customer's interests through the promotion of competition; (ii) promote access to, and affordability of, electricity services particularly in rural areas; (iii) promote least-cost investment and the security of supply for the benefit of customers;

The principles of tariff regulation are set out in the Electricity Act, notably as follows (i) tariffs should reflect the total cost of efficient business operations, without subsidies or grant; (ii) tariffs should be sufficient for the licensees to have a fair return on their investments; and (iii) tariffs should contain incentives to a more effective electricity consumption and should encourage adequate supply to satisfy demand. The approved tariffs may include automatic adjustments for changes in costs of fuel, power purchases and fluctuations in exchange rates.

It is worth noting that EWURA in the exercise of its functions has to consult the relevant Ministries on matters of (i) security; (ii) compulsory acquisition of land; (iii) preservation of the environment;(iv) cross-border trade in electricity; and (v) development of other sources of energy in the electricity supply.

Rural Electrification

The Rural Energy Act, adopted in June 2005, established the **Rural Energy Agency** (REA), the Rural Energy Fund and the Rural Energy Board. REA was in fact created in October 2007, with the objective of "promoting rural socio-economic development by facilitating extended access to modern energy services" in rural areas of Mainland Tanzania" (thus excluding the island of Zanzibar). REA is governed by the Rural Energy Board, and its activities are financed by the Rural Energy Fund.

The principles of Rural Electrification, as set out in the Act, are that:

"(i) sustainable development shall be achieved when modem energy services in rural areas are promote d, facilitated and supported through private and community initiative and involvement;

(ii) the role of Government in rural energy service provision is that of a facilitator of activities and investments made by private and community entities;

(iii) the fulfilment of Government's role shall be best managed through an institution that is independent."

Rural Electrification Fund (REF) has the mission to provide grants to qualified rural electrification project developers. REF is funded by the Government annual budgetary allocation, international development partners and levies (up to five per cent on commercial generation of electricity to the national grid and on the generation of electricity in specified isolated systems, including systems for private consumption).

The resources of the Fund can be used for:

(i) grants to qualified developers, for example to co-finance (a) training and other forms of capacity building; (b) the provision of technical assistance related to the planning and preparation of a project prior to an application for a grant, including pre-investment studies for projects; (c) the capital costs of a project implemented; and (d) investments in innovative pilot and demonstration projects and applications for renewable energy when development partners make funds available for that purpose.

(ii) payment or discharge of the expenses or obligations incurred in connection with the performance of the functions of the Agency and the Board; and

(iii) payment of any remuneration or allowances to the members of the Board and employees of the Agency.

The Fund may not make grants towards the operating or debt service costs of any project or developer.

A Trust Agent is selected by REF after a public tender to manage the disbursement of grants. The Trust Agent is a commercial bank (currently Tanzania Investment Bank – TIB), which is responsible for the administration of grant payments, including financial disbursement, verification and monitoring activities from the contract signing to commissioning.

Until now, notwithstanding its role, functions and financial resources through REF and various donors programs, it has to be noted that the bulk of activity of REA has been to manage turn-key rural electrification programs that are built by private contractors, then transferred to TANESCO and connected to its grid.

The Public Utility[1]

TANZANIA ELECTRIC SUPPLY COMPANY LIMITED (TANESCO Ltd) is a limited company fully owned by the Government of Tanzania under the Ministry of Energy and Minerals and hence was duly registered under the Companies Act Cap 12 [R. E. 2002] as amended, under the Registrar of Companies under the Business Registration and Licensing Authority (BRELA). The New Electricity Act No. 10 of 2008 (see above) as amended which repeals the Electricity Act Cap 131[R. E. 2002] is the law that facilitates and regulates generation, transmission, distribution, supply and use of electric energy and hence is the main act that governs TANESCO Ltd works as being the current sole licensee.

TANESCO Ltd, the historic monopoly company, currently carries out most of the distribution, transmission and generation activities within the Country, with the exception of some small generation and distribution companies delivering small quantity of electricity in rural areas.

Environmental issues, licenses and permits

Most SPPs will progress through the following steps;

- Project identification;
- Securing rights to the resource;
- Acquiring necessary permits and licenses;
- Financing;
- Construction;
- Testing and Commissioning; and
- Operation and reporting,

Consents (permits, licenses, and clearances) required by various authorities for a grid-connected SPP are briefly presented below. While many of these steps may be completed contemporaneously, some steps require prior permissions.

[1] Extracted mostly from Tanesco's Web Site (www.tanesco.co.tz)

These steps have been developed in the Guidelines for Developers of Small Power Projects in Tanzania from EWURA (2009).

The right to renewable energy resources that can be used to make electricity is sometimes contested. To avoid competing claims on the same resource, it is important that the SPP developer is able to demonstrate that he is the legal holder of rights of sufficient resources to make the project viable. For a hydropower project, required documents include water rights permission issued by the appropriate River/Lake Basin Water Office. Contact information depends on which basin the project is in. The water basins include: Pangani Basin, Rufiji Basin, Lake Victoria, Wami-Ruvu, Lake Nyasa, Lake Rukwa, Internal Drainage Basin to Lake Eyasi, Manyara and Bubu Depression, Lake Tanganyika, Ruvuma and Southern Coast. The Division of Water Resources within the Ministry of Water and Irrigation (MOWI) coordinates activities of the Water Basins.

In addition to permission from the River/Lake Basin Water Office, the project developer must also obtain written consent from the respective village government where the project will be executed.

2.1.2 Specificities of the Institutional and Legal Framework in Tanzania

During the last 10 years, various important reforms were implemented in the electricity sector: the new Electricity Act in 2008, creating the Energy and Water Utilities Regulatory Authority (EWURA), the Rural Energy Agency (REA) and the related Rural Energy Fund (REF). In 2010, the National PPP Law was adopted in 2010.

Relating to rural electrification and access to electricity, a comprehensive regulatory framework was developed and adopted by EWURA which included standardized power purchase agreements (SPPA) and tariffs (SPPT) for small power projects (SPPs either connected to the main grid or operating on isolated grids), simplified regulatory rules for small power projects and comprehensive guidelines for the project developers.

Now the regulatory framework, in theory, reaches international standards but still suffers from insufficient application, which might negatively alter the perceived level of risks for private investors considering investments in the Tanzanian electricity sector.

The principles of the reform set out in the Act, are suitable for the introduction of a competitive market, a Third Party Access (T.P.A.) regime and the relinquishment of any previous "Single Buyer" regime. For example, the Act mandates the Minister to define the "eligible customers" who cannot exist in the present 'single buyer regime'.

The 2008 Act can be considered as the basis of a reform towards the liberalization of the market. For example, it is written that the Minister has to define "the part of the electricity market that shall be subject to competition" but the words "electricity market" nor "electricity sector" are not used, which makes the concept a bit vague. Moreover, it is written that the Minister will have to define "the form of competition that shall be introduced in each relevant part of the electricity market".

Some statements are even more disturbing, such as paragraph 41.6 stating, "Notwithstanding the preceding provisions of this section, the Tanzania Electric Supply Company shall have a right to first refusal to the supply of electrical energy to all intensive electrical energy consumers". This means that, in practice, the future eligible consumers will not be free to contract with any supplier of their choice. This can be very detrimental for investors and IPPs.

Some other key points should also be underlined:

- To date, the legal framework for a fair competition and for attracting the private sector is still not in place, although some principles are already encrusted in the Act: no unbundling, no eligible consumers, Single Buyer system still in place, no Independent System Operator, TANESCO right of first refusal for supplying intensive consumers, etc.
- The legal framework does not seem to offer the sufficient security and stability that would be perceived as incentives for a more significant commitment of the private sector: For example, in Chapter 41.3:"The Minister may, in consultation with the Authority, the Fair Competition Commission, consumers and players in the electricity supply industry, amend the policy at any time." Or in Chapter 10.2:"The Authority may change terms and conditions of any license issued under this Act, provided that (a) the licensee has been informed of the change or (b) the modification is in the public interest, where the benefits to the public significantly exceed any disadvantages to the licensee." But, there is no mention whatsoever of any compensation to the licensee for loss of revenues, etc.

Considering the Rural Electrification, part. VIII of the Electricity Act practically prevents any private investor in entering the distribution activity as they will not be allowed to supply any "intensive energy consumer". It looks as if the private sector had to be limited to the non-profitable consumers. New initiatives are now taken by EWURA, to develop a regulatory framework for distribution licensees in rural areas. These licensees should be granted the right to supply "intensive energy consumer".

2.1.3 Electric Sector Reform Strategy and Roadmap

In June 2014, considering the supply and financial crisis known by the country in recent years, the Government adopted the long awaited Report "Electricity Supply Industry Reform Strategy and Roadmap 2014 – 2025", defining how and according to which calendar the electric sector will be reformed until complete unbundling of the state-owned electricity utility, and liberalization of the electricity trade.

The reform initiatives and key actions cover the period from 2014 to 2025, with the objective to meet the current and future demand for electricity; reduce public expenditure on ESI for operational activities; attract private capital; and increase electricity connection and access levels. It has to be noted that it is fully coherent with "Big Results Now (BRN)" as described below. It should increase transparency and competition and lead to abolition of subsidies in the electricity sub-sector.

At present, Tanzania electric sector operates on the single buyer model. The reforms envision moving gradually from the single buyer model to retail competition market.

During the reform process, REA shall continue to play an instrumental role in promoting access to modern energy services.

The strategy proposes a four stage process that will result in a fully competitive electricity market structure by 2025:

- Immediate Term (July 2014 – June 2015)
- Short Term (July 2015 – June 2018)
- Medium Term (July 2018 – June 2021)
- Long Term (July 2021 – June 2025)

During the process, an Independent System Operator (ISO) shall be established in line with Section 20(1) of the Electricity Act, 2008 and will coordinate power supply system, dispatch power to transmission facilities and monitor cross-border electricity trading. The operator will operate the power system based on the Grid Codes developed by the Regulator. An Independent Market Operator (IMO) as well, in accordance with Section 20(2) of the Electricity Act, 2008 shall be established and regulated. The IMO shall administer operations of the wholesale electricity market trading.

a) Immediate term (July 2014- June 2015)

Amongst others, tasks to be undertaken during that phase include:

- Review the Electricity Act, 2008 particularly Section 41(6) of, to allow private generators to supply power directly to bulk off takers;
- Developing technology based Standard Power Purchase Agreement (PPA) model;

TANESCO will remain vertically integrated with ring fenced business units.

b) Short Term (July 2015 – June 2018)

The short term will involve the following tasks:

- Unbundling of generation segment from transmission and distribution segments by December 2017;
- Designating an Independent Market Operator (IMO) to manage wholesale and retail electricity trading.

The existing TANESCO will continue to be responsible for transmission and distribution until June 2021 when distribution is unbundled. Based on tariff and wheeling charges approved by the regulator, bulk off takers would be able to buy power directly from generators by paying wheeling charges to the transmission company. However, monopoly characteristics will still exist in the transmission and distribution.

Wholesale prices of electricity are fixed by respective Power Purchase Agreement (PPA) signed by buyer and respective private generation companies. IPPs, SPPs and PPPs will be procured competitively.

c) Medium Term (July 2018 – June 2021)

After following tasks, amongst others:

- Unbundling of distribution from transmission segment;
- Setting up a mechanism and rules for the operation of a retail market for electricity by the Regulator;

the market structure envisaged in the medium term comprises a competitive power generation segment.

At the end of the period, the electric sector is vertically unbundled into three segments: generation, transmission and distribution. A wholesale market exists and generation companies are competing for bulk supply of electricity. A regulated monopoly transmission company undertakes the transmission role. The distribution and retailing of electricity to the final consumer is done by a Government owned Distribution Company.

d) Long Term (July 2021 – June 2025)

In the long term, commercially viable zonal offices will be established as independent distribution companies; the task thus will be to unbundle gradually distribution segment gradually into several Zonal distribution companies.

The electric sector is vertically unbundled into four segments: generation, transmission, distribution and retailing. The generation segment is comprised of a number of companies competing for wholesale supply of electricity to retailers. The Transmission Company undertakes the transmission role. The independent system operator (ISO) and independent market operator (IMO) undertake system and market operation. Distribution is horizontally unbundled.

Transmission will be fully owned by the Government, with Third Party Access: Transmission infrastructure will be guaranteed by relevant rules issued by the Regulator.

The price of electricity is determined by market forces with many buyers and sellers. Wholesale prices of electricity will be fixed in bilateral PPA between generators and distribution companies and/or retail companies. The retail market will also be competitive with prices determined by market forces. The Regulator will only set the tariff for transmission and distribution companies.

Customers will be free to choose electricity supply from a large number of retailers operating in the region.

2.2 ELECTRICITY DEMAND AND ACCESS RATE

2.2.1 Electricity Demand and access rate

For many years, the Tanzanian Electric system has not been able to satisfy the growing demand for electricity. Load shedding and power outages have become almost normality. The consequence is that naturally demand is supply driven, and thus it is very difficult to estimate what it could be if supply were sufficient. Government estimates are that demand for electricity is on average growing between 10 % and 15 % per annum.

The peak demand[2] reached 1026MW in 2016 with the average figure being around 950 MW. The total energy generated for the year ending June 2016 distributed to TANESCO customers was 6,449GWh. The Government of Tanzania declares that the per capital consumption is around 137 kW/year. According to the Energy Access Situation Report published in 2016, the electrification rate is much higher in urban (65.3%) than in rural areas (16.9%).

The transmission system is currently composed of 647km of 400kV lines, 2,745km of 220kV lines, 1,626km of 132kV lines and 580km of 66kV lines. However, the distribution and transmission losses are at 16.4%.

2.2.2 Demand Forecast

The 2016 Power System Master Plan expects an increase of electricity demand[3] by 11.1% going from 6,310GWh in 2015 to 87,890GWh by 2040. The Government of Tanzania plans to accelerate industrial development and has the purpose of expanding the power generation capacity up to 4,915MW by year 2020.

[2] Energy and Water Utilities Regulatory Authority (EWURA), *Annual Report for the year ended 30th June*, 2016

[3] The 2016 Power System Master Plan (PSMP), Ministry of Energy and Minerals, December 2016

The power demand forecast as defined in the Power System Master Plan is shown in the table below.

YEAR	2020	2030	2040
Energy demand[4] [GWh]	13 440	36 000	87 890
Peak demand [MW][5]	3,916	7,590	16,050

To meet the growing demand, TANESCO and Regional demand data survey evaluate that the total installed capacity should reach 5,091MW by 2020, 9,867MW by 2030 and 20,865MW by 2040 (base scenario).

2.3 POWER GENERATION - CURRENT AND PROJECTED SITUATION

As of June 2016, Tanzania's total installed generation capacity was 1,442 MW composed of 31% hydro generation, 56% natural gas, 13% liquid fuel generation. An installed capacity of 1,358 MW supply the Main Grid and 84 MW the Isolated Grids. The 2016 Power System Master Plan recommends for the future years an increase of the total installed generation capacity in accordance with the table presented below. To improve the growing demand and the security of supply, the GoT intends to diversify the sources of electricity generation to include natural gas, coal, hydro and renewable energies.

Table 2 Future generation plan[6]

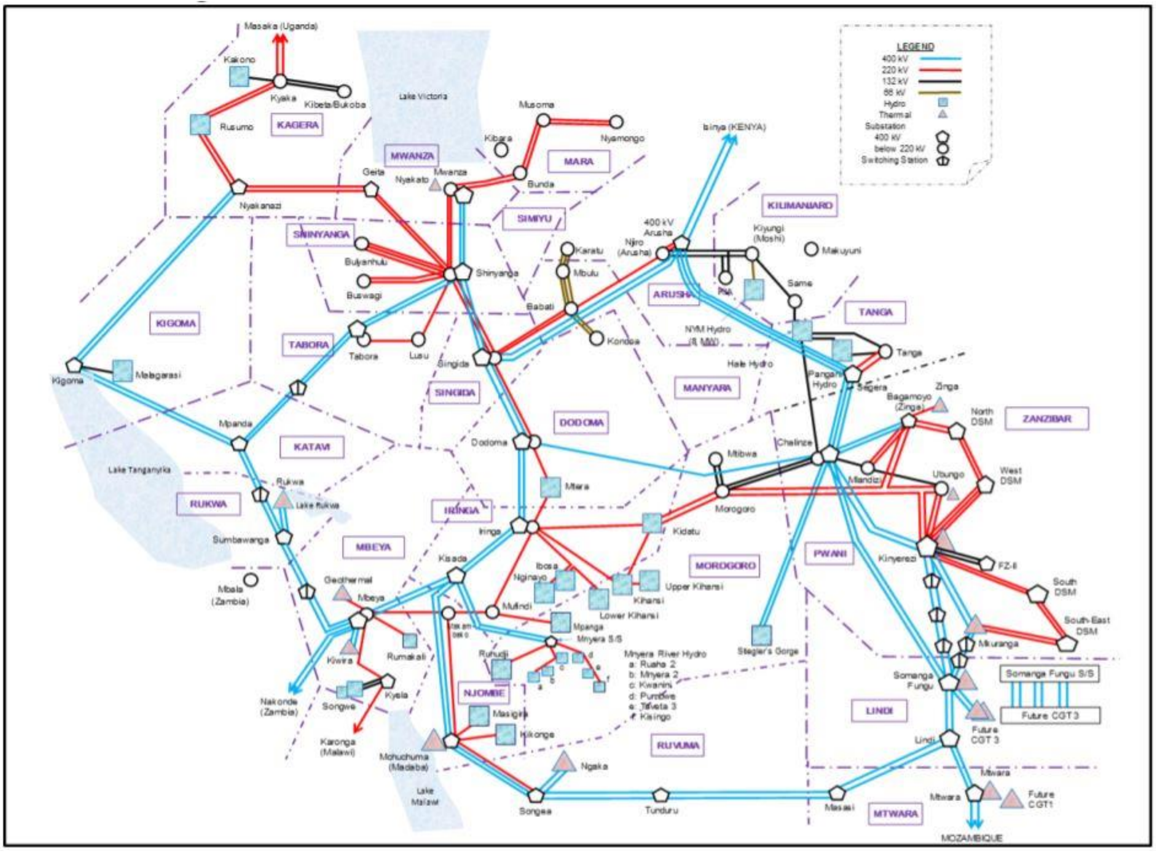
SOURCE OF ENERGY	CAPACITY BY 2040 [MW]
Hydro	5,011
Gas-fired	10,253
Coal	6,000
Renewable	850
Import	400
TOTAL	22,595

In order to achieve this goal, the generation plan[7] has to reach a total installed generation capacity of 5,011 MW (renewable and import no-included) by 2020 and 22,595 MW by 2040. The best scenario selected plans an energy generation mix of 40% gas, 35% coal, 20% hydro and 5 % renewable. The current government aims to reach an overall electrification rate of 75% by 2033.

These results lead to develop a new global grid network to support this project covering a large part of the territory as shown on the figure below. Reinforce distribution network is vital to meet electrification targets. Most of projects proposed under the Power System Master Plan 2012 Update has not been completed due to a lack of sufficient financing. Find financing resources and attract investment will be decisive to the success of such projects.

[4] Base scenario
[5] Base scenario (source : Analysis by the Task Force Team)
[6] Optimal generation plan (scenario-2)
[7] The 2016 Power System Master Plan (PSMP), Ministry of Energy and Minerals, December 2016

Figure 2 Generation and Transmission Plan – Year 2040[8]



2.4 FINANCIAL SITUATION AND FINANCING REQUIREMENTS

TANESCO's financial situation is rather precarious worrying for quite a long period already. It is one of the reasons for the urgent reform and restructuring plan recently put in place by the Government (under pressure from the international financial community).Table below show some financial indicators: over the nine-year period (2003 – 2011), there was only a single year where TANESCO had made a profit before tax. Even worse, there was only a single year where the operation had not been a loss-making exercise.

Table 3 Key Financial Indicators of TANESCO (million USD)

	2003	2004	2005	2006	2007	2008	2009	2010	2011
Electricity Sales	159	173	196	185	234	310	313	324	344
Power purchase cost	68	114	156	187	195	162	141	147	228
Total cost of sales	183	244	250	290	308	307	326	342	485
Operating profit (loss)	(63)	(33)	(22)	(125)	(51)	2	(2)	(0)	(22)
Profit (loss) before tax	(214)	(104)	43	(125)	(54)	(18)	(36)	(31)	(48)
Average tariff (US cent/kWh)	6.83	7.02	7.47	6.69	7.35	9.18	9.00	7.76	10.49

[8] The 2016 Power System Master Plan (PSMP), Ministry of Energy and Minerals, December 2016

Sources:
2003 – 2009: Power Sector Reform and Regulation in Africa, p.30
2010 – 2011: Audited Financial Statements 2011, p.23 and p.51. Exchange rate: 2010 – 1440 TSH/USD, 2011 – 1585 TSH/USD (consultant's estimates). Average tariff (= average price paid) calculated from statistics obtained from TANESCO.

In 2011, TANESCO's financial situation has suffered from the very high costs of its emergency generation program (rental of generators to private operators), caused by a severe shortage of hydropower generation.

According to figures given in the World Bank Program Document on the First Power and Gas Sector Development Policy Operation, dated January 26, 2013, and data from Tanesco Corporate Business Plan of 2013, the Government projections forecast an accumulated deficit of TANESCO, without government subsidies, to be at around US$1 billion between 2012 and 2014, depending on the scenarios relating to hydrology and the investment plans (at constant tariff). The Government had committed to closing the residual financial deficit in the sector through budget subsidies during the transition period. The authorities have engaged to do so within the limit of the macroeconomic and fiscal framework agreed upon with the IMF.

On another hand, the scope of investment required to implement plans and meet Government policy objectives as explained above, is significant. The Power System Master Plan (Update 2013) identifies short term financing requirements (2012 to 2017) as USD 11.4 billion, or about USD 1.9 billion per year of which 73.5 % would be needed for generation. The generation additions to reach 7900 MW peak in 2035 (around 46000 GWh) may require total capital investment costs of 17.5 billion USD (without inflation and IDC) until 2035.

2.5 RENEWABLE AND RURAL ENERGY

The table, inserted in section 2.3 above, as extracted from the "Electricity Supply Industry Reform Strategy and Roadmap 2014 – 2025", shows that on an additional capacity projected to be 9,300 MW between 2015 and 2025, the new and renewable energies (excluding hydro) represents only 500 MW, or 5,4 %. This table does not specify what is the portion of the small hydro in the foreseen 1,500 MW of new hydro capacity.

The Reform Strategy Study has been thought as a national strategy for the Tanzanian Electric Sector as a whole, not distinguishing urban and rural energies. The investments needed to reach the access objectives, notably in rural areas, are not specified. But the document indicates clearly the willingness to create in the short term 7 "zonal distribution business units", which of course shall include rural areas not very well served until now.

This strategic Document sates explicitly that: "During the reform process, REA shall continue to play an instrumental role in promoting access to modern energy services. In this context, rural electrification activities will continue to be funded by the GoT and Development Partners through the Rural Energy Fund. To increase connection and access levels, REA will facilitate support installation and maintenance of rural distribution systems."

2.6 OTHER RENEWABLE ENERGY SOURCES

The following data are largely issued from the SREP-Investment Plan for Tanzania (2013).

2.6.1 Geothermal Energy

Tanzania has significant geothermal potential that is not yet fully quantified. Estimations using analogue methods indicate a potential exceeding 650 MW, with most prospects located in the East African Rift System. Most geothermal prospects have been identified by their on-surface manifestation, mainly hot springs. Surface assessments started in 1976 and, to date, more than 50 sites have been identified. These are grouped into three main prospect zones: northeastern (Kilimanjaro, Arusha and Mara regions), southwestern (Rukwa and Mbeya regions), and eastern coastal belt, which is associated with rifting and magmatic intrusions (Rufiji Basin). Only the southwestern zone has undergone detailed surface exploration studies. In 2006 and 2010, the MEM, in collaboration with the Geological Survey of Tanzania (GST), the German Federal Institute for Geosciences and Natural Resources (BGR), and TANESCO, carried out surface exploration and conducted detailed studies in the Ngozi-Songwe prospect in the Mbeya region.

2.6.2 Wind

Several areas of Tanzania are known to have promising wind resources. In areas where assessments have been conducted to date, only Kititimo (Singida) and Makambako (Iringa) have been identified as having adequate wind speeds for grid-scale electricity generation. At Kititimo, wind speeds average 9.9 miles per second and 8.9 miles per second at Makambako, at a height of 30 m. The MEM, in collaboration with TANESCO, is conducting wind resource assessments in Mkumbara (Tanga), Karatu (Manyara), Gomvu (Dar es Salaam), Litembe (Mtwara), Makambako (Iringa), Mgagao (Kilimanjaro), and Kititimo (Singida). The REA is supporting wind measurements at Mafia Island (Coast region). MEM and TANESCO will be conducting wind resource assessments in Usevya (Mpanda). To date, four companies have expressed interest in investing in wind energy, namely Geo-Wind Tanzania, Ltd. and Wind East Africa in Singida and Sino Tan Renewable Energy, Ltd. and Wind Energy Tanzania, Ltd. at Makambako in Iringa. These companies are considering investments in wind farms in the 50–100 MW range.

2.6.3 Solar

Tanzania has high levels of solar energy, ranging between 2,800 and 3,500 hours of sunshine per year, and a global radiation of 4–7 kWh per m^2 per day. Solar resources are especially good in the central region of the country. Thus, solar energy as a viable alternative to conventional energy sources is a natural fit for Tanzania if efficiently harnessed and utilized. Both solar PV and solar thermal technologies are under development in the country.

2.6.4 Off-Grid Solar Photovoltaics

To date, about 6 MWp (megawatt peak) of solar PV electricity has been installed countrywide for various applications in schools, hospitals, health centers, police posts, small telecommunications enterprises, and households, as well as for street lighting. More than half of this capacity is utilized by households in periurban and rural areas. The government is implementing awareness-raising and demonstration campaigns on the use of solar systems for domestic and industrial use, as well as supporting direct installation in institutions. To make solar PV more attractive, the government has removed the value added tax (VAT) and import tax for main solar components (panels, batteries, inverters, and regulators), which has allowed endusers to get PV systems at a more affordable price.

2.6.5 Grid-Connected Solar Photovoltaics

In central Tanzania, a MWp of solar PV generates about 1,800 MWh per year (net of losses), and will require about 1 hectare of land. Theoretically, the total estimated 2025 electricity demand of 27,000 GWh could be met by solar PV fields of about 15,000 hectares or about 0.02 percent of Tanzania's land mass. That is, the theoretical potential of solar is unlimited. However, for purposes of system stability, solar is usually restricted to less than 20–30 percent of daytime peak demand. On the basis of a 20 percent constraint, the potential for grid-tied solar in 2025 could be about 800 MW. Given that large-scale, grid-tied solar PV installations are being undertaken in some countries for under US$ 1,750 per kWp, its prospects in Tanzania should be excellent. The Power System Master Plan (PSMP) envisages 120 MWp of solar in the power expansion plan by 2016. Several private firms have expressed interest in investing in 50–100 MWp of solar PV. NextGen Solawazi has signed a SPPA with TANESCO to supply electricity from 2 MWp of PV to an isolated grid. TANESCO has also signed a Letter of Intent (LOI) for a 1 MWp isolated grid-tied PV project. There is also a potential value in using solar and hydro in combination by adding capacity value to a power source considered intermittent.

2.6.6 Solar Thermal

Solar thermal energy has been used for generations in Tanzania for drying crops, wood, and salt. Currently, solar dryers are used in the agricultural sector to dry cereals and other farm products, including coffee, pyrethrum, and mangos. The Sokoine University of Agriculture, University of Dar es Salaam and TaTEDO have been at the forefront of promoting solar dryers. These institutions are also promoting solar thermal for cooking in parallel with solar drying. Solar water heating systems in Tanzania are used mainly by households and various types of institutions (e.g., hotels, hospitals, health centers, and dispensaries). Despite the potential of solar thermal and the demand for low-temperature water for both domestic and commercial applications, the uptake level is low. Lack of awareness, inability to mobilize financing, relatively lower priority given to such investments are some of reasons attributed to the little use of solar hot water heating.

2.6.7 Biomass

Biomass is Tanzania's single largest energy source. According to REA estimates, agricultural, livestock, and forestry residues amount to about 15 million tons per year (MTPY). A portion of that amount may be available for use in power generation. This includes sugar bagasse (1.5 million MTPY), sisal (0.2 MTPY), coffee husk (0.1 MTPY), rice husk (0.2 MTPY), municipal solid waste (4.7 MTPY), and forest residue (1.1 MTPY), with the balance from other crop waste and livestock. Further supplies can be obtained through sustainably harvested fuelwood from fast-growing tree plantations. For example, a 50 MW biomass power plant could obtain all its fuelwood needs from a 10,000 hectare plantation.

2.6.7.1 Heat Applications

Much of the biomass is used for heat applications. These include cooking in the residential sector and process heating for agriculture and industry.

2.6.7.2 Power Production

Tanzanian industry using wood or agricultural feedstock (e.g., sugar, tannin, and sisal) has been generating its own power from waste biomass materials. It is estimated that about 58 MW of such generation is taking place.

Under the SPPA program, two biomass power projects are supplying power to TANESCO: TPC, a major sugar producer with an SPPA for 9 MW of power, and TANWATT, a tannin producer with an SPPA for 1.5 MW. In June 2013, a third SPPA for 1 MW, the Ngombeni project, is expected to be commissioned to supply power to TANESCO's isolated grid on Mafia Island. TANESCO has signed SPPAs for three additional biomass projects with a total capacity of 9.6 MW.

3 SCALING UP THE DEVELOPMENT OF SMALL HYDROPOWER IN TANZANIA

3.1 CHALLENGES FOR THE DEVELOPMENT OF SMALL HYDRO IN TANZANIA

Tanzania is emerging as one of the few Sub-Saharan Africa (SSA) countries with a viable mini-grid program where mini-grids are operated by private companies that could be scaled up. In 2015, TANESCO had signed Small Power Purchase Agreements (SPPA) with 11 developers for 46.1 MW. Three are already selling power to TANESCO. It has also signed 7 Letters of Intent, a precursor to signing the SPPA, with 30.9 MW of projects.

Availability of renewable energy resources, increasing electricity demand, the supportive Government vision and the readiness among private sector players create viable opportunities for expanding renewable-based on grid or off-grid electrification solutions. There was consensus that Tanzania should support development of renewable energy technologies for rural electrification.

Three types of connection exist in Tanzania: main grid (Tanesco), mini-grid (Tanesco) and stand-alone off-grid system powered by a unique source of production (Tanesco/Private). These three types have the following characteristics:

3.1.1 Interconnected main grid (Tanesco)

Small hydro projects given their size and their relatively high costs of production (and with a marginal production on the network) are generally difficult to justify economically in a least cost expansion plan. This justification is mainly done by comparison with an equivalent thermal plant running on heavy fuel oil (HFO); this involves making the largest possible unity (close to 10 MW in the case of this study) to be competitive and if possible close to the HV network to minimize connection costs.

Production shortfalls during low flow periods, particularly for run-of-the river hydropower plants are relatively not disadvantageous given the limited impact that can be easily compensated by thermal power plants.

These projects must meet the standards set by Tanesco to be connected to the main grid. Projects that have a possible regulation (downstream of a reservoir) have the advantage of delivering slightly more base or peak power to the network.

The new hydroelectric options considered in the PSMP (Power System Master Plan - 2012 Update, May 2013) does not include any small hydropower projects.

3.1.2 Mini-grids (Tanesco/Private)

Hydropower projects of intermediate size can easily supply mini-grids operated by Tanesco or by a private distribution and production company that often have other expensive source of production (diesel), intermittent (solar and wind) or from local biomass. Deficits during periods of low flow require more from the thermal power plants to address the production shortages in the dry season.

For each of the mini-grids, a specific and dedicated development plan has to be produced by the Ministry of Energy and Mines/EWURA and all operators based on competing sources of production (hydro, solar, etc.).

The intermittent feature of renewable energy sources, particularly solar and wind, makes challenging the power grid operation and the scheduling of hydro and thermal power plants.

Finally, the distance between some small hydropower projects and their load centers can in some cases double the construction costs of the project which is hence less economically and financially attractive.

3.1.3 Stand-alone off-grid systems powered by a unique source of production

These power grids are supplied by small power plants (less than 1MW) that are located near the load centers. They are usually planned with the Government in the context of bilateral programs of rural or decentralized electrification.

Such small hydropower projects can only be economically justified by the comparison with costly diesel-fired power generators.

To meet the daily energy demand, the design flow of these small run-of-the-river hydropower plants should be as close as possible to the guaranteed low flow in order to consistently produce and dispose, if technically feasible, with a sufficient modulation capacity to supply the (daily) power peaks.

3.2 STRENGTHS AND WEAKNESSES OF SMALL HYDROPOWER DEVELOPMENT

The table below summarizes the strengths and weaknesses of the small hydro sector in Tanzania. It also presents recommendations to accelerate the development of small hydropower projects in Tanzania.

CONNECTION TYPOLOGY	STRENGTHS OF SMALL HYDROPOWER (1-10MW)	WEAKNESSES OF SMALL HYDROPOWER (1-10MW)	RECOMMENDATIONS
Main Grid *(TANESCO)*	- Opportunity for projects located at a short distance from the existing HV grid: Reduced cost of the transmission line to **strengthen the main grid**. - **Positive impact on GHG emissions:** Participation in reducing greenhouse gas emissions to achieve the long-term country objectives. - **Potentially eligible for CDM credits:** Improved profitability of projects if they have access to CDM credits from the World Bank. **- Low investment costs and reduced barriers to funding:** Small hydro projects that have competitive production costs with larger projects require a much lower investment cost. Financial closure is therefore facilitated. - **Shorter development process:** Duration of development and construction (including financial closure) is shorter than for large hydro. Hence, projects smaller than 10MW are faster online to supply electricity in the shorter-term. **- Competitive production costs compared to thermal:** Opportunity to replace thermal-fired production by cheaper and cleaner energy from hydropower**.** - **Energy independence:** partial replacement of energy from thermal-fired stations by small hydro reduces the need to import petroleum products, which are expensive and vulnerable to international market price fluctuations. **- Reduced environmental and social impacts** compared to large hydro projects. **- Flexibility in maintenance:** The impact of maintenance will overall have a lesser impact to national electricity output compared with for large hydropower projects. In addition, proper planning of this maintenance allows for greater flexibility.	- **Large hydro is generally preferred in national master plans:** large hydro projects are often favored in national master plans over smaller projects. In Tanzania, however, even projects of 5-10 MW can make a significant contribution to the country's energy mix. **- Potential saturation of the grid:** smaller projects are less able to justify HV lines once the grid is saturated. **- Firm power:** small hydro projects usually have limited storage capacity (reservoir) for peak production.	- **Promote short-term development projects with a capacity up to 10MW:** particularly projects that feature (i) short distance to main grid (ii) existing access roads, (iii) economically attractive with low production costs compared to other alternatives (thermal), (iv) reasonable hydrological and socio-environmental risks**.** **- Master Plan Study:** master planning should include planning scenarios analysis, taking into account the economic benefits of gradually increase the number of small hydro projects versus a single large project.
Mini-grids *(TANESCO/Private)*	- **Supply and demand balance**: The size of small hydropower projects often match better the local electricity demand. - **Energy supply to remote load centers** that would not benefit from the development of the energy produced by large	- **Complex master planning of mini-grids** due to the large number of candidate projects and energy mix alternatives. - **Complex operation of grids with a significant share of intermittent sources of renewable energy**: small hydropower (without regulation capacity (reservoir)) cannot adequately	- **Development of an investment plan** for the development of small remote load centers which consider the various sources of energy (wind, solar, biomass, thermal). **- Prioritize small hydropower projects close to remote centers** based on their cost compared to thermal units.

CONNECTION TYPOLOGY	STRENGTHS OF SMALL HYDROPOWER (1-10MW)	WEAKNESSES OF SMALL HYDROPOWER (1-10MW)	RECOMMENDATIONS
	hydropower and thermal projects since transmission and distribution lines would not reach those remote areas. - **Ability to obtain financial aids** (Concessionary finance, subsidies at low interest rates) given the capital-intensive nature of hydroelectric projects.	manage intermittent production of other RE sources such as solar and wind.	- **Where possible, provide for a phased development of small hydropower projects** following to increasing energy demand (e.g. number of penstocks and turbines/generators). - **Invest in the development and rehabilitation of roads and rural tracks** that would reduce the investment costs for the development of small hydro projects and thereby strengthen their competitiveness against large hydro.
Stand-alone off-grid systems *(supplied by a single production source)*	**- Ability to reduce development costs**: The design may be simplified to reduce production costs. **Supply and demand balance**: The size of small hydropower projects often match better the local electricity demand. - **Energy supply to remote load centers** that would not benefit from the development of the energy produced by large hydropower and thermal projects since transmission and distribution lines would not reach those remote areas. - **Ability to obtain financial aids** (Concessionary finance, grants, subsidies at low interest rates) given the capital-intensive nature of hydroelectric projects.	**- Not suitable in areas with significant periods of low flows:** The development of hydroelectric project on rivers that feature dry periods (zero streamflow) during a given period of the year is usually not appropriate for multiple reasons amongst which: (i) no energy generation during several months of the year; (ii) production difficult to predict; (iii) high maintenance costs and (iv) operation and maintenance constraints. **- Complex planning:** Complexity to undertake the necessary studies across the entire country.	- **Promote the development of projects in areas that feature favorable hydrological conditions.** **- Plan for ultimate grid integration of projects: w**hen possible, in the development of projects plan to allow future connection to the network, so that these projects are not abandoned after connection to the main grid occurs. - **Investing in the development and rehabilitation of roads and rural tracks** that would reduce the investment costs for the development of small hydro projects and thereby strengthen their competitiveness against large hydro.

3.3 SMALL HYDROPOWER DEVELOPMENT: AN OPPORTUNITY FOR TANZANIA

In the light of the strengths and weaknesses of small hydro presented in the previous section, the size of projects considered in this study (0.3-10 MW) offers interesting opportunities to support energy development in Tanzania.

Small hydropower, compared to other sources of energy, has the following comparative advantages and complementarities:

Table 4. Comparative advantages and complementarities of Small Hydro towards other sources of energy

OTHER SOURCES OF ENERGY		SMALL HYDRO (1~10MW)	COMPARATIVE ADVANTAGE	COMPLEMENTARITY
Thermal		Small hydropower is a very interesting alternative to thermal energy and particularly diesel-fired generators, especially in remote areas where the fuel costs are high due to the transportation costs. Considering that small hydropower reduces the need for fuel imports, it has a direct beneficial effect on the balance of payments of Tanzania. Given an estimated marginal production cost between 146 US$/MWh on the main grid for the current hydro-thermal mix (2013-2020)[9] and 590 US$/MWh[10] for isolated diesel generators, many small hydropower projects are an attractive alternative source of supply (direct competition with thermal production). However, there is a strong complementarity of small hydro and thermal power plants that can compensate the power production during the low flow periods and/or for (daily) peak power.	✓✓✓	✓✓✓
Large hydro	**Run-of-the river**	Large hydropower projects usually have a lower marginal production cost. Small hydropower projects are however often: • Faster online due to faster development and construction ; • Faster and easier financial closure ; • The size of small hydropower projects often match better the increasing local electricity demand. • Lower socio-environmental impacts • Reduced impact of shut-down (inspection, maintenance, failures): large hydro has a severe impact on the whole system whereas small projects will have a limited impact. Given that large projects usually have a low production cost, any new major project will challenge the relevance of smaller projects, especially those operated by private companies. Small and large projects are therefore rather in competition than complementing each other.	✓✓	-

[9] Ministry of Energy and Minerals, Power System Master Plan 2012 - Update (may 2013)
[10] SREP - Investment plan for Tanzania (2013)

OTHER SOURCES OF ENERGY		SMALL HYDRO (1~10MW)	COMPARATIVE ADVANTAGE	COMPLEMENTARITY
	Reservoir	Small hydro projects with a reservoir can be expensive with high marginal production costs if analyzed as an individual projects. Small hydro shall directly benefit from existing reservoir hydropower projects that will regulate the low flow periods and allow for peak power production. Cascade development is recommended.	-	✓✓✓
Wind		Where small hydropower potential exists, it is usually economically competitive compared to windpower (from US$ 96 to 130/MWh)[11]. Energy generation from small hydro has the advantage of being more predictable with steady production. Wind energy must be compensated by other sources of non-intermittent energy which result in additional costs. However, in region where the conditions are not favorable for the development of small hydro projects (West center and North center of the country), wind power does not compete with small hydro. Some complementarity could exist in the future with the development of small grids combining hydro-wind-thermal or medium capacity pumped-storage projects associated with wind projects.	✓✓✓	✓✓
Solar PV		Where small hydropower potential exists, it is usually competitive compared to solar PV (460 US$/MWh). Energy generation from small hydro has the advantage of being more predictable with steady production. Solar PV must be compensated by other sources of non-intermittent energy which result in additional costs. However, in region where the conditions are not favorable for the development of small hydro projects (West, the central area and in the South of the country), the solar power does not compete with small hydro. Some complementarity could exist in the future with the development of small grids combining hydro-solar-thermal or medium capacity pumped-storage projects associated with solar power plants.	✓✓✓	✓✓
Biomass		Some Biomass projects could potentially be competitive. The examples of Sao Hill and Mufindi feature generation costs at 73 and 76 US$/MWh. Some complementarity could exist in the future with the development of small grids combining hydro-Biomass (and possibly thermal).	✓	✓✓

The above analysis shows that the development of small hydro is relevant for the development of the energy mix in Tanzania.

Regarding the economic competitiveness of small hydro connected to the main grid, several new hydropower projects between 29MW and 1,048MW were considered in previous studies:

[11] SREP - Investment plan for Tanzania (2013) and Ministry of Energy and Minerals, Power System Master Plan 2012 - Update (May 2013)

Table 5. Portfolio of medium and large hydro projects. Source: Power System Master Plan, update 2016 - Ministry of Energy and Minerals.

Portfolio of medium and large hydro projects[12]	Installed capacity [MW]	Average energy [$/kWh]	Unit Cost for average Energy [US$/MWh]
Songwe Bipugu (Upper)	29	$ 0.22	$ 223.60
Iringa - Ibosa	36	$ 0.07	$ 72.70
Malagarasi Stage III	45	$ 0.11	$ 107.40
Upper Kihansi	47	$ 0.25	$ 252.60
Iringa - Nginayo	52	$ 0.05	$ 54.30
Mnyera - Ruaha	60	$ 0.09	$ 94.90
Mnyera - Taveta	84	$ 0.06	$ 57.90
Kakono	87	$ 0.07	$ 72.30
Rusumo	90	$ 0.04	$ 39.40
Masigira	118	$ 0.05	$ 50.20
Mnyera - Kisingo	120	$ 0.06	$ 61.30
Lower Kihansi Expansion	120	$ 0.42	$ 418.80
Mnyera - Pumbwe	123	$ 0.04	$ 43.80
Mnyera - Mnyera	137	$ 0.05	$ 48.20
Mnyera - Kwanini	144	$ 0.03	$ 30.30
Songwe Sofre (Middle)	159	$ 0.10	$ 98.80
Mpanga	160	$ 0.06	$ 59.50
Songwe Manolo (Lower)	178	$ 0.09	$ 85.60
Rumakali	222	$ 0.05	$ 53.40
Kikonge	300	$ 0.07	$ 67.50
Ruhudji	358	$ 0.04	$ 43.50
Steiglers Gorge Phase 1	1,048	$ 0.06	$ 61.50
Unit Cost for average Energy (all projects)			**$ 95.34**

Amongst those hydropower projects, two projects features challenging barriers for their development:

- **Songwe Project** is a multipurpose project located on the border between Tanzania and Malawi, its development shall involve trade-offs between two countries and various competing uses of water resource. It is necessary to initiate joint discussions on the best way to develop the project.

- **Stiegler's Gorge Project** is located within the Selous Game Reserve; its development is constrained by the Algiers Conventions which defines the developments possibilities within national parks and game reserves. It is therefore important to redefine the game reserve borders.

Very few of these identified medium and large hydro options have recent (pre-)feasibility study reports. There is an urgent need to verify and update these studies, considering the increasing sediment transport, the socio-environmental constraints and the other competitive use of water.

Thermal generation alternatives for Tanzania vary between 38 to 56 US$/MWh (including CAPEX amortization), including Coal and Gaz. But investigations of the gas and coal reserves need to be pursued to ensure that as much of the gas and coal reserves as possible are proven.

The small hydro projects that would be connected to the main grid should be economically competitive with the best projects.

[12] Ministry of Energy and Minerals, Power System Master Plan 2012 - Update (May 2013)

3.4 PROGRAMS SUPPORTING THE SMALL HYDRO DEVELOPMENT

3.4.1 Tanzania Energy Development and Access Expansion project (TEDAP)

TEDAP provides support to the Rural Energy Agency (REA) for the development of small renewable energy projects and off-grid electrification. With the assistance of the TEDAP project, the Government established a comprehensive support package for small renewable energy projects (up to 10MW). This project allows/facilitates selling power to Tanesco grid(s) or directly to communities. The package consists of:

- a simplified regulatory framework, including standardized power purchase agreements and tariffs;
- grants for connections from REA (US$ 500 / connection) ;
- credit line channeled through Tanzanian commercial Bank (~US$ 23 millions) and ;
- technical assistance and pre-investment support provided by REA.

As a result of this support, the SPPA7 framework and Letter of Intents have been signed for about 77 MW of renewable energy (mostly small hydro and biomass).

3.4.2 Scaling-up Renewable Energy Program (SREP)

The Scaling-up Renewable Energy Program (SREP) is part of the Climate Investment Funds and aims at demonstrating the economic, social, and environmental viability of a low-carbon development pathway by creating new economic opportunities and increasing energy access through the production and use of renewable energy.

SREP and other co-financing will support, through the Renewable Energy for Off Grid Electrification Project, the provision of transaction advisory services, investments in mini-grid, micro-grid and stand-alone renewable energy-based rural electrification, risk mitigation to cover delayed payments by power purchasers, and knowledge management and capacity building. Total estimated cost is US$ 160 million, of which US$ 25 million is sought from SREP with about $ 50 million to be sought from the World Bank Group. Private sector, other development partners and commercial banks provide the balance. The project is expected to result in investments of about 47 MW of renewable energy plants, to benefit over 100,000 households and rural enterprises directly with electricity connection, and over 300,000 indirectly through the development of investment pipeline.

The SREP RERE project is expected to finance:

- setting up of a transaction advisory facility;
- expansion of the credit line for small renewable energy projects;
- performance grants for mini-grid connections, and sustainable solar market packages for stand-alone systems;
- establishment of a risk mitigation mechanism; and
- capacity building, knowledge management and project management.

3.4.3 Integrated Rural Electrification Planning (IREP)

The program “Integrated Rural Electrification Planning” (IREP) is primarily financed by the European Commission in partnership with REA. IREP ended in June/July 2013 and produced rural electrification investment plans in six pilot regions, namely Morogoro, Lindi, Pwani/Coast, Tanga, Iringa and Dodoma as well as providing Capacity-Building activities. The rural electrification investment plans include spatial analysis (classification of villages to be electrified based on socio-economic criteria), produced load forecasts and describe network options (grid extension, off grid systems, production connected to the grid). The project included biomass, small-hydro, geothermal, PV/Diesel hybrids. However, the project does not collect long-term ground-based (stream gauge) data.

3.4.4 Mini-grids based on small hydropower sources to augment rural electrification in Tanzania - UNIDO

This project will develop micro / mini hydropower based mini-grids in Tanzania to supplement the country's effort to increase access to rural electrification. Micro / mini hydro power will substitute the GHG intensive diesel generators in areas where there is no electricity.

This project therefore aims at addressing most of these barriers by establishing a platform for the development of small scale hydro power in the country. The activities include:

- detailed feasibility studies for the demonstration sites;
- building of capacity for the stakeholders in developing micro / mini hydropower based mini-grids;
- developing viable business model for micro / mini hydropower based mini-grid
- demonstration of micro / mini hydropower plants for a cumulative capacity of at least 3.2 MW.

The project is expected to strengthen the policy, regulatory and institutional framework supporting the micro / mini hydropower based mini-grid systems in Tanzania.

The project is expected to build necessary human and institutional capacities at all levels in order to achieve the scientific, engineering and technical skills and also the infrastructure necessary for the design, development, fabrication, installation and maintenance of micro / mini hydropower plants.

The proposed micro / mini hydropower based mini-grids to be setup under the project are expected to bring global benefits by reducing around 335,658 t CO_2e directly and around 2,685,185 t CO_2e indirectly, which otherwise would have resulted from the use of diesel generators, as it is the most common electricity source in Tanzania.

3.4.5 ESME - Supporting Energy SMEs in sub-Saharan Africa - GVEP

The Supporting Energy SMEs Project is a $30 million program funded by the Russian government, managed through the World Bank, and covering Kenya, Rwanda, Tanzania and Senegal. The activities include: assisting developers of mini-grids and small hydro systems to finance and deliver their projects, supporting the development of the solar PV market, and providing capacity building and technical assistance to government agencies.

GVEP has undertaken 6 SHPP feasibility studies in 2013 including:

- Establish technical and economic feasibility of 6 mini hydro projects;
- Assess the cost of implementing each of the 6 projects;
- Prepare detailed design of the projects;
- Prepare an implementation schedule.

ITEM	PROJECT	LOCATION	EASTING	NORTHING
1	Luswisi	Ileje district, Mbeya Region	553.94E	771.29N
2	Ihalula	Njombe district, Njombe Region	776.00E	987.04N
3	Macheke	Ludewa district, Njombe Region	492.32E	695.75N
4	Lingatunda	Madaba district, Songea Region	697.21E	758.67N
5	Mwoga	Kasulu district, Kigoma region	494.41E	818.73N
6	Darakuta	Babati district, Arusha Region	767.93E	550.72N

3.4.6 Rural Electrification Master Plan and Investment Prospectus - NORAD

The Rural Electrification Master Plan and Investment Prospectus is the overall guiding framework which is currently being prepared nation-wide by REA and financed by NORAD.

The Prospectus exercise aims at identifying a least cost rural electrification strategy that together with the continued electrification development in urban areas will contribute to attain the national objective for electrification ratio: 30% by 2015 and 50% by 2020.

Therefore a twofold approach has been carried out, one forecasting the development of the urban demand and the second developing least cost approaches for rural areas for the following three markets segments, the on-grid electrification options, the off-grid supply options and the disseminated energy services options for scattered populations in remote areas.

3.4.7 Possible future funding for rural electrification and small hydropower

Regarding expected future donor contributions:

- NORAD will finance 122MUS$ during the period 2013-2016;
- SIDA will finance the 220-kV Southern Highland Transmission Project and will continue in at least 2013 to provide funds for the REF;
- KfW is said to have committed to the financing of an electrification project in the Northwest;
- The Chinese Government is expected to support RE directly or indirectly;
- The World Bank and the African Development Bank are expected to continue financing RE projects.

3.5 Lessons learnt from the Consultant in small hydro planning and development

The following section describes lessons learnt by the Consultant from the planning and development of small hydropower projects in developing countries:

- The development of small hydropower projects (1-10MW) requires high quality engineering services understood by both local and international markets, to avoid prices rocketing of equipment, material and services.
- Selecting the electromechanical equipment manufacturer at the beginning of the development process of the project should be avoided. It will otherwise results in underperformance of power capacity and energy production, and inadequate services compared to the client needs (automation, flexibility, security, etc.). Technical specifications are defined during the study process based on the local environment (existing power system and grid load), access constraints, hydrological conditions, engineering constraints and power and energy demand.
- Solutions without sufficient studies and control procedure should be avoided. Multidisciplinary independent engineering services are strongly advised for: identification, feasibility study, detailed studies, writing tender documents, tender assessment, supervise electromechanical equipment manufacturing (from the factory) and works, commissioning the electromechanical equipment both at the factory and at the site, supervision of implementation of operations and maintenance.
- To avoid construction and delivery delays, construction planning requires good knowledge of the project environment and the contractors' mobilization.

- During the study phase of small hydro projects, it is challenging to provide reliable estimates of bill of quantities especially for access roads, the dam/weir and the waterway. Indeed, geotechnical investigations carried out during the studies are often simplified for small hydro. It is in fact hardly justifiable to provide major budgets for geotechnics during the study stage. Consequently, these aspects are often shifted to construction when more funds are available with the risk/consequence of higher costs for specific budget lines (excavation, extra construction material, etc.).

- The development of small hydropower projects should be part of IWRM process (Integrated Water Resource Management). Small hydro may interfere with the environment and should therefore be planned and designed taking into account all the aspects related to the river, from conservation measures of the catchment to other water uses along the watercourse and the socio-economic environment of the proposed development.

- Hydrological data are critical for hydropower projects not only to assess the energy performance of the scheme, but also to appropriately design the key structures, including the spillway, to ensure a safe and reliable operation of the proposed project. Streamflow data are however often not available or of poor quality. Quality assessment of the available data (data and rating curves) must be carefully done to ensure an appropriate design of the scheme. It is strongly recommended that the Government of Tanzania set up a hydrological monitoring network for its rivers with high hydropower potential in order to better understand the available water resources and thus promote the development of hydroelectric projects across the country. It is only in a context of reduced uncertainties through reliable, recent and long-term records (more than 20 years) that technical parameters and economic and financial analyzes of hydroelectric developments can be defined accurately, enabling optimization of their design and their flood control infrastructure (temporary and permanent).

- Given the general degradation tends of catchments in tropical countries (deforestation, unsustainable agricultural activities, erosion and soil losses, development of mining activities along or within rivers, etc.), appropriate measures must be taken to manage or prevent erosion and soil losses that will eventually lead to high concentration of suspended sediments in the rivers. The cost of infrastructure to remove suspended sediments in rivers and associated loss of energy production must be taken into account in the economic and financial studies. Future studies of hydropower projects in Tanzania must consider suspended sediments in the light of the current context of soil deterioration in some parts of Tanzania. Beside mitigation measures through the development of appropriate infrastructure, it is necessary that national protection and conservation programs of catchments be developed while educating people on impacts of current activities on soil deterioration (reduced fertility of agricultural land, increased risk of landslides, increase of sediment transport in rivers, etc.).

- The training of staff in charge of small hydropower plants operation should start after the completion of civil works and during the commissioning of both civil works and equipment. This shall enable staff to familiarize with engineering, manipulation and awareness of the electromechanical equipment. The training shall benefit from the presence and experience of the engineering consultant and the supplier.

- Local contractors are often not competent for the constraints associated with the construction of small hydropower projects. On the other hand, opportunities to acquire new skills exist through larger companies outsourcing contracts and their ability to manage such projects. These local companies could then use the acquired skills in the smaller projects (pico and micro hydropower plants).

- In some cases, Governments may require compliance with national (should they exist) or widely accepted international (Eurocodes, ASTM, IEEE, IEC, ISO, FIDIC, etc.) standards for infrastructure and equipment. Multiplicity of standards tends to hamper the development of projects and to reduce the interest of capable companies or financials to work in the country. It is also by adopting widely accepted standards that staff from the Ministry and associated bodies shall have an expert knowledge of the adopted standards. Hence, the engineering company, contractor or supplier is not advised to impose its own standards.

4 SPATIAL DATABASE ON HYDROPOWER

4.1 COMPILATION OF SPATIAL INFORMATION AND DATA TO ASSESS THE HYDROPOWER POTENTIAL

4.1.1 Introduction

The information and data collection is of strategic importance to the entire project. The project has considerable data and information needs and some of the required information had to be collected on site during site visits. The following sections present the information and data collected throughout the duration of the project and the way it is organized for an efficient use.

4.1.2 Data management: Geographical Information System

All the information related to hydropower in Tanzania having a spatial reference are stored in a Geographical Information System (GIS) whose Geographic Coordinates System (GCS) is WGS1984 (Datum: D_WGS_1984; Prime Meridian: Greenwich; Angular Unit: Degree).

The Geographical Information System was made to meet the compatibility and standards requirements defined in the terms of reference so that data can be easily retrieved, used and published by the wider audience. The Consultant used the open-source GIS software *QuantumGIS*, to process, analyze and publish the spatial data. The use of an open-source software facilitates the dissemination of the database, the organization of the training sessions and guarantee its free transfer to the Department of Energy at the end of the Study.

There are two types of spatial data:

- **Raster Data** consist of a matrix of uniform pixels (or cells) where a value is assigned to each pixel representing the information. The information is therefore assumed homogeneous within each pixel.
- **Vector Data** are graphical data given as points, lines, or polygons to which attributes are assigned.

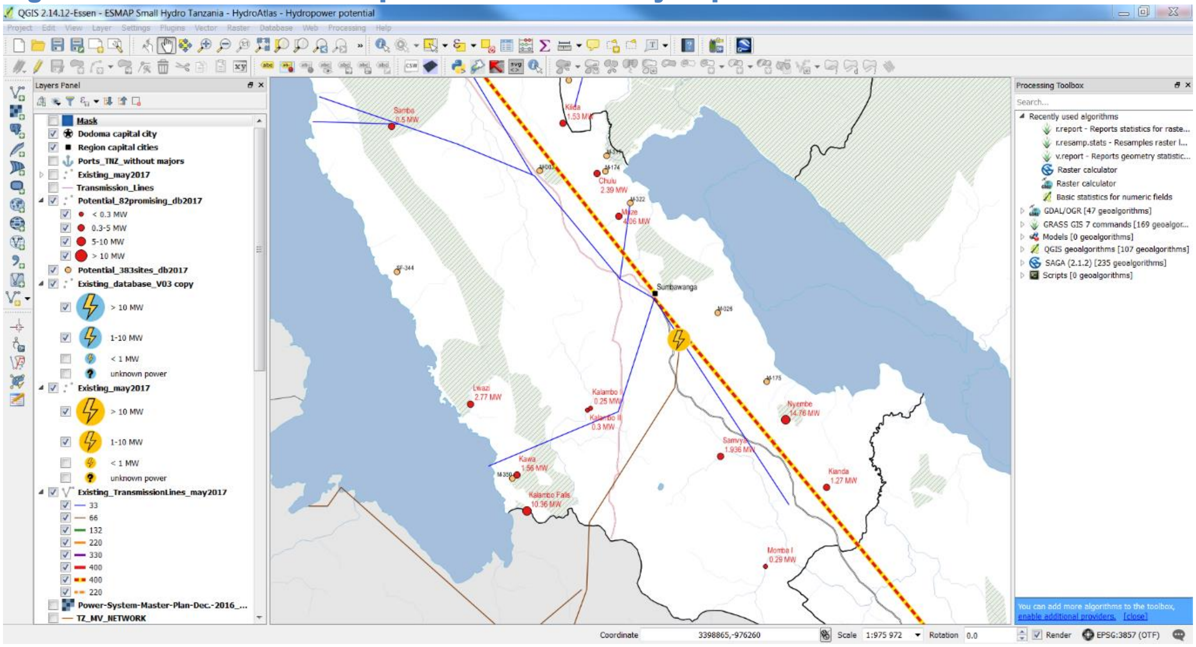
All geographic data are delivered as ESRI shapefiles or geoTIFF rasters. A *QuantumGIS* project has been created to group all spatial data in a GIS whose symbology is explicit and similar to the maps presented in this report. An Excel file containing all the metadata associated with the layers (shapefiles and rasters) presented in the GIS is part of the spatial database. The metadata standards are based on ISO 19115:2003 (Geographic Metadata Standards).

Finally, the main elements are also available in KML format (Keyhole Markup Language) usable in Google Earth[13] to facilitate the use and dissemination of information to a wider audience.

An illustration of the Spatial Database on Hydropower in the GIS software is given in Figure 3 below.

[13] https://www.google.com/earth/

Figure 3. Illustration of the Spatial Database on Hydropower in the Quantum GIS software.



4.2 CONTEXTUAL DATA AND INFORMATION

Spatial data collected during this study, their key features and their sources are summarized in the table below:

Table 6. Key features of the spatial data and information collected

THEMATIC	FORMAT	MAIN CHARACTERISTICS	SOURCE	ROLE IN THE ANALYSIS
Administrative boundaries: Country	ESRI Shapefile	-	Global Administrative Areas (GADM database), v. 2.8, November 2015	Mapping / Small Hydro Atlas
Administrative boundaries: Regions	ESRI Shapefile	31 regions (with Songwe in 2016)	Global Administrative Areas (GADM database), v. 2.8, November 2015	Mapping / Small Hydro Atlas Analytical synthesis by region
Administrative boundaries: Districts	ESRI Shapefile	169 districts	Global Administrative Areas (GADM database), v. 2.8, November 2015	Mapping / Small Hydro Atlas
Administrative boundaries: Wards	ESRI Shapefile	3643 wards 1 islands archipel	Global Administrative Areas (GADM database), v. 2.8, November 2015	Mapping / Small Hydro Atlas
Capital cities	ESRI Shapefile	1 capital city (Dodoma) 30 region capital cities	Open Street Map (OSM), 2013; Google Maps, 2017	Mapping / Small Hydro Atlas
Main rivers of Africa	ESRI Shapefile	-	Rivers of Africa (Derived from HydroSHEDS), FAO, 2014	Mapping / Small Hydro Atlas
Main waters bodies (lakes) of Africa	ESRI Shapefile	-		Mapping / Small Hydro Atlas
Water Management Basins	ESRI Shapefile	9 Water Management Basins (WMB)	Ministry of Water and Irrigation of The United Republic of Tanzania	Mapping / Small Hydro Atlas Analytical synthesis by basin
Protected Areas	ESRI Shapefile	831 protected areas classified into 15 categories	World Database on Protected Areas (WDPA), IUCN and UNEP-WCMC, 2017	Mapping / Small Hydro Atlas Site identification/selection process (exclusion criterion)
Satellite Imagery	Enhanced Compression Wavelet (ECW) Raster file	-	Google Earth, October 2013	Mapping / Small Hydro Atlas Site identification process (Stage 2 - desk-based analysis/confirmation of SiteFinder results)
Land Cover	Raster GeoTIFF file	27 classes of land cover (cropland, forest, shrubland, urban areas,…)	ESA Climate Change Initiative - Land cover Project 2015	Mapping / Small Hydro Atlas Hydrological study of potential hydropower projects
Average annual precipitation	Raster GeoTIFF file	-	WorldClim v.2, 30 arc-seconds, 2017	Mapping / Small Hydro Atlas Site identification process (SiteFinder input data) Hydrological study of potential hydropower projects
Main faults	ESRI Shapefile	-	Global Faults layer by ArcAtlas (ESRI), 2014	Mapping / Small Hydro Atlas Site identification process (assessment of the geological risks)
Geological map	ESRI Shapefile	15 classes of geological layers	U.S. Geological Survey, 2002	Mapping / Small Hydro Atlas Site identification process (assessment of the geological risks)
Elevation	Raster GeoTIFF file	-	Digital Surface Model (DSM) - SRTM 1 arc-second, NASA 2014	Mapping / Small Hydro Atlas Site identification process (SiteFinder input data) Hydrological study of potential hydropower projects
Slopes	Raster GeoTIFF file	-	Calculated from Digital Surface Model (DSM) - SRTM 1 arc-second, NASA 2014	Mapping / Small Hydro Atlas Hydrological study of potential hydropower projects

Major ports	ESRI Shapefile		Tanzania Ports Authority (TPA)	Mapping / Small Hydro Atlas
Major airports	ESRI Shapefile		Tanzania Airports Authority (TAA)	Mapping / Small Hydro Atlas
Main roads (national and regional)	ESRI Shapefile	-	World Bank, Africa Infrastructure Country Diagnostic (AICD), 2009	Mapping / Small Hydro Atlas Site identification/selection process (assessment of the requirements for access roads (rehabilitation or creation)) Economic analysis of projects (access roads length and type)
Main railways	ESRI Shapefile	-	World Bank, Africa Infrastructure Country Diagnostic (AICD), 2009	Mapping / Small Hydro Atlas
Density of population by square kilometer	Raster GeoTIFF file	-	AfriPop v2b (adjusted to match UN national estimates), 2015	Mapping / Small Hydro Atlas
Main existing and planned transmission lines (schematic)	ESRI Shapefile	6 different voltages: 33kV, 66kV, 132kV, 220kV, 330kV and 400kV	Compilation of data from The World Bank Group (IBRD 42944), May 2017 and TANESCO, 2016	Mapping / Small Hydro Atlas Site identification/selection process (assessment of the requirements for transmission lines and type of connexion) Economic analysis of projects
Main existing hydropower plants	ESRI Shapefile	52 existing hydropower plants	Compilation of data from TANESCO, 2016, The World Bank Group, 2017 and SHER, 2015	Mapping / Small Hydro Atlas
Main existing thermal power plants	ESRI Shapefile	41 existing thermal power plants	Compilation of data from TANESCO, 2016, The World Bank Group, 2017 and SHER, 2015	Mapping / Small Hydro Atlas Site selection process (assessment of the opportunity to substitute existing thermal generation by clean hydropower)
Electricity distribution by region of the Mainland	ESRI Shapefile	26 regions	Rural Energy Agency (REA), 2017	Mapping / Small Hydro Atlas
Potential hydropower sites identified by SHER	ESRI Shapefile	383 potential hydropower sites (not visited)	SHER, 2017	Mapping / Small Hydro Atlas Study output
Promising hydropower sites selected by SHER	ESRI Shapefile	82 promising hydropower sites (visited) with 55 promising small hydropower sites (0.3-10 MW) studied by SHER at different levels: - Site Visit 2015 (82 sites) - Reconnaissance 2015 (20 sites) - Prefeasibility Study (4 sites)	SHER, 2017	Mapping / Small Hydro Atlas Study output
Small Hydropower potential (0.3-10 MW) by region	ESRI Shapefile	31 regions	SHER, 2017	Mapping / Small Hydro Atlas Study output
Small Hydropower potential (0.3-10 MW) by Water Management Basin	ESRI Shapefile	9 Water Management Basins (WMB)	SHER, 2017	Mapping / Small Hydro Atlas Study output

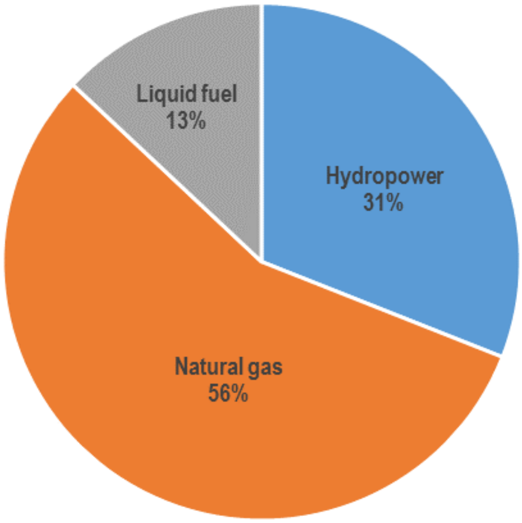
4.3 EXISTING POWER SYSTEM

4.3.1 Current status of the power system

According to the EWURA's annual report (2016), Tanzania has an installed electricity production capacity of 1,442 MW, of which 1,358 MW supplying the Main Grid and 84 MW in Isolated Grids. During the reporting period, the electricity generation mix consisted of hydropower 31% and thermal 69% (natural gas 56% and liquid fuel 13%) as shown Figure 4. In total, 6,449 GWh were available for sale. These units were received from TANESCO plants (61%), Independent Power Producers (IPPs, 37%), Small Power Producers (SPPs, 0.8%) and imports from neighboring countries (1.3%).

Due to traditional dependence on hydropower, the droughts that occurred in 2010 resulted in power supply shortages in the country. To bridge the electricity supply gap in the country, in 2011, TANESCO contracted Emergency Power Producers (EPP) at a relatively high cost.

Figure 4. Electricity generation mix in Tanzania. [Source: EWURA, Annual Report, 2016].



4.3.2 Thermal power system

Tanzania has a thermal installed capacity of 908.7MW (2013) distributed as follow: 574MW gas-fired (63.2%), 208MW HFO-fired (22.9%), 100MW GO-fired (11%), 19.7 biomass-fired (2.2%) and 7MW IDO-fired (0.7%)14. The spatial distribution of the major plants is presented in Figure 5 and shows that most of the thermal power is installed around Dar Es Salaam with a total of 757MW representing 83.3% of the total thermal installed capacity of the country. The key characteristics of the existing thermal power plants are presented in Table 7 below.

[14] Ministry of Energy and Minerals, Power System Master Plan, 2013.

Table 7 Existing thermal power plants: key characteristics (source: Ministry of Energy and Mineral, 2013)

POWER PLANT NAME	FUEL TYPE	INSTALLED CAPACITY (MW)	AVAILABLE ENERGY (GWH)	YEAR INSTALLED
IPP Units				
Songas 1	Gas	42	251	2004
Songas 2	Gas	120	721	2005
Songas 3	Gas	40	242	2006
Tegeta IPTL	HFO	103	595	2002
TPC	Biomass	17	70	2011
TANWAT	Biomass	2.7	10	2010
	Sub total	***324.7***	***1889***	
TANESCO				
Ubungo 1	Gas	102	655	2007
Tegeta GT	Gas	45	282	2009
Ubungo 2	Gas	105	655	2012
Zuzu D	IDO	7	31	2014
	Sub total	***259***	***1623***	
RENTAL UNITS (IPP's)				
Symbion	Gas/Jet	120	746	2011
Aggreko (Ubungo)	GO	50	674	2011
Aggreko (Tegeta)	GO	50		
Symbion Dodoma	HFO	55	371	2012
Symbion Arusha	HFO	50	337	2012
Sub total		***325***	***2128***	
	TOTAL	**908.7**	**5640**	

4.3.3 Hydropower system

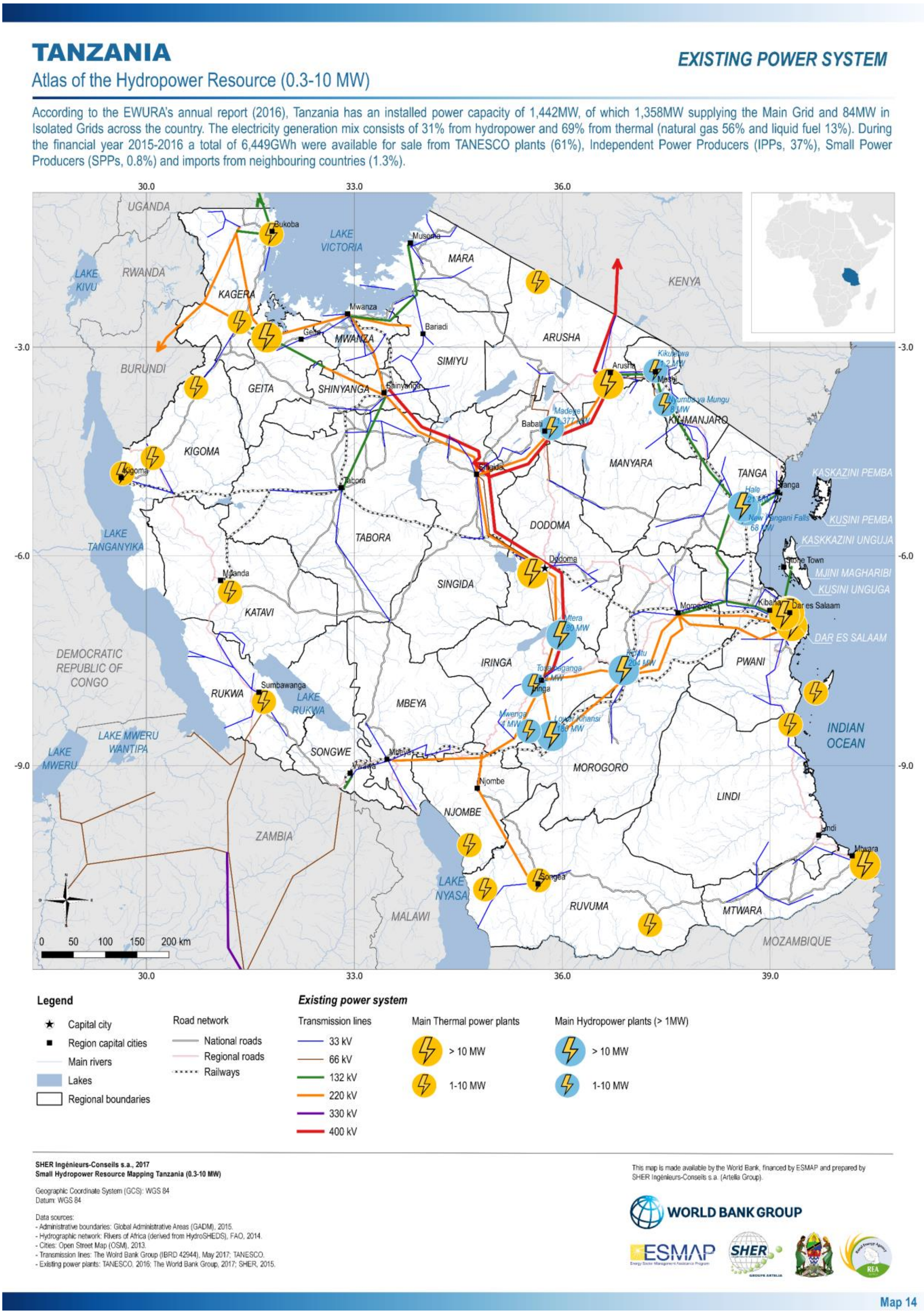
Large hydropower as a share of total capacity declined by nearly two-thirds between 2002 and 2006 (from 98% to 40%), and now stands at 31% of available capacity, with output declining due to extended droughts. This situation has necessitated extensive load shedding and the running of expensive thermal power plants as base load. [*Source*: African Development Bank Group, *Renewable Energy in Africa*, 2015].

According to TANESCO, Tanzania has seven major hydropower plants (with an installed capacity greater than 1MW) connected to the national power grid, totalizing 562MW. The largest facility is Kitadu and features an installed capacity of 204MW followed by Kihansi (180MW), Mtera (80MW) and New Pangani Falls (68MW). These hydropower stations are located in the areas characterized by steep slopes and abundant rainfall i.e. along the two branches of the East Africa Rift. The key characteristics of these hydropower plants are presented in Table 8 and their location is illustrated in Figure 5.

Table 8. Main existing hydropower plants [Source: Ministry of Energy and Minerals, Power System Master Plan – 2016 Update, December 2016].

Name (Location)	Type	Number of units	Installed Capacity [MW]	Annual Energy Generation [GWh]	Installation Year
Owned by TANESCO					
Hale (Korogwe)	Run-of-the-river	2	21	36	1964
Nyumba Ya Mungu (Mwanga)	Reservoir	2	8	22	1968
New Pangani (Muheza)	Run-of-the-river	2	68	137	1995
Kidatu (Kilombero-Morogoro)	Reservoir	4	204	558	1975 (2 units) 1980 (2 units)
Mtera (Kilolo)	Reservoir	2	80	167	1988
Uwemba (Njombe)	Run-of-the-river	3	0.8	2	1991
Kihansi (Kilombero-Iringa)	Run-of-the-river	3	180	793	1999 (1 unit) 2000 (2 units)
Owned by Small Power Producers (SPPs)					
Mwenga (Mufindi)	Run-of-the-river	1	4	17	2012
Darakuta (Magugu)	Run-of-the-river	N/A	0.5	N/A	2015
Yovi (Kisanga)	Run-of-the-river	1	1	N/A	2016
Tulila (Songea)	Run-of-the-river	2	5	N/A	2015
Ikondo (N/A)	Run-of-the-river	3	0.6	N/A	2015
Mbangamao (Mbinga)	Run-of-the-river	1	0.5	N/A	2014

Figure 5. Existing power system.



4.3.4 Transmission and distribution networks

The transmission and distribution network of Tanzania are owned and operated by TANESCO. The transmission system consists of 647km of 400kV lines, 2,745km of 220kV lines, 1,626km of 132kV lines and 580km of 66kV lines[15]. On the top of that, transboundary transmission lines exist between Tanzania and Uganda (132kV) and between Tanzania and Zambia (66kV) to import power to Tanzania. Beside the national grid exists a series of isolated grid supplied by an aggregate power capacity of 81.5 MW.

4.4 POTENTIAL HYDROPOWER RESOURCE

4.4.1 Overview of the methodological approach for hydropower resource assessment

The identification of new potential hydropower sites at the country or regional scale relies on the following three-stage approach:

1. **Screening phase**: *SiteFinder* is a screening tool that calculates hydropower potential along a network of rivers (more information in Appendix 1). For that purpose, the river system is rasterized (decomposed into a matrix of pixels of equal size). A that stage, the hydropower potential assessment relies on the calculation of the difference in elevation between two adjacent cells (from upstream to downstream) and an estimated average annual streamflow at each cell (based on the spatial distribution of average annual rainfall).

   Hence, the result of SiteFinder is a set of river stretches that appear to be relevant for the development of small hydropower scheme i.e. river stretches that features the combination of a high gradient of the river slope and favorable hydrological conditions.

   Figure 6. Illustration of SiteFinder results (SF022 and SF178) near the Mahale Mountain National Park

   Those results feed the second stage of the identification process describe below.

[15] Source: Power System Master Plan, 2016 update

It is worth mentioning that the quality of the input data (elevation and hydrological data) will affect the quality of the results of the model and hence the time spent on the subsequent stages of the identification process.

2. **Desk-based analysis phase:** Hydropower Planning Experts then further analyze the river stretches that were identified at the screening stage. This stage is based on the analysis of satellite imageries and topographic maps. It aims at identifying the actual location of potential hydropower site along the river stretch and carrying out a first estimate of the site key features i.e. indicative scheme layout, available gross head, presence of major constraints that may jeopardize the development of the site, etc. This stage is time-consuming and requires strong experience in potential hydropower site identification.

3. **Field-based validation phase:** Site visits are integral part of the potential site identification process. Site visits are critical for the validation of the key features assessed at the previous stage and to confirm, at the reconnaissance study level, the technical and economic feasibility of the project.

The database of potential hydropower sites is complemented by the sites that have been already studied. The key features of the latter provides from a **literature review** as describe below.

4.4.2 Contribution from the available literature review

More than 100 documents were collected and reviewed during the Study. Those documents embrace a large scope of fields related to the electricity sector in Tanzania and from all kinds of authors ranging from government officials to international consultants and agencies. The type of documents reviewed includes:

- Environmental reports
- Official mails
- Policy reports/recommendations
- Laws
- Hydrological studies
- Technical hydropower studies
- Regional/worldwide fact sheets
- Data sheets
- Documents from the Ministry, REA, TANESCO
- Etc.

Given the number of institutions involved directly or indirectly in the hydropower sector, data collection was particularly complex. The main institutions are REA and TANESCO but contacts were made with the Tanzanian Meteorological Agency, Water Basin Offices, Survey and Mapping, Donors, NGO, Private owners, all requiring huge efforts for data access and/or authorization.

It is important to note that the existing lists of potential sites are mostly summaries of several documents. Most of the time, the latter are not or are no longer available. Very often, there are significant errors in the location or the technical parameters, and it is impossible to find the source of the data neither to correct them. There is also a large incertitude on the technical parameters, when they are mentioned, because we generally do not have information on the hypotheses that helped in determining them.

All the data and information was consolidated into a single GIS. If a potential hydropower project is mentioned by various studies, its key features are retrieved from the most up-to-date document. The database was then manually cleaned up by removing duplicates and sites with inconsistent data and constitutes the database of the *"potential hydropower projects already studied*" that contains **278 potential hydroelectric projects**. The list of collected and reviewed documents is given in Appendix 2.

4.4.3 Contribution of SiteFinder

The results of SiteFinder were analyzed based on satellite imagery, topographic and geological maps and regional hydrological studies in order to assess whether the site is favorable or not for hydropower development.

This analysis assessed the indicative available gross head, the size of the watershed drained by the river at the proposed intake location and identified the obvious development constraints due to the presence of villages, protected areas, etc.

The geological maps gave a first indication on the nature of the rocks, the possible tectonic events and the presence of geological faults which could make the implementation of a hydropower project more complex.

As mentioned earlier, the result of SiteFinder is a set of river stretches that appear to be relevant for the development of small hydropower scheme i.e. river stretches that features the combination of a high gradient of the river slope and favorable hydrological conditions.

351 sites were detected by SiteFinder, amongst which :

- 44 sites are located in the middle of protected areas and have therefore been discarded;
- 6 sites are existing hydropower stations;
- 36 sites have already been studied and are therefore not repeated in the database;
- 91 sites have been discarded after it appears that they did not feature any actual hydropower potential based on the analysis/confirmation on satellite imagery and 1:50,000 topographic maps.

Considering the existing hydropower stations and the sites that have already been studied, 42 sites identified with SiteFinder coincide with the sites obtained from the literature review.

Finally, **SiteFinder contributes to add 174 potential sites to the final spatial database of hydropower.** It is worth mentioning that potential stretches that have not been visited may eventually not be favorable for hydropower development.

The potential river stretches identified by SiteFinder are presented in the GIS. In the database, the source of information for those sites is referred as "*SiteFinder 2017*".

4.4.4 Consolidated spatial database of small hydropower resource

Each of the 455 potential hydroelectric projects identified from the various sources described above were analyzed using satellite imagery, topographical and geological maps and a regional hydrological study in order to assess whether each site is potentially favorable for hydropower development. The technical feasibility these sites must be confirmed by site visits since a desk-based analysis cannot guarantee that the sites that were identified are suitable for hydropower development.

The result is a consolidated database containing 455 potential hydropower sites, distributed over the country. The content of this database is presented in Appendix 3.

4.5 SMALL HYDROPOWER RESOURCE ATLAS OF TANZANIA

The **Small Hydropower Resource Atlas of Tanzania** is a separate document that contains all the information directly or indirectly related to hydropower and collected during Phase 1 and Phase 2 of this study. The information has been compiled and processed in a **Geographic Information System (GIS)** and is presented as thematic maps, tables, graphs and various illustrations.

The information of this Atlas presents the hydropower potential of Tanzania including the new potential sites identified by the **Consulting and Engineering firm SHER** within the framework of this study, using the SiteFinder tool as well as the existing hydropower sites. The creation of the Atlas started with Phase 1 of the study. The Atlas has been finally updated at the end of Phase 3, by including new information collected on the field and updating the contextual information.

The Geographic Information System has been designed to meet the compatibility and standardization requirements defined in the terms of reference so that geographic data can be easily published on the World Bank GIS platform. In addition, the consultant used the free of charge GIS software QuantumGIS for processing and publishing the geographic data, which makes it possible to disseminate and transfer the data free of charge during the training sessions carried out under Phase 1.

The **Small Hydropower Resource Atlas of Tanzania** focuses exclusively on potential sites in the range of capacities between 0.3 and 10 MW and contains the spatial data presented in the below.

The hydropower potential of Tanzania is important and still largely underexploited. Opportunities exist in all power capacity ranges. The analysis shows that Tanzania has a great small hydro potential for private or government investments.

Without technical or economic considerations, the small hydro potential in Tanzania consists of more than 400 potential sites from 0.3 to 10 MW. Eighty-two (82) potential projects were visited with a cumulated capacity of approximately 162 MW (confirmed small hydropower potential).

The spatial distribution of the small hydropower potential is showed in Figure 7 below while its breakdown by region and by water basin is presented in Table 9 and Table 10.

Table 9. Confirmed small hydropower potential (0.3-10MW) by region[16]

Region	Small Hydropower Potential	
	[MW]	[%]
Iringa	40.6	25.1%
Rukwa	29.2	18.1%
Singida	16.6	10.3%
Tanga	14.1	8.7%
Lindi	11.9	7.3%
Ruvuma	11.6	7.2%
Kigoma	10.2	6.3%
Mara	9.6	6.0%
Dodoma	8.9	5.5%
Mtwara	3.5	2.2%
Kagera	2.2	1.3%
Morogoro	2.0	1.3%
Katavi	0.8	0.5%
Njombe	0.7	0.4%
TOTAL	**162**	**100.0%**

Table 10. Confirmed small hydropower potential (0.3-10MW) by water basin[16]

Water Basin	Small Hydropower Potential	
	[MW]	[%]
Rufiji	43.6	27.0%
Lake Tanganyika	25.6	15.8%
Internal Drainage	22.5	13.9%
Ruvuma & Southern Rivers	17.2	10.7%
Lake Rukwa	14.5	9.0%
Pangani	14.1	8.7%
Lake Victoria	11.8	7.3%
Lake Nyasa	10.4	6.4%
Wami/Ruvu and Coast Rivers	2.0	1.3%
TOTAL	**162**	**100.0%**

[16] The potential hydropower resource is estimated without considering environmental flows that must be evaluated during the development process of the each project.

Figure 7. Confirmed small hydropower potential: breakdown by region (0.3-10MW) [16]

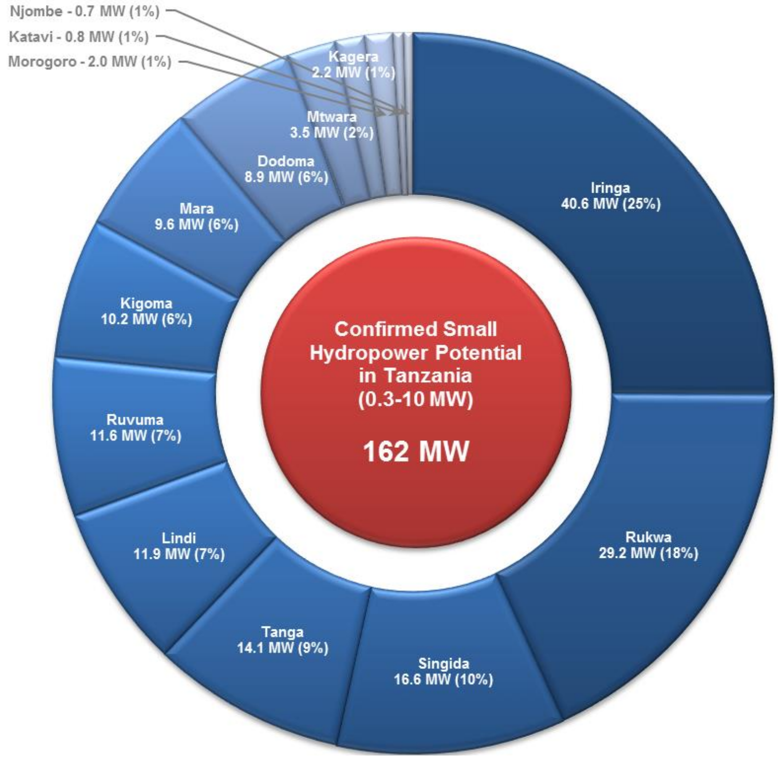


Figure 8. Confirmed small hydropower potential: breakdown by water basin (0.3-10MW) [16]

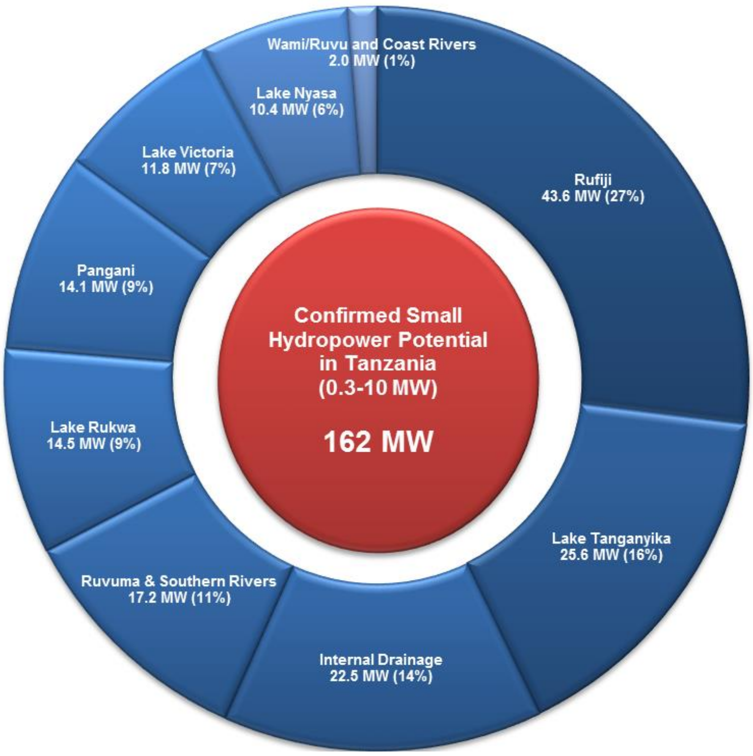


Figure 9. Confirmed small hydropower potential by region (0.3-10MW)

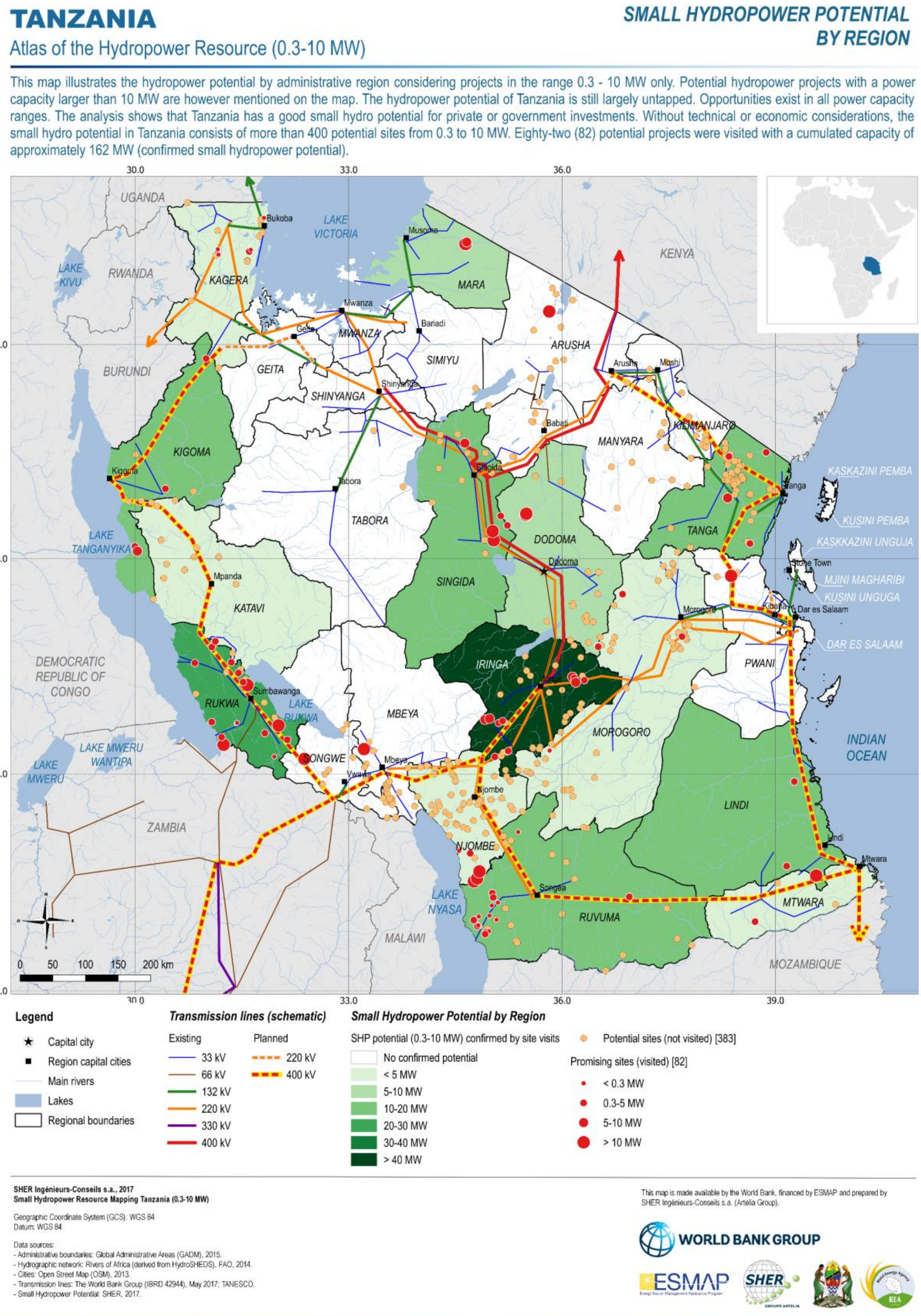
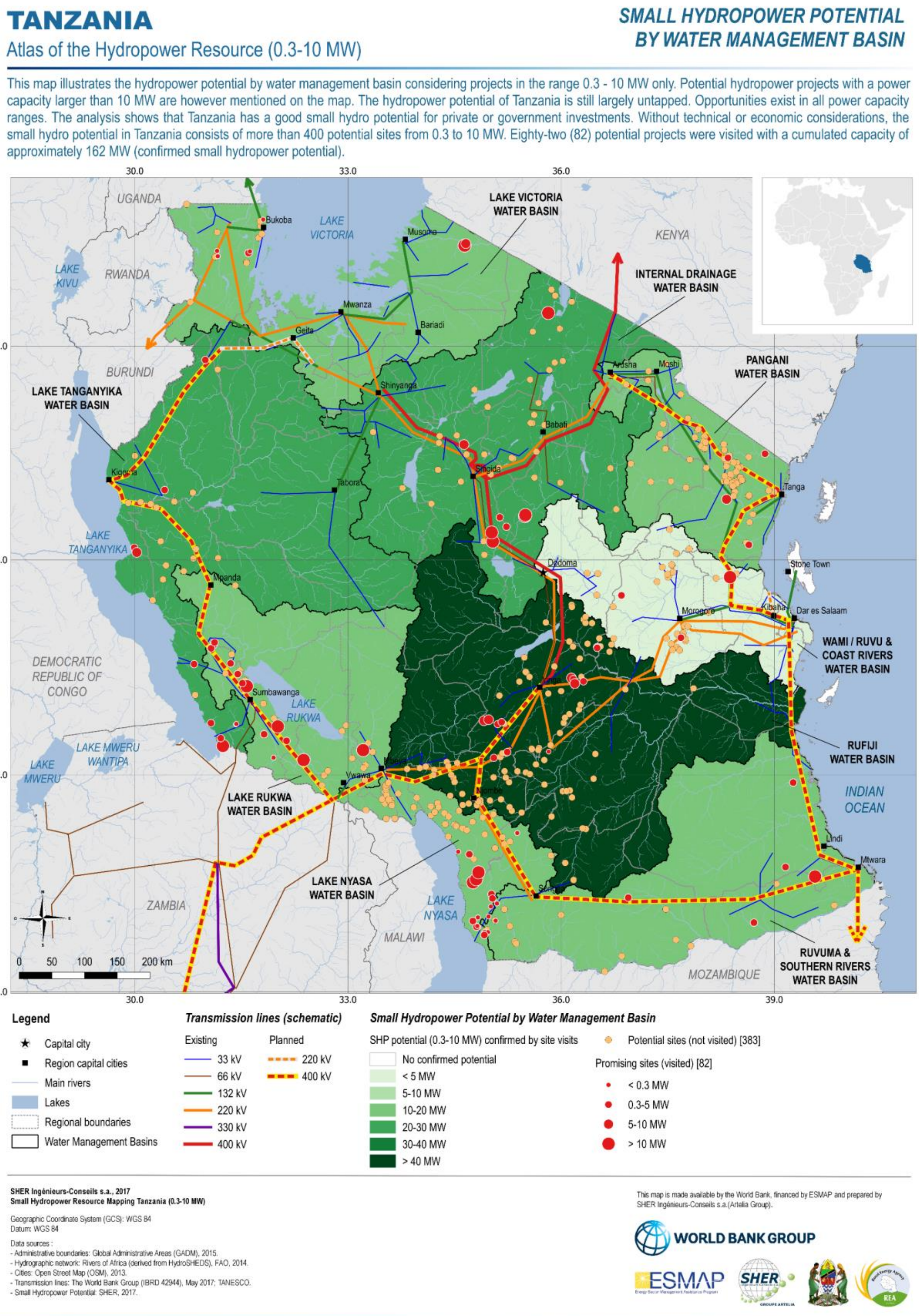


Figure 10. Confirmed small hydropower potential by water basin (0.3-10MW)



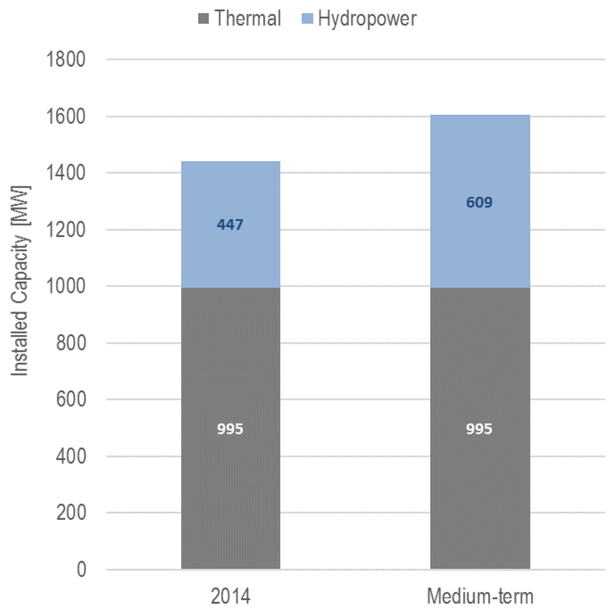
As presented in the previous chapters, Tanzania's potential for small hydro development is important. Small hydropower has the advantage of a faster project development process (~ 2.5 to 4 years), a better progression in meeting the growing electricity demand and an easier financial closure compared to large hydro. The latter requires a longer development process (6 to 10 years), significant funding and may encounter severe socio-environmental constraints. Given the opportunity of thermal substitution and the future increase in energy demand on the main grid and mini-grids, small hydro projects remain appealing even when a larger project is developed.

Figure 11 highlights the contribution of small hydropower in the energy mix of Tanzania. This figure compares the energy mix in 2016 (source: EWURA's Annual Report 2016), as detailed in Chapter 3, and a medium term projection with the implementation of the top 20 priority hydropower projects identified and selected for this study. This figure considers that the sources of thermal generation remain identical. The data on other renewable energies are not available.

The contribution of these top 20 priority projects is 162MW, which represents an increase of 36.2% (from 447 MW to 609 MW) of the available hydropower power capacity.

These figures show the importance of small hydro development to achieve the country's objectives in terms of energy security and economic development.

Figure 11. Medium-term contribution of small hydro to the energy mix in Tanzania.

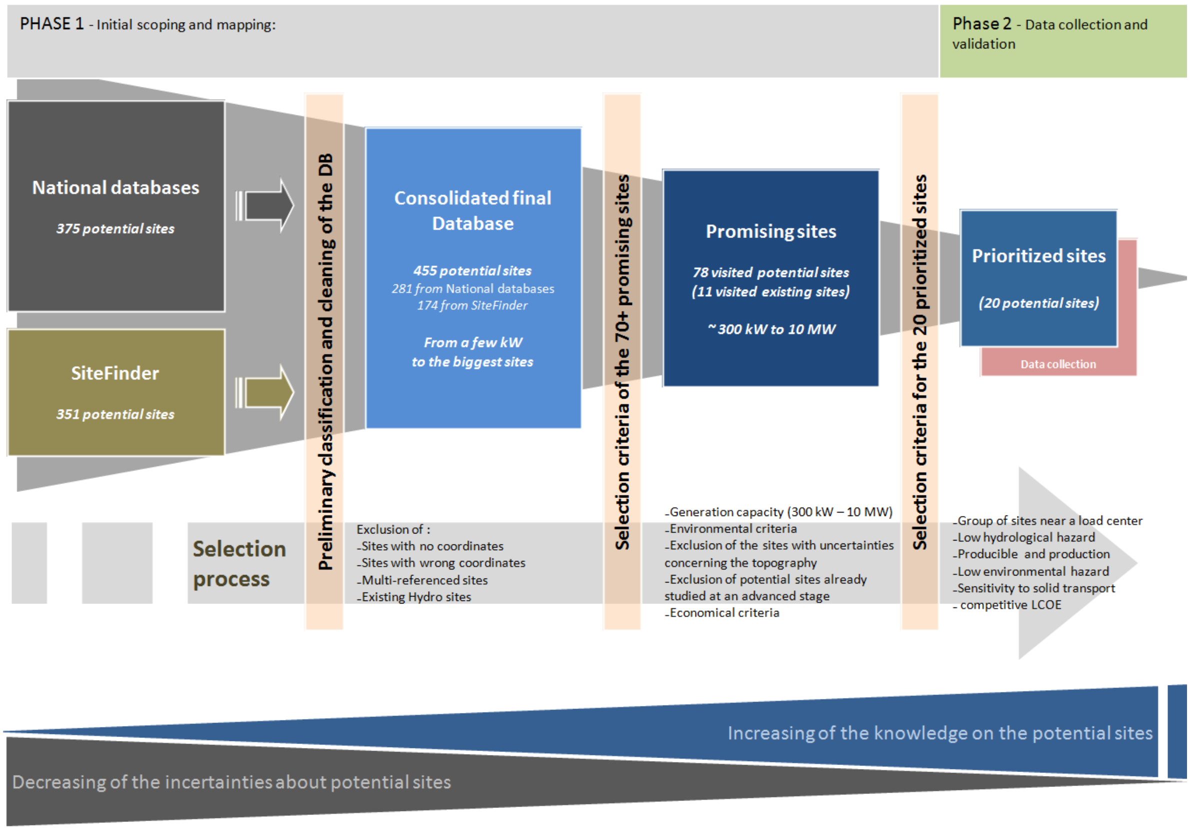


5 70+ PROMISING SITES FOR THE DEVELOPMENT OF SMALL HYDRO

5.1 INTRODUCTION

Figure 12 presents the overall process for the selection of the most promising sites to develop hydropower projects: creation of the consolidated spatial database of potential hydropower sites, selection of 70+ promising SHPP sites and the selection of top 20 prioritized SHPP. The diagram shows that the uncertainties decrease as the Study progresses and more information and data become available.

Figure 12 Prioritization in the study process



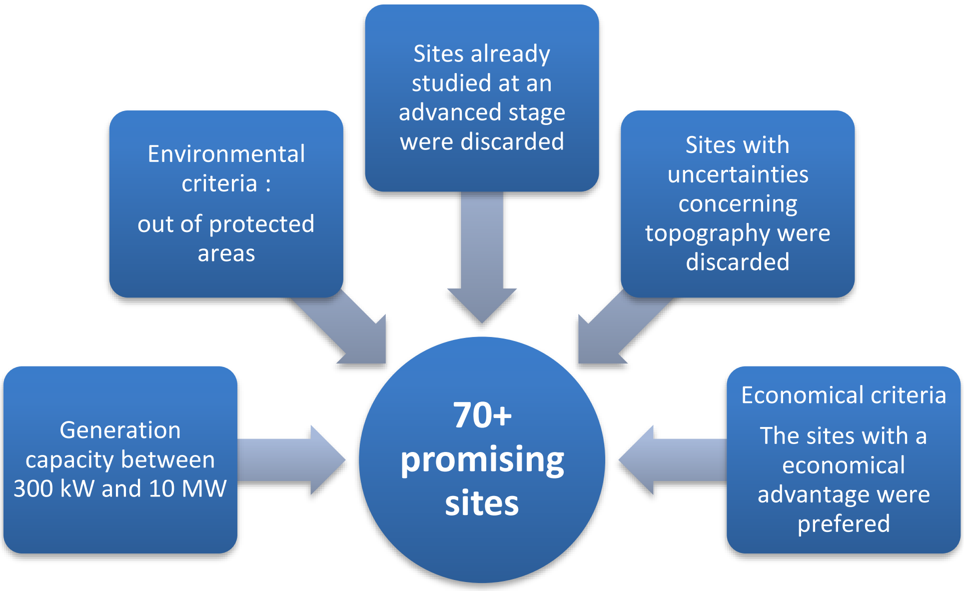
Consequently, the selection process is dynamic and iterative. Hence, the technical features of potential hydropower projects may evolve as the Study progresses and more information and data becomes available (reduced uncertainties).

5.2 SELECTION PROCESS OF THE 70+ PROMISING SITES

The selection process of the 70+ promising potential sites was carried out during PHASE 1 and the results have been validated during the workshop held in Dar Es Salaam in March 2015 at The Rural Energy Agency (REA) premises. The selection has been slightly reviewed in October 2016 with REA during additional site visits that were commissioned by REA.

The selection process was applied on the spatial database of 455 potential sites and relies on the following criteria:

Figure 13 Selection criteria



5.2.1 Power capacity

The terms of reference of this study indicate that 'small hydro' shall be defined as having a generation capacity of between 1 to 10 MW. Nevertheless, REA expressed its wish to include potential sites under 1 MW in the selected potential sites list for which a site visit is foreseen.

It has consequently been decided to set a minimum of 300 kW under which sites are not included in the selection, which corresponds to a minimal size in terms of investment and technical barrier for electro-mechanical equipment under which a private developer will face problems to recover its investment and/or find quality equipment for a reasonable price (transport cost amongst price of equipment). The database includes 122 sites with a potential lower than 300 kW.

5.2.2 Environmental criteria

Tanzania has a tremendous natural and environmental potential. All the potential sites located in protected areas were discarded (National Parks, Nature Reserves, Forest Reserves, Game Reserves, Wildlife Management Areas, Village Forest Reserves World Heritage Sites) to avoid any future environmental barriers in the development of the potential sites.

5.2.3 Uncertainties concerning topographical criteria

37 sites, with a power potential above 300 kW and under 10 MW, were discarded after a visual check of the 1:50,000 topographic maps. The main findings are lack (or absence) of head or watershed much smaller than expected or described in the previous studies and/or lists of sites.

5.2.4 36 sites studied at an advanced stage

An advanced stage of study is considered here as a study giving at least a basic layout for the site, referenced by drawings or a sketch on a map, with accurate head and hydrological information, and visited on the field.

Because we already possess all the sub-mentioned information, a single site visit would not be of any use. Those sites are thus not considered for phase 1 - step 2 (single site visit). They will however be considered again for phase 2: hydrological monitoring, since some of them are considered as very interesting but suffer from lack of consistent hydrological data.

The concerned studies and sites are:

- SECSD (Malagarasi (Kigoma), Muhuwesi (Ruvuma-Tunduru), Kikuletwa (Kilimanjaro)
- Norconsult:
  - Pinyinyi (see Tanzania Rural Electrification Study, Hydropower Sub-Project 1.5 Lower Pinyinyi Hydropower Plant, Sweco, 2005a),
  - Nzowve (see Tanzania Rural Electrification Study, Hydropower Sub-Project 4.2 Nzowve Hydropower Plant, Sweco, 2005c),
  - Mtambo (see the unfounded Pre-investment report on mini hydropower development. Case study on the Mtambo River, SECSD, 2000).,
  - Kwitanda (see Pre-investment report on mini hydropower development. Case study onthe Muhuwesi River, SECSD, 1999. Tanzania Rural Electrification Study, Hydropower Sub-Project 7.2 Sunda Falls Hydropower Plant.)
- Sweco (Nzovwe - Malagarasi - Lower Pininyi - Upper Pininyi - Nakatuta - Sunda Falls)
- Intec Entec Skat (Darakuta - Ihalula - Lingatunda - Luswisi - Mlangali - Mwoga)
- Enco (Zigi - Nkole)
- IED (only those that were visited on site)
- SNC Lavalin (Rusumo Falls)

36 sites have been previously studied at an advanced stage and are therefore discarded from the list of promising sites.

5.2.5 Economic criteria

The selection process was carried out in 2014, based on the economic considerations valid at that time, as detailed below.

For hydropower, two tariffs applies depending if the electricity is sold to the main grid or to a mini-grid-grid where hydropower generation replace costly generation from thermal power plants. The standardized small power projects tariffs for years 2011 and 2012 are:

Table 11 EWURA standardized small power projects tariffs for years 2011 and 2012

Description		2011 Tariff		2012 Tariff		Increase
		TZS/kWh	US$/kWh[17]	TZS/kWh	US$/kWh[18]	
Main grid connection tariff						
Standardized SPP Tariff		121.13	**0.08**	152.54	**0.10**	26 %
Seasonally adjusted SPPT Payable in	Dry season (August to November)	145.36	**0.09**	183.05	**0.12**	26 %
	Wet season (December to July)	109.02	**0.07**	137.29	**0.09**	26 %
Mini grid connection tariff						
Standardized SPP Tariff		380.22	**0.24**	480.50	**0.31**	27 %

It appears that the tariff is approximately 3 times better for the mini-grid/micro-grid connection. As private investment and generally attractive investment are promoted throughout this Study, sites selection will focus on mini-grid developments, which are better remunerated.

As outlined in the SREP-Investment Plan for Tanzania, 20 townships in other regions served by TANESCO depend on isolated diesel (18) and natural gas (2) generators and imports. In addition, there is an estimated 300 MW of private

[17] Average exchange rate for 2011 : 1US$ = 1562 TZS (source : OANDA)
[18] Average exchange rate for 2012: 1US$ = 1561 TZS (source : OANDA)

diesel generation not connected to the TANESCO grid whose fuel cost is expected to exceed 0.35 US$/kWh, to be compared to the levelized cost of energy from small hydropower at 0.23 US$/kWh[19].

Moreover, new TANESCO tariffs were approved for 2014 and 2015 with the following increases:

Customers Category	Component	Unit	Existing tariff	Approved tariff		Increase
			2013	2014	2015	2013-2014
Low usage tariff for Domestic customers	Service Charge	[TZS/month]	-	-	-	-
	Energy charge (0-75 kWh)	[TZS/kWh]	60	100	100	67%
	Above 75 kWh	[TZS/kWh]	273	350	350	28%
General usage tariff	Service Charge	[TZS/month]	3841	5520	5520	44%
	Energy charge	[TZS/kWh]	221	306	306	38%
Customers with average consumption above 7,500 kWh per year	Service Charge	[TZS/month]	14233	14233	14233	0%
	Energy charge	[TZS/kWh]	132	205	205	55%
Connected to MV	Service Charge	[TZS/month]	14233	16769	16769	18%
	Energy charge	[TZS/kWh]	118	163	163	38%
Connected to HV	Service Charge	[TZS/month]	14233	-	-	-100%
	Energy charge	[TZS/kWh]	106	159	159	50%

It has been therefore decided with REA to target potential projects located close to a mini-grid or in a pure off-grid location to supply isolated load centers. The potential hydropower sites located outside a buffer of 15 km of the planned MV grid were discarded. Some exceptions exist when their potential is interesting only to supply a large demand or when located just beyond the 15 km.

5.2.6 Results of the 70+ promising sites selection

The selection process of the 70+ potential sites was carried out during PHASE 1 and the results have been validated during the workshop held in Dar Es Salaam in March 2015 at The Rural Energy Agency (REA) premises.

As shown in the table below, the portfolio of the 75 promising small hydropower sites features a total firm power capacity of 41.4MW with a secured (95% of the time) expected annual energy generation of 365.3GWh (firm energy). The total installed capacity of the 75 sites sums up to 394.8MW should the sites be equipped with a design flow corresponding to the long-term annual average (Q50%). With the latter scenario, the expected annual generation would reach up to 2358.2 GWh. The breakdown per region and per water basin of the number of sites, firm power and energy and installed capacity are presented in the tables below.

[19] Source : SREP - Investment plan for Tanzania

Table 12. Regional breakdown of the installed capacity and energy produced by the 70+ potential sites

Region	Number of sites	Firm power (MW)	Power @Q50% (MW)	Firm energy (GWh/y)	Energy @Q50% (GWh/y)
Arusha	1	1.2	15.6	10.1	99.2
Dar Es Salaam	0	-	-	-	-
Dodoma	5	2.2	46.5	20.5	226.1
Geita	0	-	-	-	-
Iringa	8	4.3	34.7	37.5	275.9
Kagera	5	0.1	2.6	1.3	7.1
Kaskazini-Pemba	0	-	-	-	-
Kaskazini-Uguja	0	-	-	-	-
Katavi	1	0.0	0.8	0.0	4.4
Kigoma	4	11.4	27.6	99.8	205.8
Kilimanjaro	0	-	-	-	-
Kusini-Pemba	0	-	-	-	-
Lindi	3	2.6	4.3	22.5	36.0
Manyara	0	-	-	-	-
Mara	2	2.0	27.0	17.5	171.9
Mbeya	2	1.2	38.1	10.6	286.8
Morogoro	0	-	-	-	-
Mtwara	1	0.0	3.5	0.4	20.8
Mwanza	0	-	-	-	-
Njombe	4	7.9	41.8	69.5	285.7
Pwani	1	0.8	11.2	7.3	87.1
Rukwa	16	1.5	73.7	12.9	282.8
Ruvuma	16	4.2	25.4	36.5	170.9
Shinyanga	0	-	-	-	-
Simiyu	0	-	-	-	-
Singida	4	1.6	40.2	14.6	166.8
Tabora					
Tanga	2	0.5	2.1	4.3	30.9
Zanzibar South and Central	0	-	-	-	-
Zanzibar West	0	-	-	-	-
Grand Total	**75**	**41.4**	**394.8**	**365.3**	**2358.2**

Table 13. Water basin breakdown of the installed capacity and energy produced by the 70+ potential sites

WATER BASIN	NUMBER OF SITES	FIRM POWER (MW)	POWER @$Q_{50\%}$ (MW)	FIRM ENERGY (GWH/Y)	ENERGY @$Q_{50\%}$ (GWH/Y)
Kagera and Lake Victoria	7	2.1	29.6	18.8	178.9
Lake Nyasa	16	11.9	63.9	103.8	436.1
Lake Rukwa	13	2.2	98.2	19.0	486.3
Malagarasi and Lake Tanganyika	10	11.9	41.9	104.3	293.5
Northern Lakes	8	4.5	99.2	42.2	468.0
Pangani and Northern Indian Ocean Coast	2	0.5	2.1	4.3	30.9
Rufiji	10	4.6	37.8	40.6	300.0
Ruvuma and Southern Indian Ocean Coast	8	2.9	11.1	25.1	77.3
Wami, Ruvu and Central Indian Ocean Coast	1	0.8	11.2	7.3	87.1
Grand Total	**75**	**41.4**	**394.8**	**365.3**	**2358.2**

Not surprisingly, it appears that 42% of the sites are located in the Rukwa and Ruvuma regions (both regions having 16 promising hydropower sites), characterized by steep slopes and interesting rainfall throughout the year. Ten (10) regions does not feature any potential hydropower sites responding to the scope of this study due to their less attractive hydropower potential due to the combination of the following parameters: unfavorable topography (lack of head), low flow season characterized long zero flow periods, extreme solid transport in the river (sedimentation issues), inadequate power supply/demand balance, high production costs.

In terms of water basins, the Northern Lakes basins counts 8 sites featuring a total installed capacity of 99.2MW, followed by the Lake Rukwa basin and Lake Rukwa basin featuring 98.2MW and 63.9MW respectively.

The 75 potential hydropower sites cover a wide range of scheme types with gross head varying from a few meters up to 800m for the SF-206 site located on the Chulu River in the Rukwa region. The statistical distribution of gross head amongst the 75 sites is illustrated in Figure 14. It shows that 19% of the sites have a gross head greater than 200m, 43% greater than 100m and 36% lower than 50m.

Figure 16 shows that 23% of the sites (17 sites) features an installed capacity greater than 10MW with a maximum of 26MW for the site SF-029 on the Ruhuhu River. 29% of the sites (22 sites) have an installed capacity above 5MW and 35% (26 sites) have an installed capacity below 1MW.

In terms of firm energy generation, 23% of the sites (17 sites) have an expected firm annual generation above 5GWh, as illustrated in Figure 16.

The location of the 75 promising potential hydropower sites is presented in Figure 17.

Figure 14. Distribution of gross head amongst the 70+ promising sites.

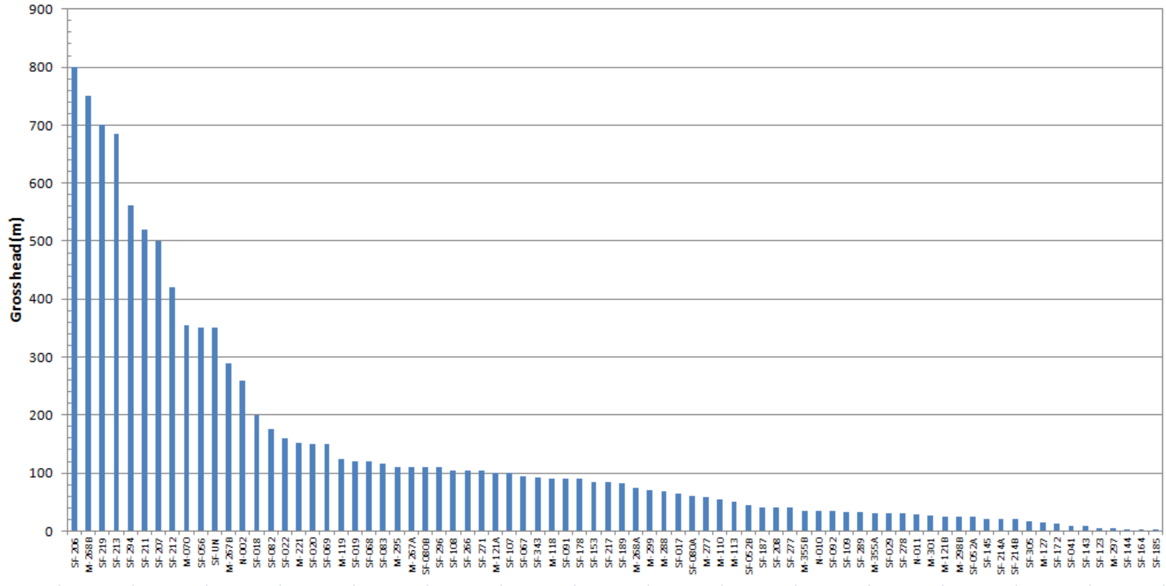


Figure 15. Distribution of the installed capacity amongst the 70+ promising sites.

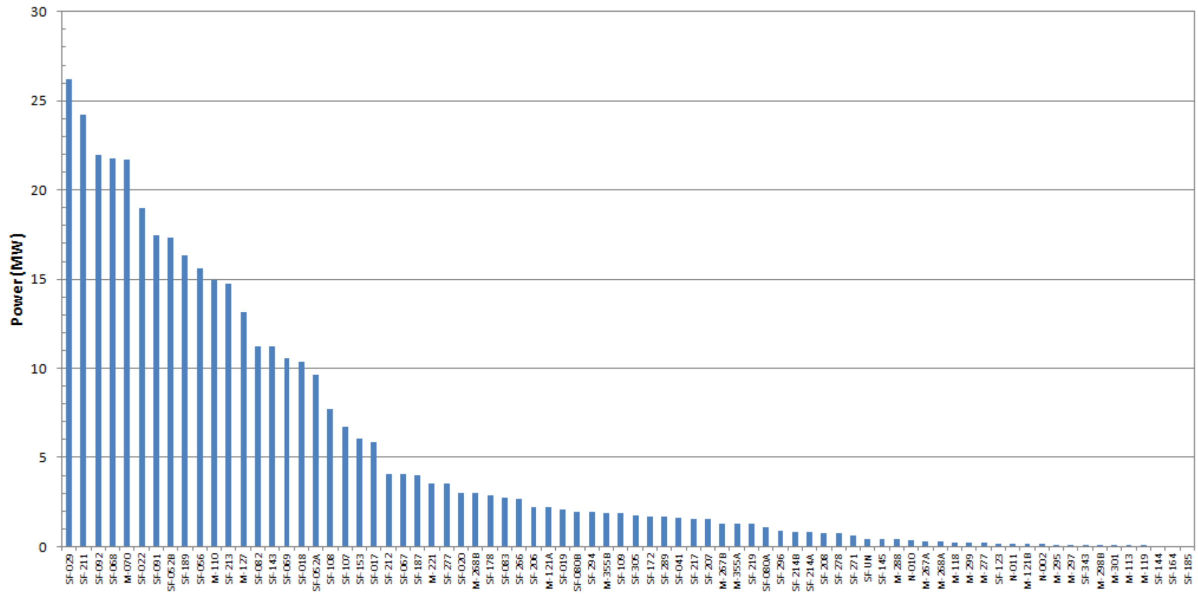


Figure 16. Distribution of the firm energy amongst the 70+ promising sites.

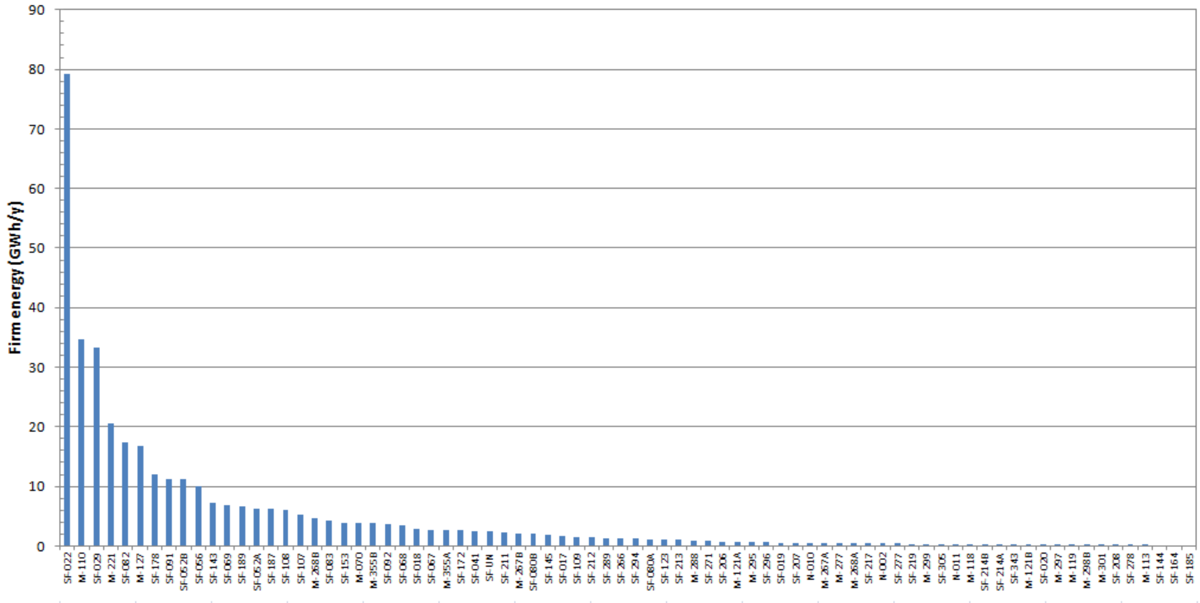


Figure 17. Location map of the 70+ promising sites

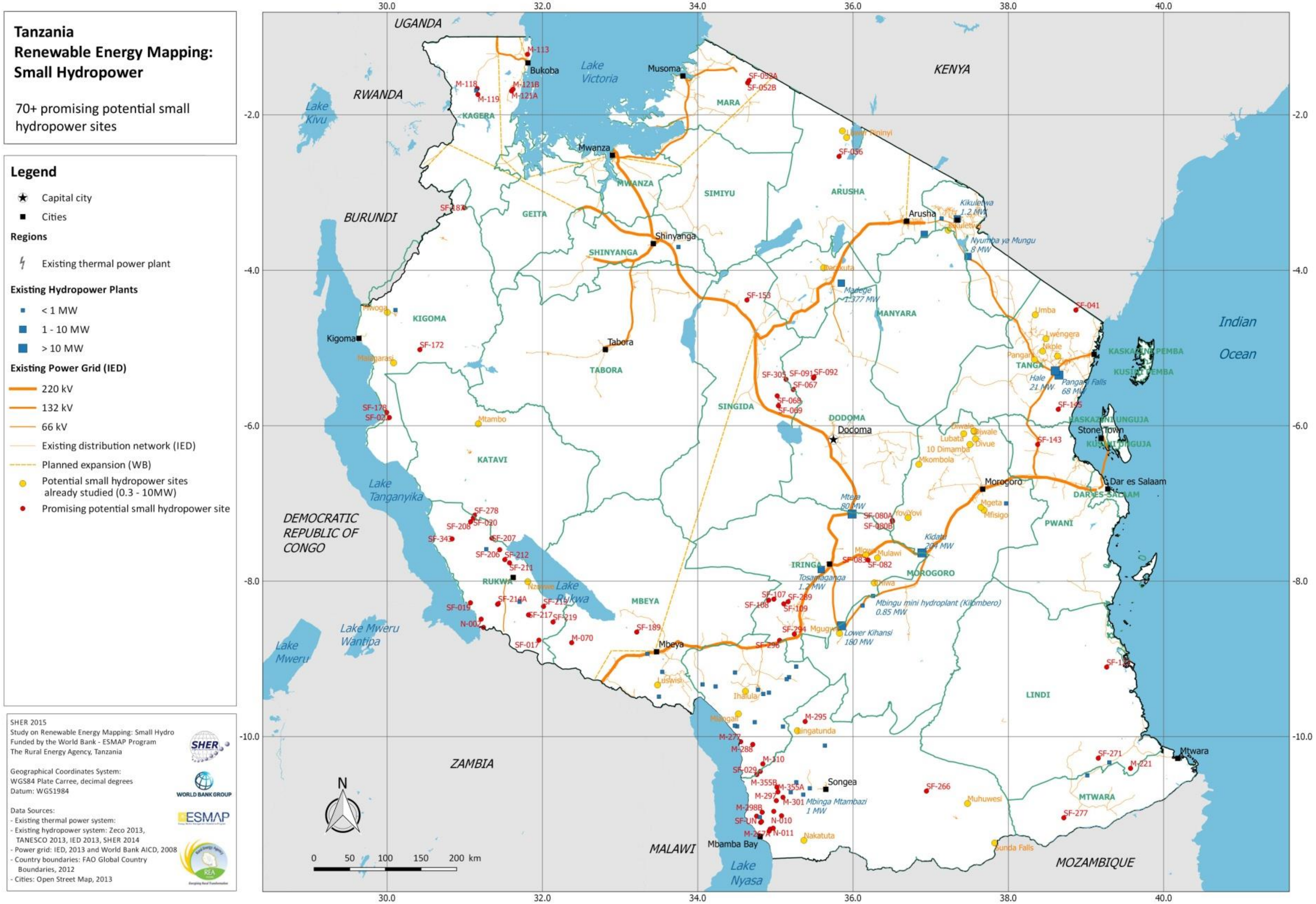


Table 14. Key features of the 70+ promising hydropower sites

SITE		COORDINATES		REGION	WATERSHED CHARACTERISTICS			GROSS	FIRM		@ $Q_{50\%}$	
		LAT	LON					HEAD	POWER	ENERGY	POWER	ENERGY
CODE	NAME	(DD)	(DD)		MAJOR WATER BASIN	RIVER	AREA (km²)	(m)	(kW)	(GWh/y)	(kW)	(GWh/y)
M-070	Momba II	32.376	-8.792	Mbeya	Lake Rukwa	Momba	4978	355	441	3.9	21700	161.8
M-110	Kitewaka	34.837	-10.352	Njombe	Lake Nyasa	Kitewaka	2461	54	3958	34.7	14960	106.0
M-113	Kyamato	31.809	-1.222	Kagera	Kagera and Lake Victoria	Kyamato	11	50	4	0.0	30	0.2
M-118	Achesherero	31.159	-1.663	Kagera	Kagera and Lake Victoria	Achesherero	55	90	27	0.2	200	1.3
M-119	Lubare	31.167	-1.739	Kagera	Kagera and Lake Victoria	Lubare	18	125	12	0.1	20	0.2
M-121A	Kitogota I	31.601	-1.693	Kagera	Kagera and Lake Victoria	Kitogota	104	100	74	0.7	2180	4.3
M-121B	Kitogota Falls	31.621	-1.671	Kagera	Kagera and Lake Victoria	Kitogota	118	25	23	0.2	160	1.1
M-127	Ruhuhu	34.805	-10.448	Ruvuma	Lake Nyasa	Ruhuhu	14582	15	1905	16.7	13120	87.7
M-221	Mambi	39.573	-10.409	Lindi	Ruvuma and Southern Indian Ocean Coast	Mambi	1481	152	2348	20.6	3560	30.4
M-267A	Ngongi I	34.932	-11.191	Ruvuma	Lake Nyasa	Ngongi	52	110	55	0.5	310	2.1
M-267B	Ngongi II	34.919	-11.217	Ruvuma	Lake Nyasa	Ngongi	84	290	232	2.0	1310	8.9
M-268A	Luwika I	34.820	-11.095	Ruvuma	Lake Nyasa	Luwika/lualala	72	75	50	0.4	290	2.0
M-268B	Luwika II	34.809	-11.104	Ruvuma	Lake Nyasa	Luwika/lualala	78	750	535	4.7	3030	20.6
M-277	Luika	34.553	-10.066	Njombe	Lake Nyasa	Luika	63	58	54	0.5	200	1.4
M-288	Kelolilo	34.708	-10.102	Njombe	Lake Nyasa	Kelolilo	104	69	109	1.0	400	2.9
M-295	Myombezi	35.383	-9.806	Ruvuma	Lake Nyasa	Myombezi	36	111	73	0.6	100	0.9
M-297	Lipumba	35.012	-10.825	Ruvuma	Lake Nyasa	Mngaka	350	4	13	0.1	70	0.5
M-298B	Litembo Extension	34.830	-10.975	Ruvuma	Lake Nyasa	Ndumbi	34	25	8	0.1	50	0.1
M-299	Luaita	34.979	-10.963	Ruvuma	Lake Nyasa	Luaita	54	70	35	0.3	200	1.4
M-301	Lukarasi shp	35.097	-10.782	Ruvuma	Ruvuma and Southern Indian Ocean Coast	Mkurusi	30	27	7	0.1	40	0.3
M-355A	Mgaka I	35.031	-10.712	Ruvuma	Lake Nyasa	Mgaka	520	30	299	2.6	1300	9.1
M-355B	Mgaka II	35.019	-10.652	Ruvuma	Lake Nyasa	Mgaka	651	35	436	3.8	1900	13.3
N-002	Kawa	31.211	-8.489	Rukwa	Malagarasi and Lake Tanganyika	Kawa	170	260	48	0.4	130	1.1
N-010	Kitandazi II	35.079	-11.019	Ruvuma	Ruvuma and Southern Indian Ocean Coast	Mbinga	180	35	58	0.5	330	2.3

SITE		COORDINATES		REGION	WATERSHED CHARACTERISTICS			GROSS	FIRM		@ $Q_{50\%}$	
		LAT	LON					HEAD	POWER	ENERGY	POWER	ENERGY
CODE	NAME	(DD)	(DD)		MAJOR WATER BASIN	RIVER	AREA (km²)	(m)	(kW)	(GWh/y)	(kW)	(GWh/y)
N-011	Kingilikiti	34.971	-11.179	Ruvuma	Ruvuma and Southern Indian Ocean Coast	Lumeme	115	28	30	0.3	170	1.2
SF-017	Momba I	31.954	-8.759	Rukwa	Lake Rukwa	Momba	2683	64	182	1.6	5860	35.7
SF-018	Kalambo Falls	31.240	-8.596	Rukwa	Malagarasi and Lake Tanganyika	Kalambo	3193	200	315	2.8	10360	63.1
SF-019	Lwazi	31.073	-8.278	Rukwa	Malagarasi and Lake Tanganyika	Lwazi	505	120	65	0.6	2100	12.8
SF-020	Mfizi II	31.110	-7.187	Rukwa	Lake Rukwa	Mfizi	2505	150	21	0.2	3040	17.6
SF-022	Luegere	30.029	-5.895	Kigoma	Malagarasi and Lake Tanganyika	Luegere	1320	159	9037	79.2	19010	145.4
SF-029	Lupapilo	34.759	-10.489	Njombe	Lake Nyasa	Ruhuhu	14618	30	3810	33.4	26230	175.5
SF-041	Kivumilo	38.869	-4.512	Tanga	Pangani and Northern Indian Ocean Coast	Umba	5490	9	289	2.5	1640	13.3
SF-052A	Mara I	34.659	-1.560	Mara	Kagera and Lake Victoria	Mara	10076	25	712	6.2	9630	61.4
SF-052B	Mara II	34.642	-1.588	Mara	Kagera and Lake Victoria	Mara	10076	45	1283	11.2	17340	110.5
SF-056	Manique	35.819	-2.535	Arusha	Northern Lakes	Manique	1289	350	1153	10.1	15570	99.2
SF-067	Mponde II	35.230	-5.535	Dodoma	Northern Lakes	Mponde	1913	95	301	2.6	4060	31.6
SF-068	Luwila	35.023	-5.616	Singida	Northern Lakes	Luwila	2176	120	328	3.5	21750	34.7
SF-069	Maparengi	35.038	-5.743	Singida	Northern Lakes	Maparengi	3111	150	781	6.8	10560	82.1
SF-080A	Sasimo I	36.505	-7.218	Dodoma	Rufiji	Sasimo	514	60	123	1.1	1070	8.5
SF-080B	Sasimo II	36.508	-7.230	Dodoma	Rufiji	Sasimo	514	110	225	2.0	1970	15.6
SF-082	Lukosi	36.192	-7.728	Iringa	Rufiji	Lukosi	1521	176	1976	17.3	11210	91.1
SF-083	Mlowa	36.172	-7.665	Iringa	Rufiji	Mlowa	694	117	477	4.2	2710	22.0
SF-091	Bubu II	35.490	-5.387	Dodoma	Northern Lakes	Bubu	7601	90	1290	11.3	17430	135.5
SF-092	Bubu I	35.497	-5.372	Dodoma	Northern Lakes	Bubu	7566	35	214	3.6	21970	35.0
SF-107	Ndembela I	34.980	-8.232	Iringa	Rufiji	Ndembela	1641	100	609	5.3	6740	52.8
SF-108	Ndembela II	34.913	-8.245	Iringa	Rufiji	Ndembela	1794	105	698	6.1	7720	60.5
SF-109	Lyandembela I	35.108	-8.292	Iringa	Rufiji	Lyandembela	1375	33	169	1.5	1860	14.6
SF-123	Mchakama	39.265	-9.106	Lindi	Ruvuma and Southern Indian Ocean Coast	Mavuji	3002	5	118	1.0	190	1.6

SITE		COORDINATES		REGION	WATERSHED CHARACTERISTICS			GROSS	FIRM		@ $Q_{50\%}$	
		LAT	LON					HEAD	POWER	ENERGY	POWER	ENERGY
CODE	NAME	(DD)	(DD)		MAJOR WATER BASIN	RIVER	AREA (km²)	(m)	(kW)	(GWh/y)	(kW)	(GWh/y)
SF-143	Wami	38.377	-6.241	Pwani	Wami, Ruvu and Central Indian Ocean Coast	Wami	39982	8	829	7.3	11210	87.1
SF-145	Mkalamo	38.642	-5.790	Tanga	Pangani and Northern Indian Ocean Coast	Msangazi	3827	20	204	1.8	420	17.6
SF-153	Ndurumo	34.633	-4.383	Singida	Northern Lakes	Ndurumo	2524	85	449	3.9	6080	47.2
SF-172	Ruchugi	30.421	-5.022	Kigoma	Malagarasi and Lake Tanganyika	Ruchugi	2816	13	295	2.6	1680	11.4
SF-178	Mgambazi	29.994	-5.828	Kigoma	Malagarasi and Lake Tanganyika	Mgambazi	618	90	1363	11.9	2870	21.9
SF-187	Muyovozi	30.993	-3.196	Kigoma	Malagarasi and Lake Tanganyika	Muyovozi	2484	40	702	6.2	3990	27.1
SF-189	Lupa	33.214	-8.655	Mbeya	Lake Rukwa	Lupa	5886	82	764	6.7	16360	125.0
SF-206	Chulu	31.449	-7.596	Rukwa	Lake Rukwa	Chulu	91	800	84	0.7	2240	13.8
SF-207	Kilida	31.348	-7.447	Rukwa	Lake Rukwa	Kilida	98	500	61	0.5	1530	9.4
SF-208	Mfizi I	31.075	-7.235	Rukwa	Lake Rukwa	Mfizi	2382	40	5	0.0	770	4.5
SF-211	Lwiche	31.576	-7.765	Rukwa	Lake Rukwa	Lwiche	832	519	241	2.2	24240	44.8
SF-212	Muze	31.515	-7.723	Rukwa	Lake Rukwa	Muze	305	420	158	1.4	4060	25.0
SF-213	Nyembe	32.014	-8.326	Rukwa	Lake Rukwa	Nyembe	178	684	114	1.0	14760	27.2
SF-214A	Kalambo I	31.430	-8.291	Rukwa	Malagarasi and Lake Tanganyika	Kalambo	1305	20	26	0.2	840	5.1
SF-214B	Kalambo II	31.423	-8.298	Rukwa	Malagarasi and Lake Tanganyika	Kalambo	1318	20	26	0.2	850	5.2
SF-217	Samvya	31.820	-8.434	Rukwa	Lake Rukwa	Samvya	565	85	49	0.4	1570	9.6
SF-219	Kianda	32.136	-8.526	Rukwa	Lake Rukwa	Kianda	60	700	39	0.3	1270	7.7
SF-266	Muhuwezi	36.945	-10.702	Ruvuma	Ruvuma and Southern Indian Ocean Coast	Muhuwezi	630	105	149	1.3	2680	16.8
SF-271	Mihima	39.157	-10.278	Lindi	Ruvuma and Southern Indian Ocean Coast	Mihima/namangale	129	104	104	0.9	590	4.0
SF-277	Mbagala	38.715	-11.049	Mtwara	Ruvuma and Southern Indian Ocean Coast	Mbagala	3323	40	46	0.4	3530	20.8
SF-278	Mfizi III	31.124	-7.154	Katavi	Lake Rukwa	Mfizi	3108	30	5	0.0	760	4.4
SF-289	Lyandembela II	35.163	-8.265	Iringa	Rufiji	Lyandembela	1214	33	149	1.3	1650	12.9
SF-294	Kigogo	35.243	-8.682	Iringa	Rufiji	Kigogo	56	562	141	1.2	1930	15.0

SITE		COORDINATES		REGION	WATERSHED CHARACTERISTICS			GROSS	FIRM		@ $Q_{50\%}$	
		LAT	LON					HEAD	POWER	ENERGY	POWER	ENERGY
CODE	NAME	(DD)	(DD)		MAJOR WATER BASIN	RIVER	AREA (km²)	(m)	(kW)	(GWh/y)	(kW)	(GWh/y)
SF-296	Vambanungwi	35.054	-8.763	Iringa	Rufiji	Vambanungwi	160	110	66	0.6	890	6.9
SF-305	Mponde I	35.137	-5.404	Singida	Northern Lakes	Mponde	1547	16	15	0.3	1780	2.8
SF-343	Samba	30.836	-7.457	Rukwa	Malagarasi and Lake Tanganyika	Samba	336	92	24	0.2	60	0.5
SF-UN	Mbawa	34.757	-11.025	Ruvuma	Lake Nyasa	Mbawa	90	350	281	2.5	450	3.9

5.3 SITE VISITS

5.3.1 Site visits of the 70+ promising sites

As mentioned earlier in this report, site visits are integral part of the identification process. Site visits are critical for the validation of the key features assessed during the desk-based study, define a preliminary layout for the hydropower scheme and to confirm at identification stage the technical and economic feasibility of the project.

The visits took place between March 2014 and May 2014, a period of 3 months for the first set of 50+ sites and between October 2014 and January 2015 for the second set of 20 site visits.

During the Phase 1 workshop held in Dar es Salaam in March 2015, it was agreed upon with REA and the World Bank that the Consultant will undertake (during Phase 2) the review of the 36 potential sites that were previously studied at an advanced stage ((pre)feasibility study, design) to select a subset of 7 sites matching the selection criteria detailed in section 5.2.

The results of the site visits are consolidated in the Site Visit Report. In total, the report presents the project sheets of **85 potential hydropower sites that were visited by the Consultant's team of Experts**. The Site Visits Report is presented in Appendix 9 of this report.

The class of data and information related to one potential hydropower site are either primary data (measured on site) or secondary data (derived from the primary data).

Six (6) categories of data and information can be collected during the site visits:

- **Administrative** data to validate (or fill voids) the site name, river and nearest villages;
- **Points** data obtained using a GPS/altimeter (three-dimensional coordinates: longitude, latitude, altitude);
- **Vector** data derived from point data type, allowing to obtain the length of the different linear structures (canal, penstock, access road, transmission line, etc.);
- **Judgment of Expert** to describe particular elements at the site;
- **Photos**, giving a better perception of the site. The photos are georeferenced and oriented.

The table below summarizes the different data collected by categories. The tools used to collect the data and the class to which they belong is also specified.

CATEGORY	COLLECTED DATA	MATERIAL OR TOOL	CLASS 1ST	CLASS 2ND
Administrative	River name	Questioning the locals	×	
	Name of the nearest villages to the site	Questioning the locals	×	
Point	along the river	GPS / altimeter	×	
	at the intake location	GPS / altimeter	×	
	at the forebay / surge chamber location	GPS / altimeter	×	
	At the powerhouse location	GPS / altimeter	×	
	At any remarkable point identified on the site (head, tributary, bridge, ford ...)	GPS / altimeter	×	
Vector	Field visit tracking (access)	GPS / altimeter	×	
	Canal or tunnel	GIS software		×
	Penstock	GIS software		×
	Power line to create	IS software		×
	Access roads to create	GIS software		×
	Access road section to be rehabilitated	GPS / altimeter	×	
Measurement	Width of the river	Laser rangefinder	×	
	Estimated width of the dam/weir	Laser rangefinder	×	
	Estimated height of the dam/weir	Topographic map		×
	Turbidity of water	Turbidity estimation	×	
	Slopes of the valley	Topographic map		×
	Channel geometry for streamflow calculation (width, depth, length and slope)	Laser rangefinder	×	
	Streamflow	Spreadsheet software		×
Judgment of Expert	General description of the scheme layout	Observation	×	
	Shape of the valley	Observation	×	
	Type of the envisaged dam/weir	Observation	×	
	Type of the envisaged project	Observation	×	
	Type of the envisaged connection	Observation/planning		×
	Network to which the project will be connected	GIS data		×
	General geology of the site	Observation/geological maps	×	×
	Sediment transport	Observation	×	
	Potential impact of the project	Observation and discussion with the locals	×	
	Accessibility to the site	Observation	×	
	Annual and exceptional flood levels	Observation	×	
Photos			×	

5.3.2 Sites visits of the existing hydroelectric projects

In addition to the potential sites visit, the team of experts have also visited 11 existing sites. The information about these sites has been synthesized in a "Site Visit Report - Existing sites".

Table 15. Key features of the existing sites visited

Code	Name	River	Region	Type	Connection	H [m]	Q [m³/s]	P [kW]	E [GWh/y)	BV [km²]
E-001	Peramiho - Likingo	Luhira and Mkingazi	Ruvuma	Run of the river	Connected to a mini-grid	43,3	2,6	940	6,4	422,22
E-002	Lupilo	Ruvuma	Ruvuma	Daily reservoir	Off-grid	8	11,4	620	1,31	1662,6
E-003	Kitai	Likoyu	Ruvuma	Run of the river	Off-grid	9,5	0,1	8	0,07	60,47
E-004	Kitandazi I	Mbinga	Ruvuma	Run of the river	Connected to a mini-grid	36	1,1	330	2,28	176,24
E-005	Maguu	Unknown	Ruvuma	Daily reservoir	Off-grid	7,5	0,072	4	0,01	9,99
M-266	Lumeme	Lumeme	Ruvuma	Run of the river	Off-grid	26	0,2	40	0,35	105,62
M-298A	Litembo Existing	Ndumbi	Ruvuma	Run of the river	Off-grid	12	0,062	6	0,05	33,82
M-348	Ndanda	Ndanda	Mtwara	Daily reservoir	Connected to the main grid	170	0,2	310	0,5	12,84
N-001	Lundomato Mission	Mhusi	Ruvuma	Run of the river	Off-grid	10	0,016	1	0,01	18,81
N-003	Kindimba Existing	Mangaka	Ruvuma	Run of the river	Off-grid	25	0,039	8	0,07	21,4
SF-030	Masigira	Ruhuhu	Iringa	Run of the river	Off-grid	30	15,8	3.920	33,57	1997,03

5.4 HYDROLOGICAL STUDY FOR THE 70+ PROMISING SITES

5.4.1 Objectives and limitations of the hydrological study

The main objective of the hydrological study is to assess the key statistical characteristics of the hydrological time series at the selected potential hydropower sites locations.

These statistical characteristics have a major role for the estimation of the technical and economic parameters of the potential hydropower schemes as well as for their development planning and connection type.

For the vast majority of the potential hydropower sites of interest in the context of this study, only little reliable hydrological information exists at the sites location. Hence, we have developed and applied a specific methodology to estimate the key statistical characteristics of the hydrological time series at ungauged locations. This methodology relies on the information (flow gauging stations and rainfall gauges) available within the watersheds or located in watersheds that can be considered as similar from a hydrology point of view. This methodology, the available data and the key results are described in the following sections.

The spatial and temporal resolution of the information available for the rivers of interest in the context of this study and the related methodology applied constraints the accuracy of the results. Indeed, the estimated statistical characteristics of the hydrological time series at the sites of interests are indicative only and cannot be used for detailed design purposes without further hydrological measurements and analysis.

5.4.2 Hydro-meteorological database

5.4.2.1 Data sources

The data collection process has started with the information available at the Water Basins level. Tanzania is divided into nine water basins as follow: Wami/Ruvu, Internal Drainage Basin, Lake Victoria Basin, Lake Tanaganyika Basin, Lake Rukwa Basin, Rufiji Basin, Ruvuma & Southern Rivers, Lake Nyasa Basin and Pangani Basin.

Information has been collected from three of those nine water basins: (i) Pangani Water Basin, (ii) Rufiji Water Basin and (iii) Lake Nyasa Water Basin.

In addition to the data collected in the Water Basin Agencies, data from the Global Runoff Data Centre (GRDC) have been received. The GRDC is an international database (with data up to 200 years old) that fosters multinational and global long-term hydrological studies (www.bafg.de). The data archived by the GRDC come from official monitoring networks. As a consequence, for the Pangani, Rufiji and Lake Nyasa water basins, most of the data received from the GRDC were the same that those received from the water basins agencies. GRDC database also covers the six other water basins for which we have not received information from the national level focal point. Unfortunately, the data archived by the GRDC are often quite old.

Regarding the rainfall data, the SIEREM (Système d'Information Environnementale sur les Ressources en Eau et leur Modélisation) website (www.hydrosciences.fr/sierem/) gives a good and comprehensive overview of the existing rainfall gauges for the whole country. The website gives an inventory of the existing rainfall gauges but not the measured data themselves. For Tanzania, the SIEREM indicates the existence of 2,156 rainfall gauges across the country.

Finally, we completed our data collection with information available in the literature amongst which regional studies like the Ruhudji Hydropower Project Design Hydrology Report.

The data collected during the inception phase, as well as its key characteristics are summarized in Table 16 below. These data were received in various formats such as Microsoft Excel files, Microsoft Access database, text files, etc.

Table 16. Collected data and their key characteristics

Date source	Streamflow data			Rainfall data			Concerned area
	Timestep	Number of identified stations	Number of station with data	Timestep	Number of identified stations	Number of station with data	
Pangani water basin	Daily	47	8	-	27	0	Pangani Water Basin
Rufiji Water Basin	Daily	19	19	Daily	11	11	Rufiji Water Basin
Lake Nyasa Water Basin	Daily	24	11	Daily	12	12	Lake Nyasa Water Basin
GRDC	Daily	97	89	-	-	-	Tanzania
SIEREM	-	-	-	-		-	Tanzania
Tanzanie Kagera	Daily	36	9	Daily	176	176	Kagera basin
Ruhudji hydrology	Daily	4	4	Monthly	18	18	Ruhudki Basin

5.4.2.2 Database consolidation

5.4.2.2.1 Data compilation

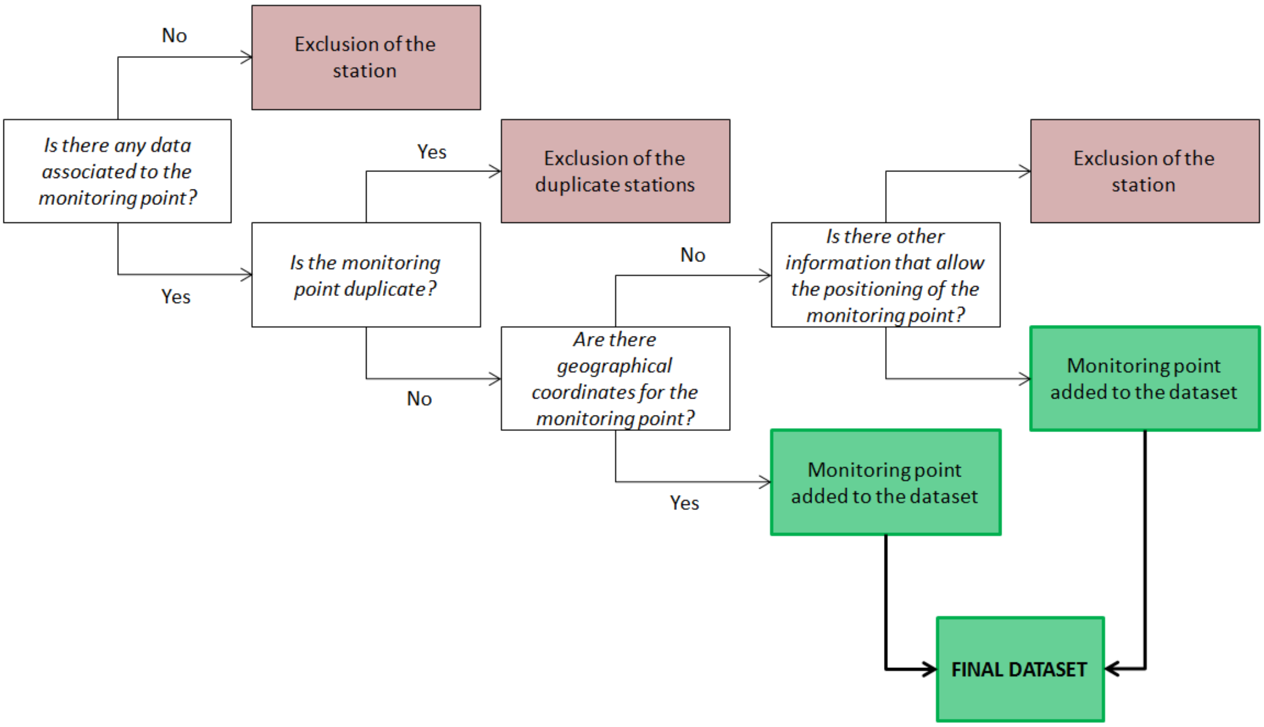
There are obviously numbers of duplicates among the information coming from the various sources. There are also many stations without available data. And finally, there are a numbers of stations for which the accurate location (geographical coordinates) is unknown or unclear.

A considerable effort has been made to constitute a collection of unique and properly located hydrological and meteorological stations with their associated data. This work was carried out using the following steps (for both the hydrological and meteorological stations):

1. Identification and deletion of the stations without data;
2. Identification and merging of the duplicated stations (and associated data) coming from the various sources of information;
3. Validation of the stations location:
    - If the station has geographical coordinates, validation on maps and satellite imagery;
    - If the station does not have any geographical coordinates, we tried to locate it by using the metadata associated with the station (name of the river, name of the city in the neighborhood of the station). This thorough effort was carried out using the topographical maps of Tanzania, the DEM and Google Earth imagery. If the location process was unsuccessful, the station was excluded from the database.

The aforementioned process is illustrated in the flow chart below (Figure 18).

Figure 18. Dataset selection process: flow chart



The compilation process resulted in two datasets:

- The hydrological dataset with 664,470 daily streamflow data from 100 different flow gauging stations. This figure of 100 is lower than the 203 stations previously mentioned in the inception report because of the large number of duplicates and the number of stations without enough data to be considered.
- The meteorological dataset with 965,598 daily rainfall measurements and 23,426 monthly rainfall data coming from 243 different stations.

The table below (Table 17) shows the breakdown of rainfall and hydrological stations for which data are available within the nine water basins. Figure 19 illustrates the spatial distribution of the hydrological stations and rainfall gauges in Tanzania.

Figure 19. Spatial distribution of the hydrological and rainfall stations in Tanzania

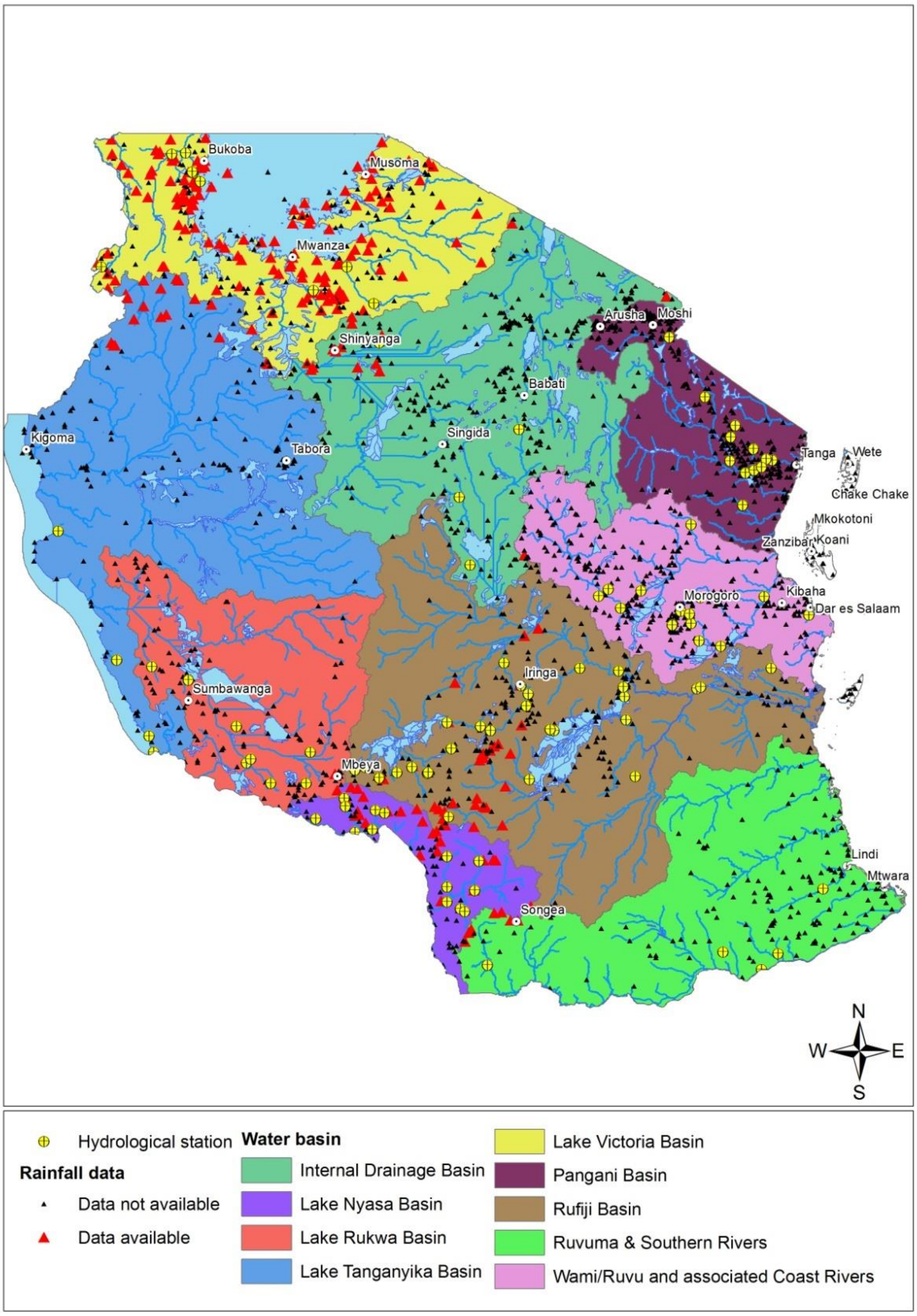


Table 17. Breakdown of the hydrological and rainfall stations within the nine water basins.

Water basin	Area [km²]	Hydrological station: Number of stations with data [-]	Hydrological station: Average density [km²/station]	Meteorological station: Number of stations with data [-]	Meteorological station: Average density [km²/station]
Internal Drainage Basin	146 289	4	36 572	15	9 753
Lake Nyasa Basin	27 654	14	1 975	25	1 106
Lake Rukwa Basin	77 707	9	8 634	1	77 707
Lake Tanganyika Basin	161 203	4	40 301	17	9 483
Lake Victoria Basin	119 968	9	13 330	144	833
Pangani Basin	54 748	12	4 562	0	/
Rufiji Basin	179 745	29	6 198	32	5 617
Ruvuma & Southern Rivers	106 153	5	21 231	8	13 269
Wami/Ruvu and associated Coast Rivers	67 138	14	4 796	1	67 138
Total	**940 605**	**100**	**9 406**	**243**	**3 871**

To facilitate the processing of this large amount of data, the data were stored in a geodatabase (standard database with geographical capabilities).

The geodatabase not only stores the rainfall and flow measurements, but also the hydrological and rainfall stations, their characteristics, their location and other geographical information useful for hydrological analysis (river networks, natural catchments and catchments associated to the hydrological stations, etc.). This approach provides the flexibility to query data with spatial criteria using any GIS software or other criteria in MS Access (or other database management packages).

5.4.2.2.2 Watersheds delineation

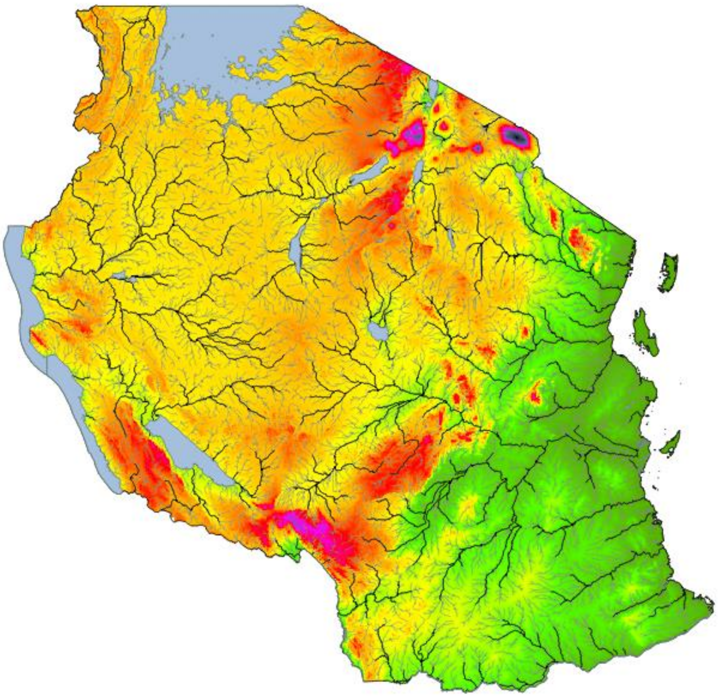
Given the size of the country and the large number of hydrological stations and potential hydropower sites, the watersheds delineation process has been done using ArcHydro from the ESRI's ArcGIS software. The process involves the following steps:

- The Digital Elevation Model (DEM) is modified, where necessary, by interpolation in order to fill any areas that contain no value and to eliminate possible imperfections in the DEM (pour points);
- Calculation of the flow direction for each cells of the DEM corresponding to the direction of the strongest gradient between adjacent cells;
- Calculation of the flow accumulation grid (the value associated to each cell of the grid corresponds to the number of cells located upstream of this cell);
- Stream definition based on the flow accumulation layer;
- Watersheds delineation.

The results of this spatial analysis are GIS layers (shapefiles and rasters) with the hydrographic network and the corresponding catchments.

The surface hydrological network determined by the aforementioned process is illustrated in the Figure 20 below.

Figure 20. Hydrological network calculated from the DEM



Tanzania's topography features a series of internal drainage basins (endorheic basins) which outlets are the series of endorheic lakes in the Northern part of the country, along the Eastern Rift Valley. Internal drainage basins must be processed semi-manually because they are not properly managed by the watershed delineation algorithm and could otherwise lead to errors in the delineation of the other watersheds. The position of the internal drainage basins is shown in Figure 21 below.

Figure 21 Location of the internal drainage basins of Tanzania

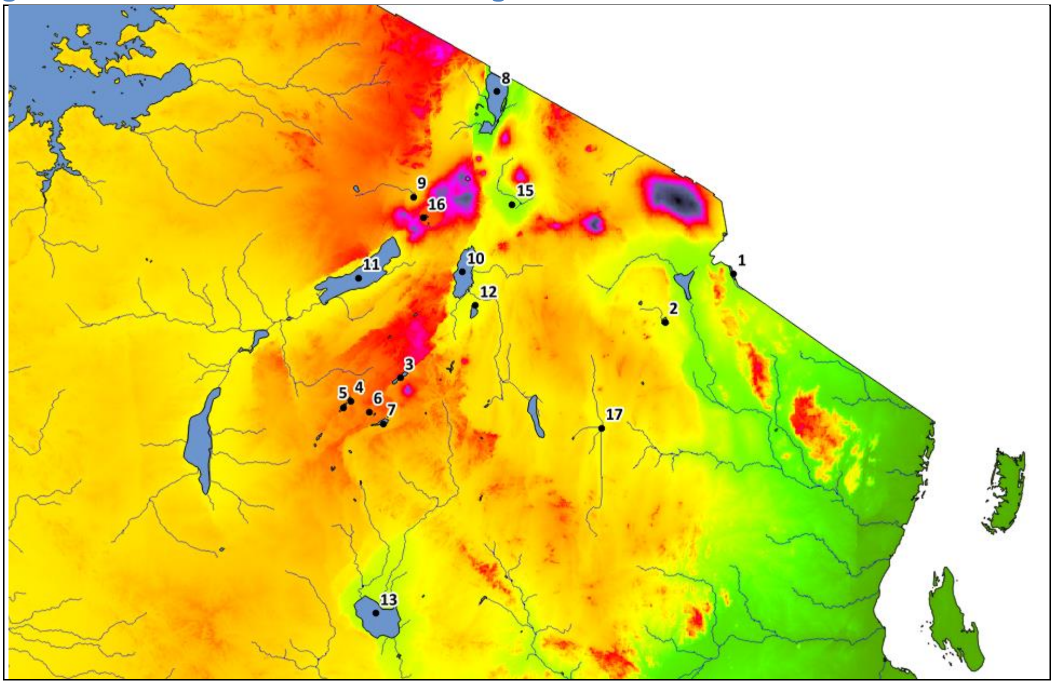


Table 18 Internal drainage basins and associated lakes of Tanzania

Number	Name
1	Lake Jipe
2	Lake Ambussel
3	Lake Balangida
4	Lake Mikuya
5	Lake Mikuya
6	Lake near Endesh
7	Lake Balangida Lehu
8	Lake Natron
9	Sink with no lake
10	Lake Manyara
11	Lake Eyasi
12	Lake Burungi
13	Bahi Swamp
14	Lake Rukwa
15	Unknown
16	Lake Madagi (Ngorongoro Crater)
17	Masai Steppe

The figures below present some of the lakes associated with an internal drainage basin. Blue and light colors show low elevation values while dark colors show higher elevation value. Hence, lakes and depressions are represented by blue or light shapes.

Figure 22. Lake Rukwa and Lake Eyasi

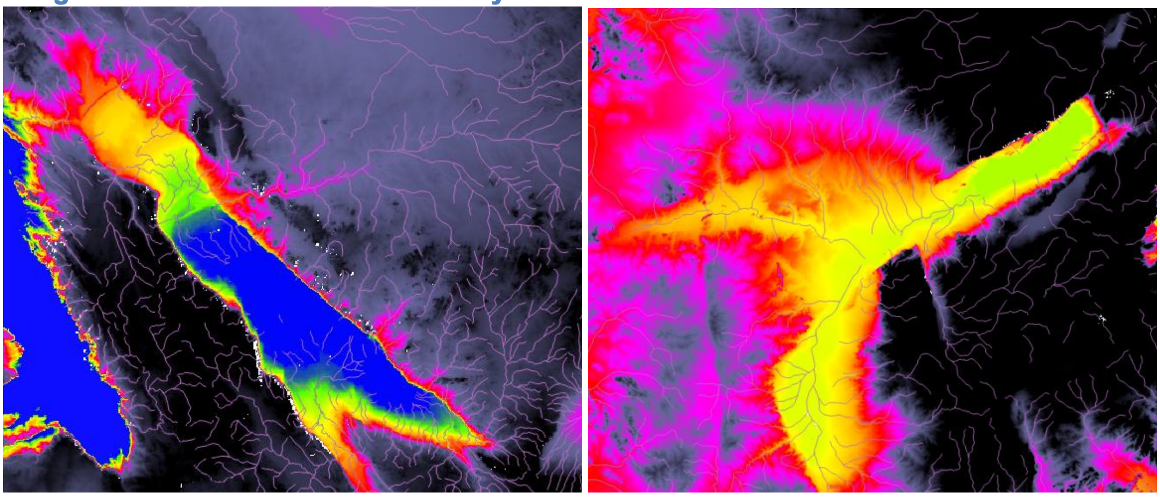


Figure 23 Lake Jipe, unknown lake and Bahi Swamp

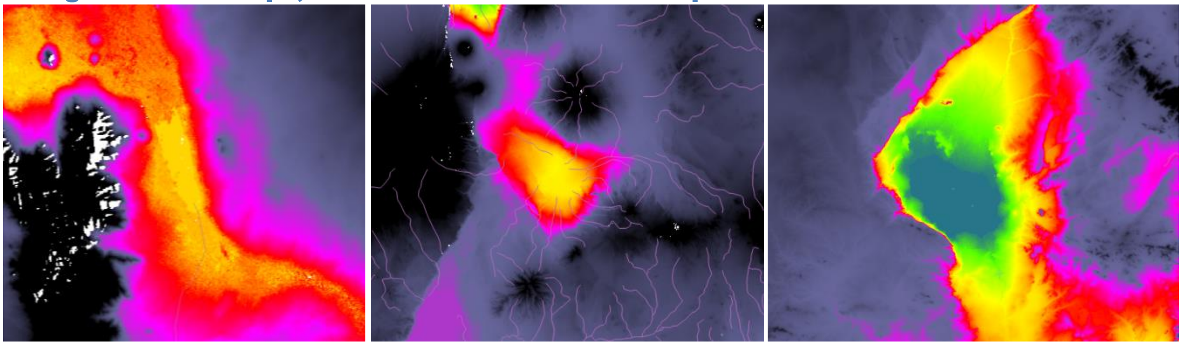


Figure 24 Lake Ambussel, a sink without lake on North-West of Ngorongoro Crater Area, and another south of Mbeya

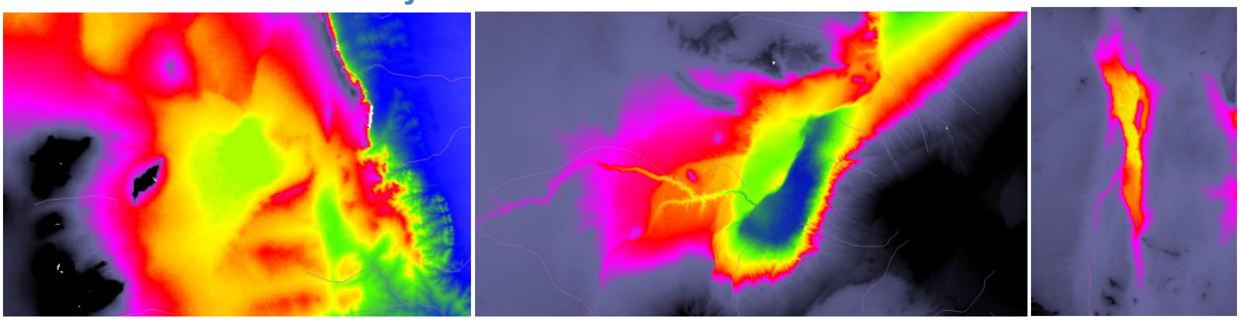


Figure 25 Lake Manyara and lake Burungi (2 on the same picture), lake Natron, and Lake Madagi in Ngorongoro Crater

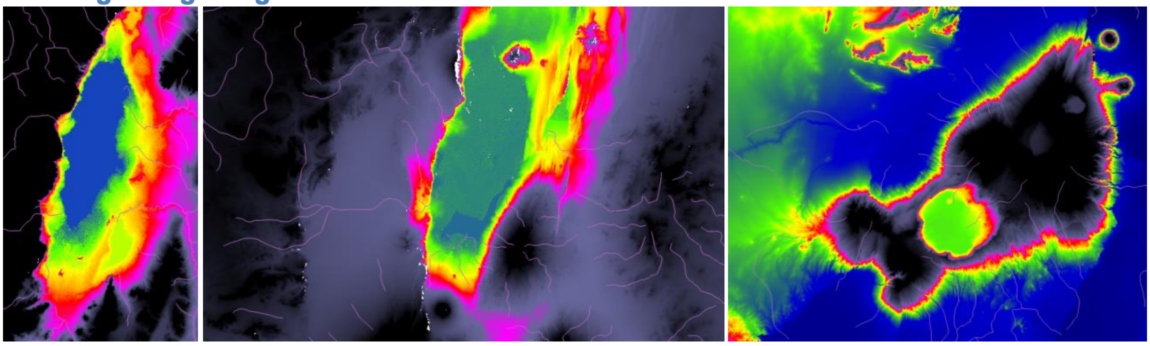
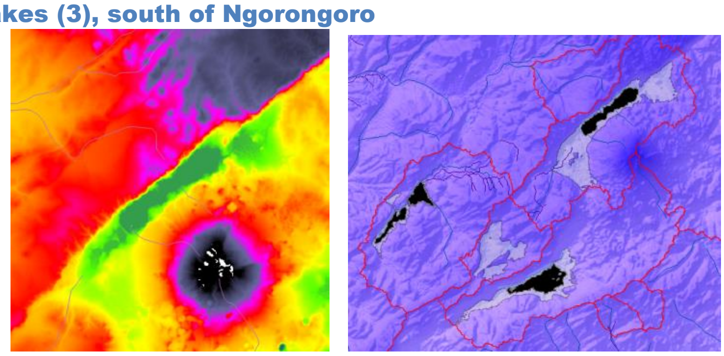


Figure 26. Determination of the country's hydrographic network : Lake Balangida and neighboring lakes (3), south of Ngorongoro



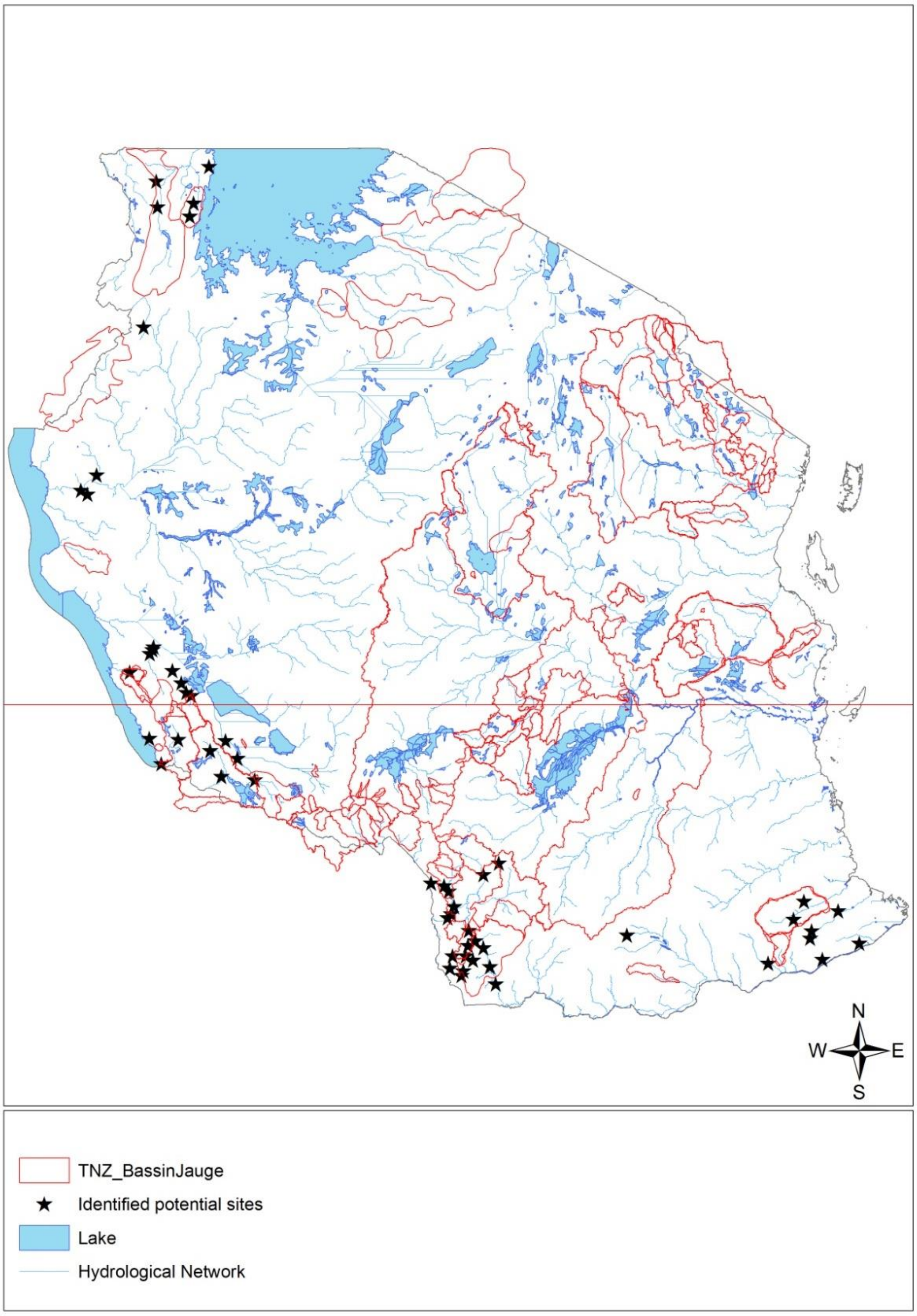
The last step of the delineation process consists in a visual check of the calculated watershed using topographical maps.

The watersheds associated to the flow gauging stations are illustrated in Figure 27 below. The area covered by the verified, available and usable gauged catchments represents 37% (344,779 km²) of the total country area. Also, 28 of the 53 potential hydropower sites are located in a gauged catchment.

Finally, it should be noted that some of the hydrological stations have approximate locations (we did not receive their exact location). As a consequence, the delineation of their associated catchment is also approximate. An update will be required should we get the exact location of these hydrological stations.

It is important to note that the accuracy of the river network identification depends on the elevation contrasts and the DEM's cells size. The delineation process will be less accurate in flat areas than in mountainous regions. Also, a DEM featuring large cells could artificially hide some steep-sided valleys.

Figure 27. Calculated watersheds associated with the flow gauging stations



5.4.2.2.3 Data quality assessment

Quality data are necessary to produce meaningful and reliable information on the hydrological regime (historical and future) of rivers at a specific location. Exploitable time series of hydrological data have the following important characteristics:

- it covers a long period;
- it covers a recent period. This is very important for assessing the potential existence of trends, especially in a context of possible climate change;
- it has a high degree of completeness (few missing data).

Figure 28 shows the lengths of the daily streamflow time series associated with the hydrological gauging stations. Just over 50% of the hydrological stations have at least 20 years of recorded data and only 23 stations have measured data for the years after 1990 and 13 until 2010.

The hydrological stations are characterized by various degree of completeness. Hence, we suggest keeping for each station the daily data for the years that have no more than 5% of missing data. Beyond this threshold, we can consider that the results of the statistical analysis will be influenced by the missing data. Figure 29 shows the number of "exploitable" years (years with less than 5 % of missing data) compared to the total length of the time series for each hydrological station.

Figure 28. Period of activity of the hydrological stations

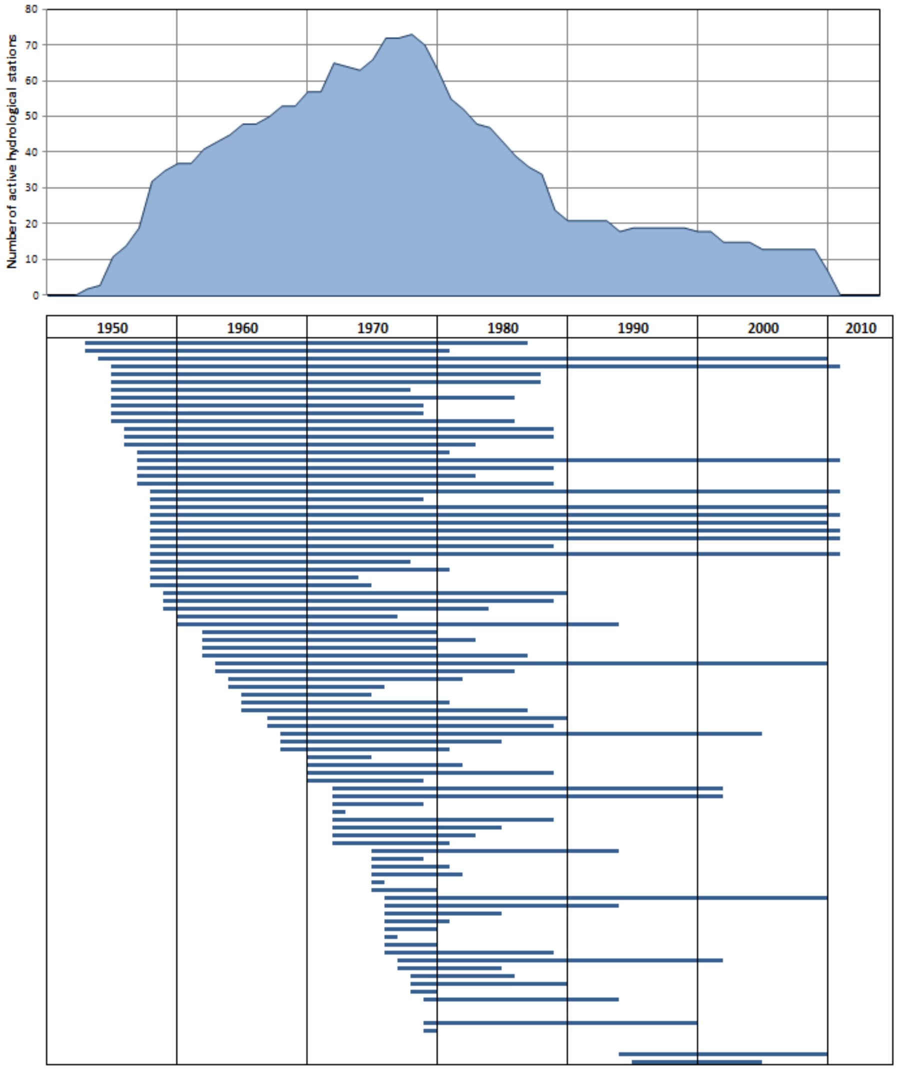


Figure 29. Number of "exploitable" years in relation with the streamflow time series length

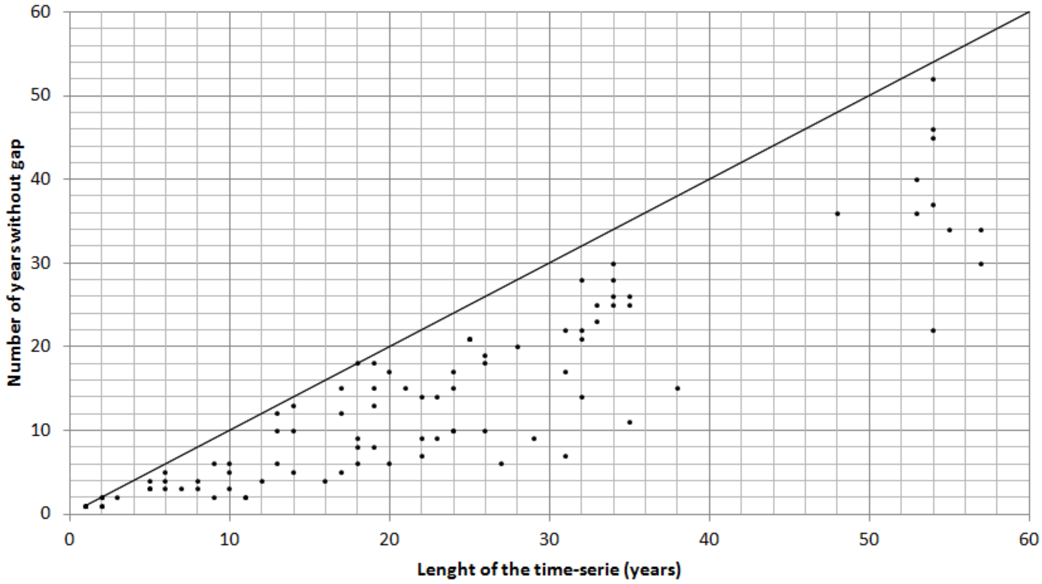


Figure 30 shows the length of the available daily rainfall time series. The rainfall dataset has 186 rainfall stations for which daily rainfall are available. However, as it can be seen on this figure, most of the stations feature relatively old data: only 12 stations have recent measurements. Regarding the length of the time series, 56 % of the rainfall stations have at least 20 years of data.

Figure 30. Period of activity of the rainfall stations with daily data

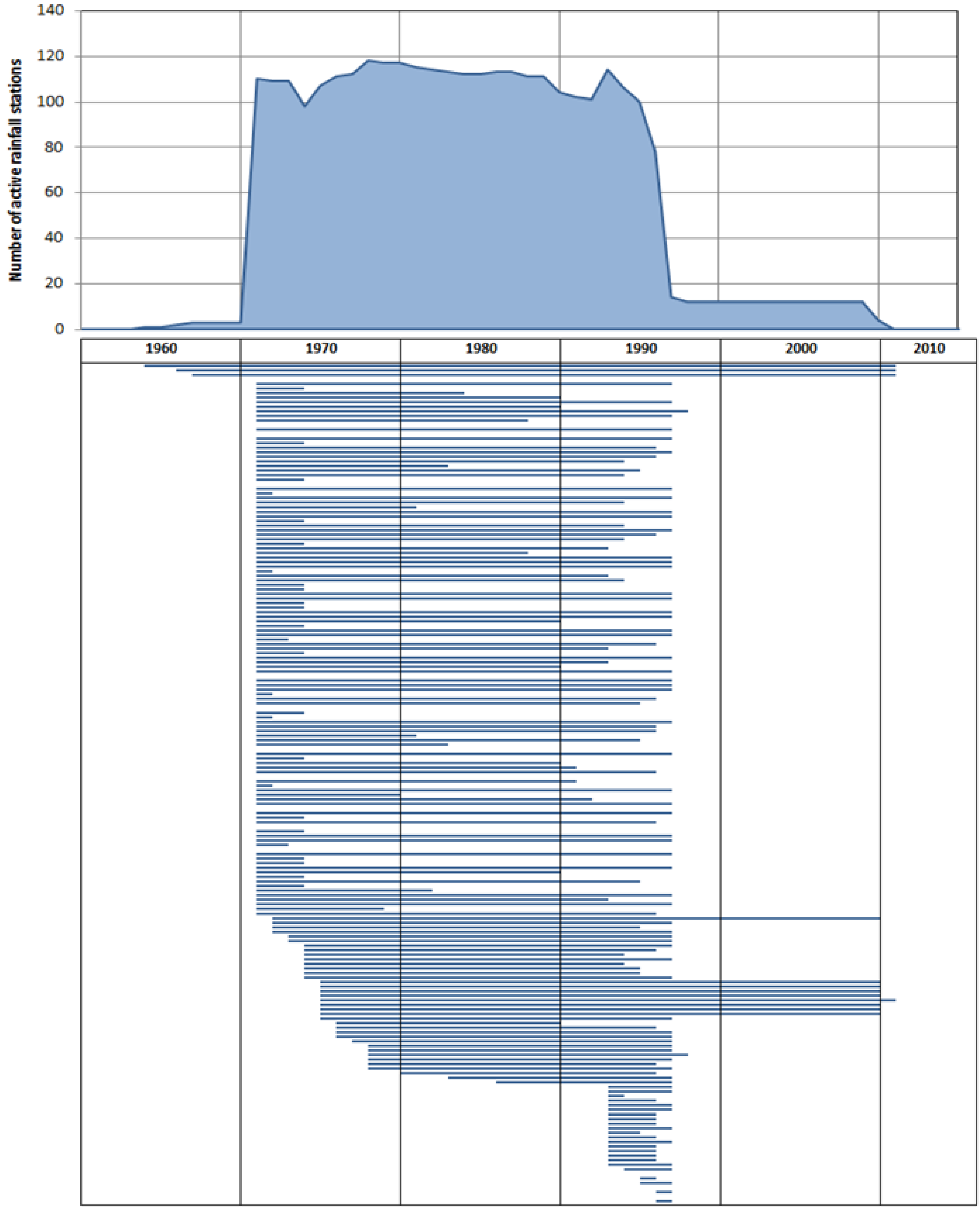


Figure 31. Period of activity of the rainfall stations with monthly data

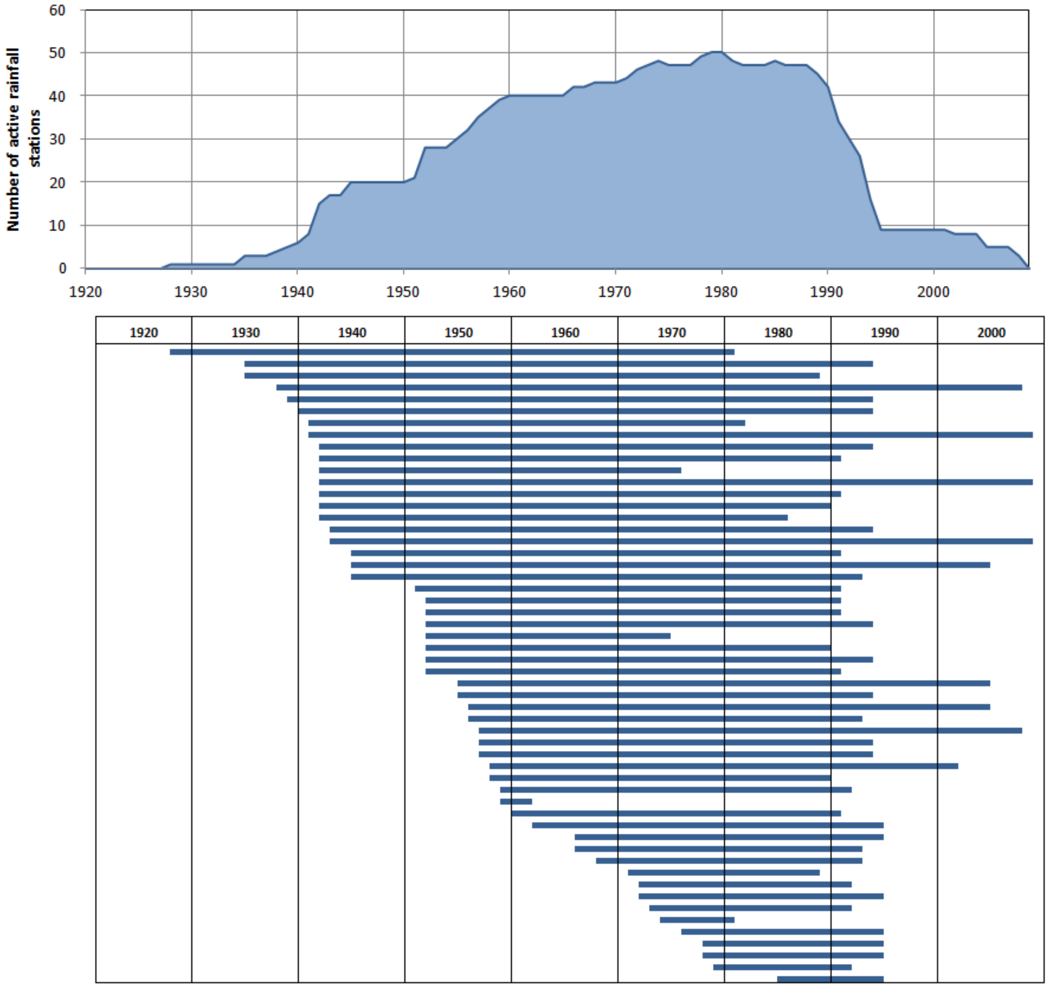


Figure 28, Figure 30 and Figure 31 illustrate strongly how collection of hydromet data have drastically fallen over the last two decades. It is strongly recommended that the Government of Tanzania set up a hydrological monitoring network for its rivers with high hydropower potential in order to better understand the available water resources and thus promote the development of hydroelectric projects across the country. It is only in a context of reduced uncertainties through reliable, recent and long-term records (more than 20 years) that technical parameters and economic and financial analyzes of hydroelectric developments can be defined accurately, enabling optimization of their design and their flood control infrastructure (temporary and permanent).

5.4.3 Flow duration curves modeling

5.4.3.1 Introduction

As mentioned previously, there is little information on the hydrological regime of the rivers at the location of the potential hydropower sites identified in the context of this study. Hence, we propose the following two-stage approach to estimate the key hydrological statistics at the sites of interest:

- Stage 1: Models selection and parameterization at gauged sites;
- Stage 2: Actual modeling by extrapolation at ungauged sites.

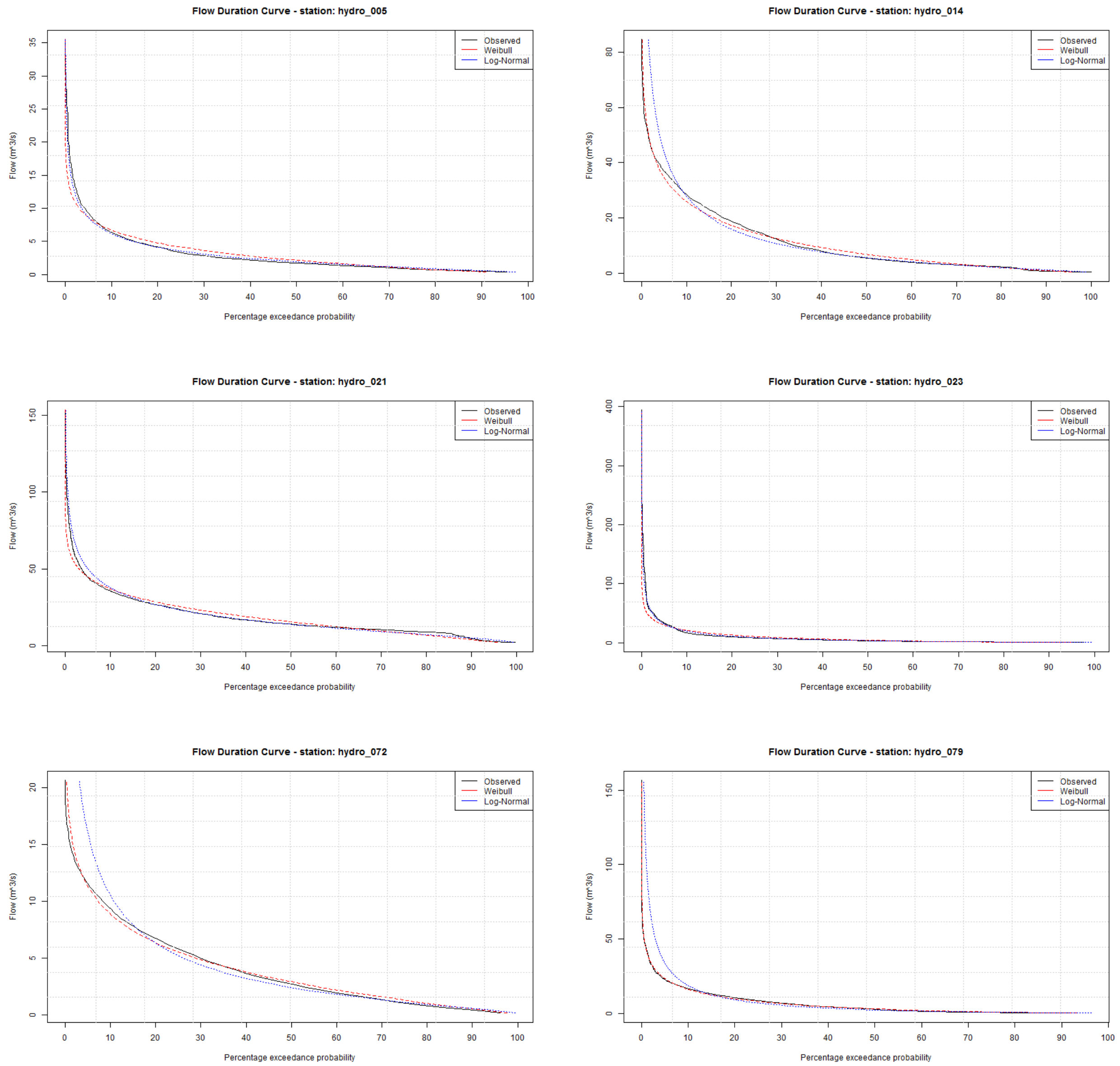
5.4.3.2 Model selection and parameterization

5.4.3.2.1 Statistical model selection

The model selection and parameterization is carried out using the hydrological and rainfall datasets described in the previous sections. The objective of this first step is to fit a statistical model for the flow duration curves at the 90 gauged sites using the key features of their watersheds.

Two statistical models widely used in hydrology are compared: Weibull and Lognormal laws, both characterized by two parameters. By fitting these two models to the observed data, it appeared that both models are relevant; however the Weibull law performed usually slightly better as illustrated in the Figure 32 below. As a consequence, the 2 parameters-Weibull law will be used to model the flow duration curves in the subsequent analysis.

Figure 32. Examples of flow duration curves modeled by the Weibull and lognormal laws



The selected Weibull law is characterized by two parameters:

- The shape factor γ determines the shape of the curve. As illustrated in Figure 33, the Weibull law is flatter as the shape factor increases;
- The scale factor λ determines the area below the curve. As illustrated in Figure 34, the area below Weibull law is larger as the scale factor increases.

Figure 33. Impact of the shape factor of the Weibull law

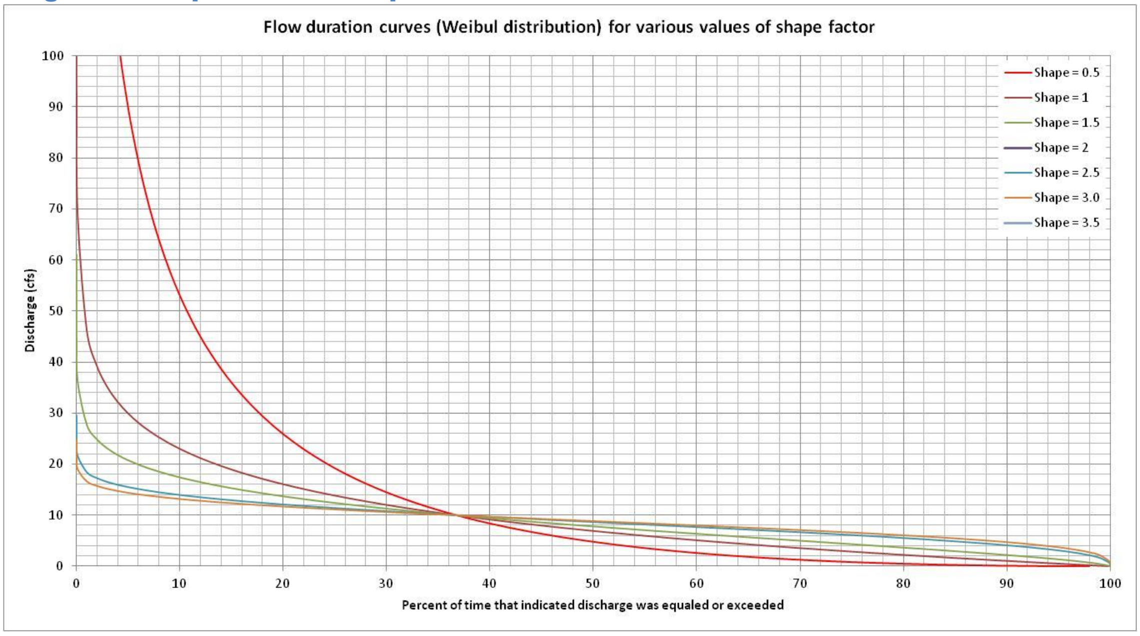
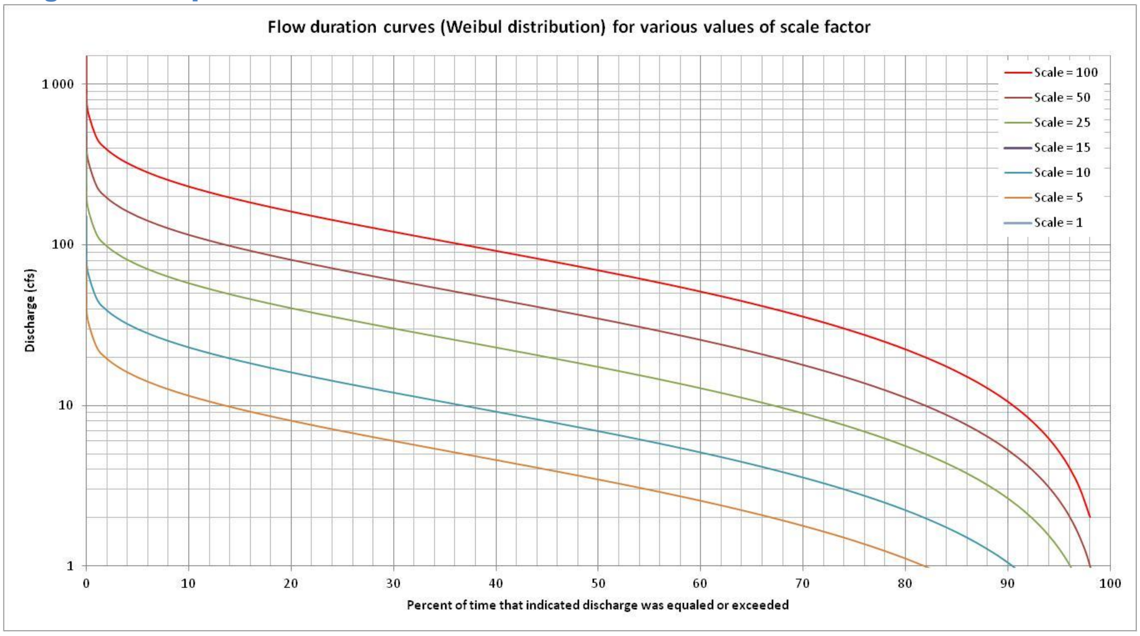


Figure 34. Impact of the scale factor on the Weibull law

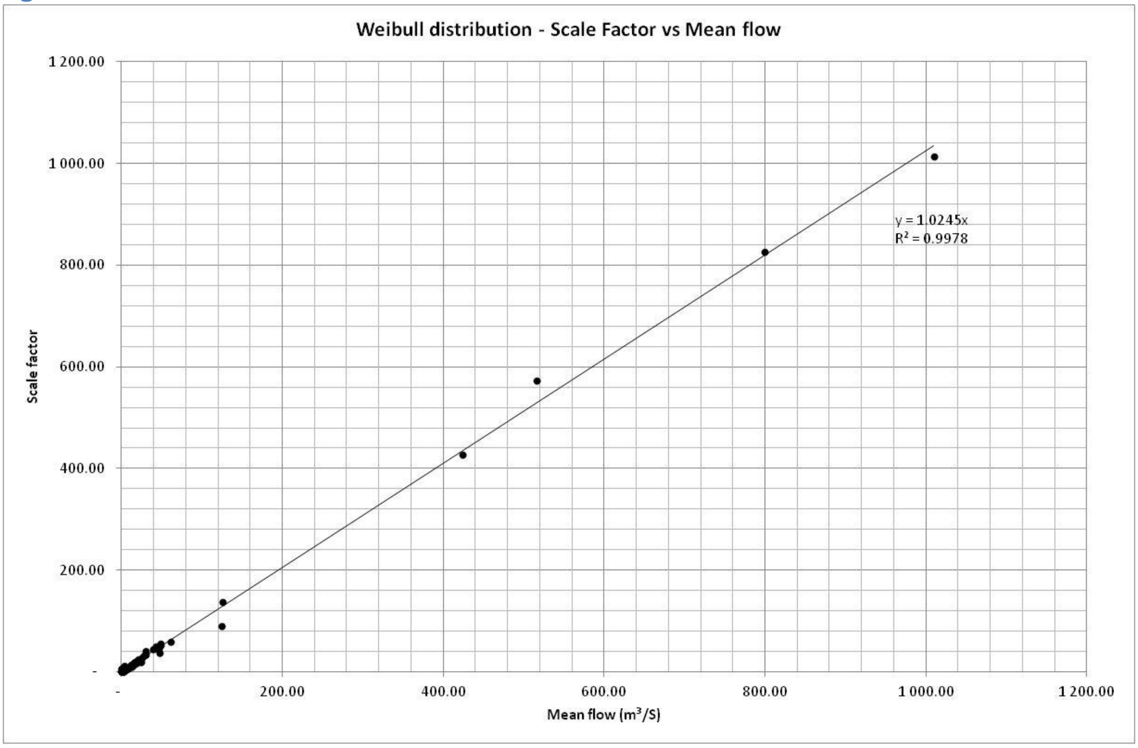


5.4.3.2.2 Model parameterization

The objective of the model parameterization is to build a relationship between the aforementioned two parameters of the selected Weibull law and the key features of the related gauged sites. These key features include the average annual rainfall, the watershed area, watershed average slope, altitude, etc.). This analysis is carried out using the 90 flow gauged sites sample.

Scale factor (λ) analysis - For each gauged site, the scale factor of the Weibull law is equal to the average flow of that site, as illustrated in Figure 35.

Figure 35. Weibull law: scale factor versus mean flow

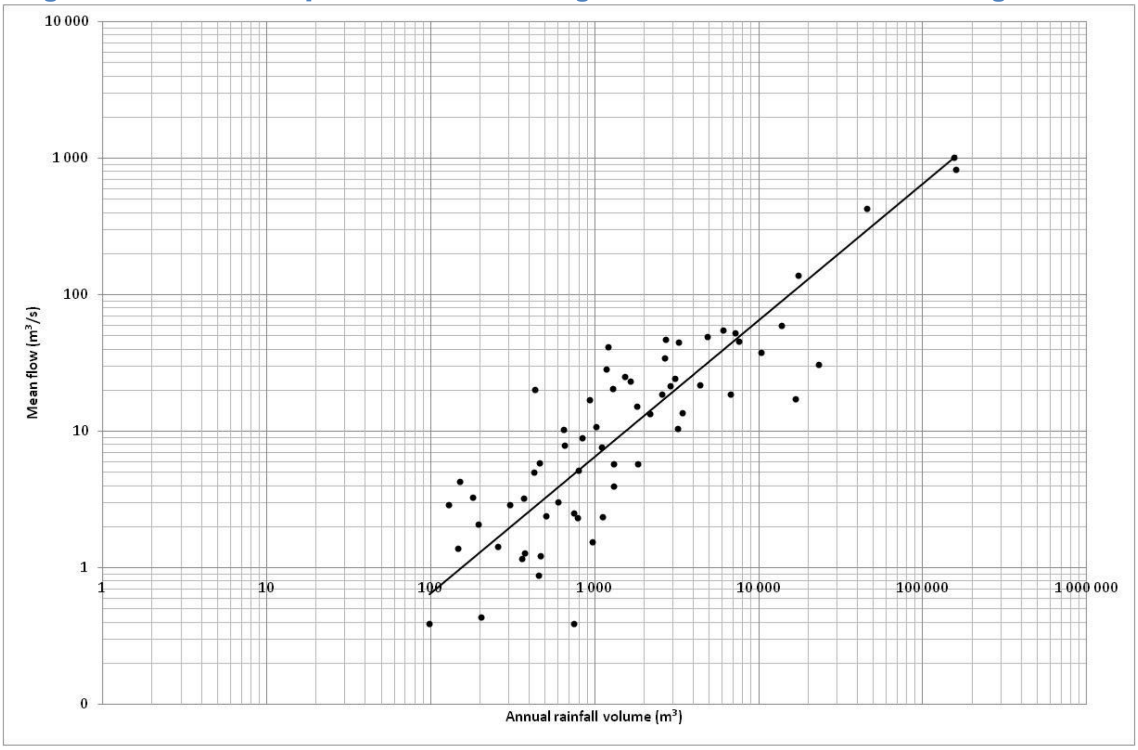


The analysis revealed that the average flow of the river is the most correlated to the average annual volume of rainfall in the watershed. The advantage of the latter is that it takes into account the size of the watershed and other climatic characteristics of the watershed). The relationship obtained by statistical regression is as follow (based on the 90 gauged sites sample):

$$\textit{Scale factor} = Q_{mean}\ (m^3/s) = 0.0065 \times \textit{Average annual rainfall in the watershed}\ (m^3)$$

The relationship is illustrated in Figure 36 and shows a R^2 of 75%.

Figure 36. Relationship between the average annual rainfall and the average flow.



Shape factor (ɣ) analysis - This parameter is more difficult to adjust because it implicitly includes considerations that affect the shape of the flow duration such as: presence of temporary runoff storage zones, physiographic characteristics of the watershed (distribution of slopes, shape of the river network), hydrogeology characteristics, etc. The variance-covariance analysis did not to identify satisfactory relationships between those variables and the value of the shape factor.

5.4.3.2.3 Extrapolation to ungauged sites

Given the lack of good quality data and their non uniform spatial distribution across the country characterized by a variety of different hydro-climatic context, we consider hazardous to use the above statistical relationships for all the ungauged sites. Hence we classified the ungauged watersheds into three categories depending on their locations relative to the existing gauging stations. The three categories are as follow:

- **Group 1:** the ungauged site is located upstream or downstream an existing gauging station and their watersheds ratio is between 0.5 and 2. In this case, we consider that the hydrological conditions of the gauged site are representative for the ungauged site. Therefore, we assume the shape factor of the ungauged site remains identical to the one of the gauged site but the scale factor is adjusted based on the watersheds ratio. Hence we have:
  - $\gamma_{\text{ungauged site}} = \gamma_{\text{gauging station}}$
  - $\lambda_{\text{ungauged site}} = \lambda_{\text{gauging station}} * A_{\text{ungauged site}} / A_{\text{gauging station}}$

Where $\gamma_{\text{ungauged site}}$ and $\gamma_{\text{gauging station}}$ are the shape factors of the Weibull laws at the ungauged and gauged sites respectively, $A_{\text{ungauged site}}$ and $A_{\text{gauging station}}$ are the area of the watersheds at the ungauged and gauged sites respectively.

We make the assumption that estimations of the flow duration curves of the ungauged sites within this category are relatively accurate (high confidence).

- **Group 2:** the ungauged site is located upstream or downstream an existing gauging station and their watersheds ratio is either below 0.5 or above 2. In this case, we consider that the hydrological conditions of the gauged site are representative for the ungauged site. Therefore, we assume the shape factor of the ungauged site remains identical to the one of the gauged site but the scale factor is calculated using the statistical relationship between the scale factor and the average annual volume of rainfall as explained in the previous section. Hence we have:

    - $\gamma_{\text{ungauged site}} = \gamma_{\text{gauging station}}$
    - $\lambda_{\text{ungauged site}} = 0.0065 \times P_{\text{ungauged site}} \times A_{\text{ungauged site}}$

Where $\gamma_{\text{ungauged site}}$ and $\gamma_{\text{gauging station}}$ are the shape factors of the Weibull laws at the ungauged and gauged sites respectively, $A_{\text{ungauged site}}$ and $P_{\text{ungauged site}}$ are the area and the average annual precipitation in the ungauged watershed respectively.

We make the assumption that estimations of the flow duration curves of the ungauged sites within this category are less accurate than those from group 1 (medium confidence).

- **Group 3:** the ungauged site is located within an ungauged watershed and there is no gauged watershed in the immediate neighborhood. In this case, we assume that the scale factor is calculated using the statistical relationship between the scale factor and the average annual volume of rainfall as for group 2. The estimation of the shape factor remains a challenge as no statistical relationship with other variables was found, as previously explained. Hence, the shape factor of the ungauged sites was estimated based on similarities with other watersheds that could be considered as being similar i.e. with similar range of altitudes, slopes, climatic zones and sizes.

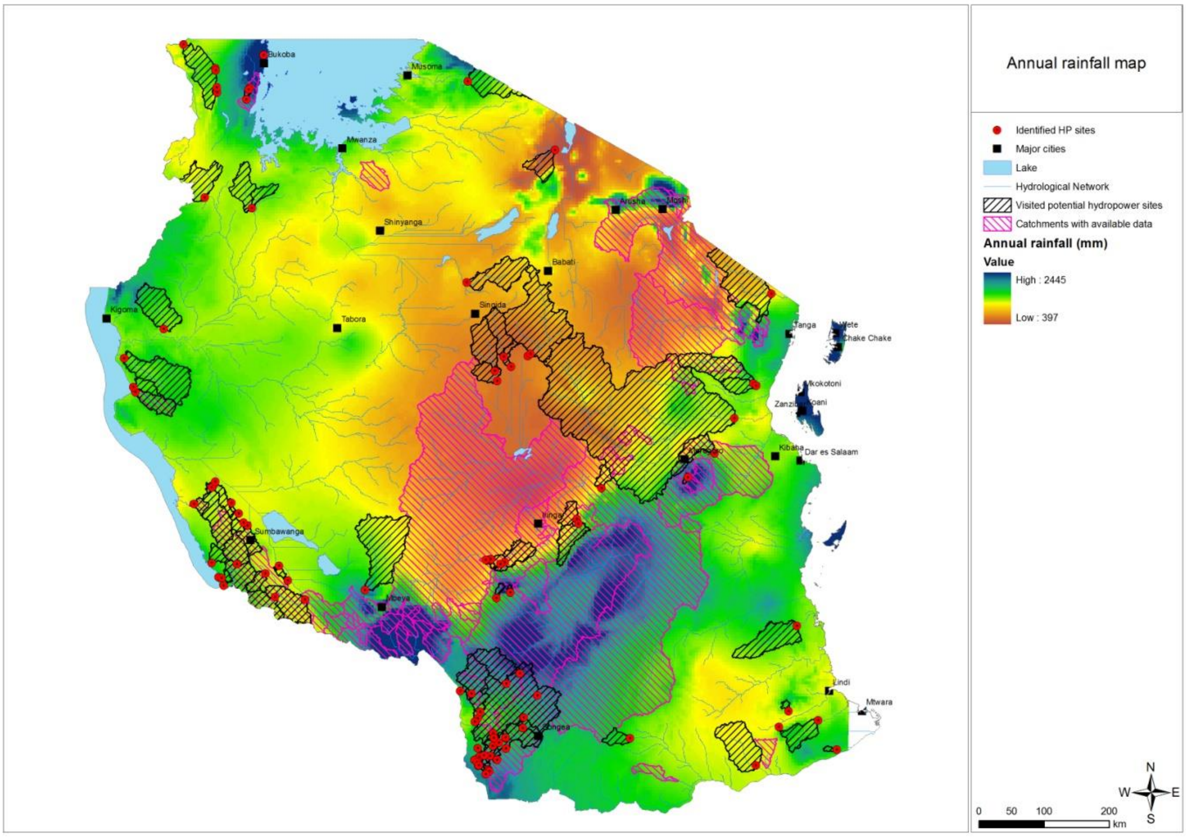
We make the assumption that estimations of the flow duration curves of the ungauged sites within this category are less accurate than those from group 2 (low confidence).

It is important to bear in mind that the proposed method is flexible: ungauged sites can be moved from one group to another if more gauging stations becomes available during the course of the study. Indeed, the initial inventory of the existing flow gauging stations is probably not exhaustive but is based on the information collected up to this stage of the study.

5.4.3.3 Results

Figure 37 presents the average annual rainfall map of Tanzania. This map was produced by the spatial analysis of the rainfall dataset presented in the previous section. The purpose of this map is to allow the calculation of the average annual rainfall which is the key variable used for the estimation of the scale factor of the Weibull model for group 2 and 3.

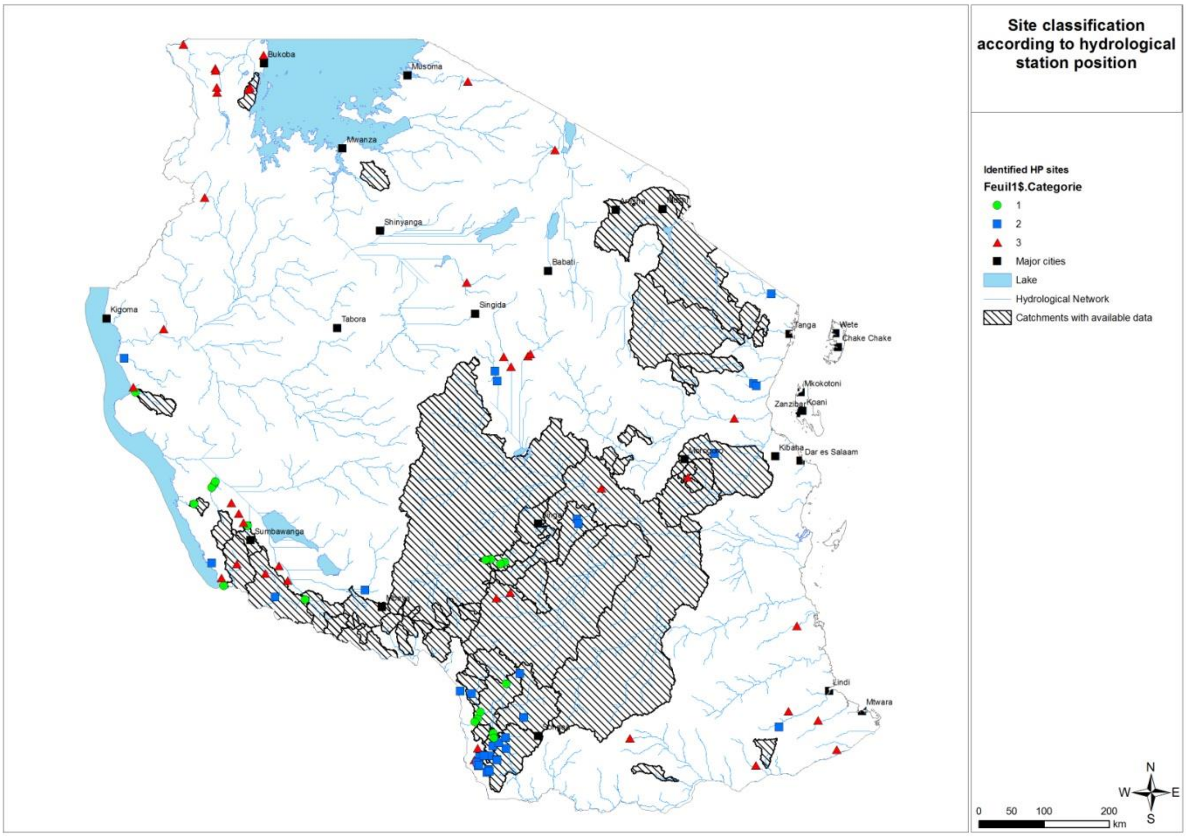
Figure 37. Average annual rainfall (spatial extrapolation)



Each ungauged sites were classified in one of the aforementioned groups based on their location relative to an existing gauging station as illustrated in Figure 38 and distributed among those groups as follow:

	NUMBER OF SITES
Group 1	18
Group 2	35
Group 3	43

Figure 38. Ungauged sites classification



Finally, the flow duration curves of the ungauged sites were estimated using the methodologies specifics to each group. The key results are presented in Table 19.

Table 19 Estimated key features of the flow duration curve at the ungauged sites

Site code	Scale Factor	Shape Factor	Flow (m³/s)									
				Percentiles								
			Q mean	2.5	30	50 / Median	65	90	95	96	97	98
E-001a	0.52	1.50	0.51	1.28	0.59	0.41	0.30	0.12	0.07	0.06	0.05	0.04
E-001b	2.84	1.50	2.78	7.04	3.21	2.22	1.62	0.63	0.39	0.34	0.28	0.21
E-002	12.82	1.50	12.59	31.83	14.51	10.04	7.31	2.86	1.77	1.52	1.25	0.95
E-003	0.45	1.50	0.44	1.12	0.51	0.35	0.26	0.10	0.06	0.05	0.04	0.03
E-004	1.44	1.50	1.41	3.58	1.63	1.13	0.82	0.32	0.20	0.17	0.14	0.11
E-005	0.08	1.50	0.08	0.20	0.09	0.06	0.05	0.02	0.01	0.01	0.01	0.01
M-070	12.86	0.67	12.85	98.88	16.97	7.43	3.65	0.44	0.15	0.11	0.07	0.04
M-110	40.39	1.96	39.07	81.05	44.40	33.49	26.27	12.80	8.86	7.89	6.79	5.51
M-113	0.09	1.30	0.09	0.26	0.11	0.07	0.05	0.02	0.01	0.01	0.01	0.01
M-118	0.36	1.30	0.36	1.04	0.42	0.27	0.19	0.06	0.04	0.03	0.03	0.02
M-119	0.11	1.30	0.11	0.33	0.13	0.09	0.06	0.02	0.01	0.01	0.01	0.01
M-120	0.01	1.30	0.01	0.03	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00
M-121A	0.90	1.35	0.89	2.47	1.03	0.69	0.48	0.17	0.10	0.08	0.07	0.05
M-121B	1.03	1.35	1.02	2.83	1.18	0.79	0.55	0.20	0.11	0.10	0.08	0.06
M-127	138.05	1.35	136.14	379.32	158.40	105.22	73.96	26.05	15.28	12.90	10.39	7.66
M-221	10.49	1.73	10.22	23.08	11.68	8.49	6.45	2.86	1.88	1.65	1.39	1.10
M-266	0.88	1.50	0.86	2.17	0.99	0.69	0.50	0.20	0.12	0.10	0.09	0.07

SITE CODE	SCALE FACTOR	SHAPE FACTOR	FLOW (M³/S)									
				PERCENTILES								
			Q MEAN	2.5	30	50 / MEDIAN	65	90	95	96	97	98
M-267a	0.44	1.50	0.43	1.10	0.50	0.35	0.25	0.10	0.06	0.05	0.04	0.03
M-267b	0.71	1.50	0.70	1.77	0.81	0.56	0.41	0.16	0.10	0.09	0.07	0.05
M-268a	0.60	1.50	0.59	1.48	0.68	0.47	0.34	0.13	0.08	0.07	0.06	0.04
M-268b	0.64	1.50	0.63	1.59	0.73	0.50	0.37	0.14	0.09	0.08	0.06	0.05
M-277	0.50	2.00	0.48	0.98	0.55	0.41	0.33	0.16	0.11	0.10	0.09	0.07
M-288	0.85	2.00	0.82	1.68	0.93	0.71	0.56	0.28	0.19	0.17	0.15	0.12
M-295	0.36	2.00	0.35	0.71	0.39	0.30	0.24	0.12	0.08	0.07	0.06	0.05
M-297	2.80	1.50	2.75	6.95	3.17	2.19	1.60	0.63	0.39	0.33	0.27	0.21
M-298	0.28	1.50	0.27	0.69	0.32	0.22	0.16	0.06	0.04	0.03	0.03	0.02
M-299	0.44	1.50	0.43	1.10	0.50	0.35	0.25	0.10	0.06	0.05	0.04	0.03
M-301	0.24	1.50	0.23	0.58	0.27	0.18	0.13	0.05	0.03	0.03	0.02	0.02
M-348	0.08	1.00	0.08	0.33	0.10	0.06	0.04	0.01	0.00	0.00	0.00	0.00
M-355A	6.47	1.77	6.29	13.98	7.18	5.26	4.02	1.81	1.21	1.06	0.90	0.71
M-355B	8.09	1.77	7.88	17.50	8.99	6.58	5.03	2.27	1.51	1.33	1.12	0.89
N-001	0.15	1.00	0.15	0.58	0.18	0.10	0.06	0.02	0.01	0.01	0.01	0.00
N-002	1.20	0.75	1.20	7.38	1.53	0.73	0.39	0.06	0.02	0.02	0.01	0.01
N-003	0.18	1.50	0.17	0.44	0.20	0.14	0.10	0.04	0.02	0.02	0.02	0.01
N-010	1.47	1.50	1.45	3.66	1.67	1.15	0.84	0.33	0.20	0.18	0.14	0.11
N-011	0.95	1.50	0.93	2.36	1.07	0.74	0.54	0.21	0.13	0.11	0.09	0.07
N-020	0.00	1.30	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SF-017	18.14	0.75	18.12	111.83	23.24	11.13	5.90	0.90	0.35	0.26	0.17	0.10
SF-018	10.26	0.75	10.25	63.95	13.16	6.27	3.31	0.50	0.19	0.14	0.10	0.06
SF-019	3.46	0.75	3.45	21.31	4.43	2.12	1.13	0.17	0.07	0.05	0.03	0.02
SF-020	4.99	0.52	4.99	68.53	7.12	2.47	0.99	0.07	0.02	0.01	0.01	0.00
SF-022	16.11	3.50	529.47	23.78	16.99	14.51	12.66	8.47	6.90	6.46	5.94	5.28
SF-024	29.33	3.50	27.30	43.30	30.92	26.41	23.05	15.42	12.55	11.76	10.82	9.62
SF-029	138.39	1.35	14.99	380.26	158.80	105.48	74.15	26.12	15.32	12.94	10.41	7.68
SF-030	46.89	2.07	45.21	90.75	51.29	39.26	31.19	15.77	11.13	9.97	8.65	7.09
SF-041	28.18	1.50	27.66	69.96	31.89	22.07	16.07	6.29	3.89	3.34	2.75	2.09
SF-052	67.27	1.00	66.96	263.17	80.99	46.63	28.98	7.09	3.45	2.75	2.05	1.36
SF-056	7.85	1.00	7.81	30.71	9.45	5.44	3.38	0.83	0.40	0.32	0.24	0.16
SF-067	7.48	1.00	7.45	29.28	9.01	5.19	3.22	0.79	0.38	0.31	0.23	0.15
SF-068	8.67	1.00	8.63	33.93	10.44	6.01	3.74	0.91	0.45	0.35	0.26	0.18
SF-069	12.33	1.00	12.27	48.23	14.84	8.55	5.31	1.30	0.63	0.50	0.38	0.25
SF-080	2.95	1.20	2.92	9.18	3.44	2.17	1.46	0.45	0.25	0.21	0.16	0.11
SF-082	9.86	1.50	9.68	24.48	11.16	7.72	5.62	2.20	1.36	1.17	0.96	0.73
SF-083	3.59	1.50	3.53	8.92	4.07	2.81	2.05	0.80	0.50	0.43	0.35	0.27
SF-091	33.85	1.00	33.69	132.41	40.75	23.46	14.58	3.57	1.74	1.38	1.03	0.68
SF-092	33.72	1.00	33.57	131.93	40.60	23.38	14.53	3.55	1.73	1.38	1.03	0.68
SF-107	11.44	1.08	11.36	40.29	13.58	8.16	5.26	1.43	0.74	0.60	0.46	0.31
SF-108	12.50	1.08	12.42	44.05	14.84	8.92	5.75	1.57	0.81	0.65	0.50	0.34
SF-109	9.59	1.08	9.52	33.76	11.38	6.83	4.41	1.20	0.62	0.50	0.38	0.26
SF-123	20.71	1.50	20.32	51.41	23.43	16.22	11.81	4.62	2.86	2.46	2.02	1.54
SF-143	243.46	1.00	242.32	952.40	293.11	168.75	104.88	25.65	12.49	9.94	7.42	4.92

SITE CODE	SCALE FACTOR	SHAPE FACTOR	FLOW (M³/S)									
				PERCENTILES								
			Q MEAN	2.5	30	50 / MEDIAN	65	90	95	96	97	98
SF-144	18.09	1.00	18.00	70.75	21.77	12.54	7.79	1.91	0.93	0.74	0.55	0.37
SF-145	24.02	1.00	23.91	93.96	28.92	16.65	10.35	2.53	1.23	0.98	0.73	0.49
SF-147	10.34	0.90	10.31	47.08	12.71	6.88	4.06	0.85	0.38	0.30	0.21	0.14
SF-153	12.51	1.00	12.45	48.92	15.06	8.67	5.39	1.32	0.64	0.51	0.38	0.25
SF-164	17.33	1.30	17.12	49.50	20.00	13.08	9.07	3.07	1.77	1.48	1.18	0.86
SF-172	19.98	1.50	19.61	49.61	22.61	15.65	11.40	4.46	2.76	2.37	1.95	1.48
SF-178	4.29	3.50	3.99	6.33	4.52	3.86	3.37	2.26	1.84	1.72	1.58	1.41
SF-185a	0.32	1.00	0.32	1.24	0.38	0.22	0.14	0.03	0.02	0.01	0.01	0.01
SF-185b	4.51	1.00	4.49	17.63	5.43	3.12	1.94	0.48	0.23	0.18	0.14	0.09
SF-185c	10.20	1.00	10.15	39.90	12.28	7.07	4.39	1.08	0.52	0.42	0.31	0.21
SF-187	15.37	1.50	15.09	38.17	17.40	12.04	8.77	3.43	2.12	1.82	1.50	1.14
SF-189	37.08	0.85	37.00	184.53	46.13	24.09	13.77	2.63	1.13	0.86	0.61	0.38
SF-189	37.08	0.85	37.00	184.53	46.13	24.09	13.77	2.63	1.13	0.86	0.61	0.38
SF-206	0.55	0.80	0.55	3.04	0.70	0.35	0.19	0.03	0.01	0.01	0.01	0.00
SF-207	0.60	0.80	0.60	3.29	0.75	0.38	0.21	0.04	0.02	0.01	0.01	0.01
SF-208	4.74	0.52	4.74	65.18	6.78	2.35	0.94	0.06	0.02	0.01	0.01	0.00
SF-211	2.26	0.82	2.26	12.06	2.84	1.44	0.81	0.14	0.06	0.05	0.03	0.02
SF-212	1.87	0.80	1.87	10.29	2.36	1.18	0.65	0.11	0.05	0.03	0.02	0.01
SF-213	1.09	0.75	1.09	6.70	1.39	0.67	0.35	0.05	0.02	0.02	0.01	0.01
SF-214A	8.31	0.75	8.30	51.22	10.64	5.10	2.70	0.41	0.16	0.12	0.08	0.05
SF-214B	8.40	0.75	8.39	51.75	10.75	5.15	2.73	0.42	0.16	0.12	0.08	0.05
SF-217	3.65	0.75	3.65	22.52	4.68	2.24	1.19	0.18	0.07	0.05	0.04	0.02
SF-219	0.37	0.75	0.37	2.26	0.47	0.23	0.12	0.02	0.01	0.01	0.00	0.00
SF-260	0.57	1.00	0.57	2.23	0.69	0.40	0.25	0.06	0.03	0.02	0.02	0.01
SF-266	4.66	0.90	4.65	21.24	5.73	3.10	1.83	0.38	0.17	0.13	0.10	0.06
SF-267	0.80	1.50	0.78	1.98	0.90	0.62	0.45	0.18	0.11	0.09	0.08	0.06
SF-271	0.88	1.50	0.87	2.19	1.00	0.69	0.50	0.20	0.12	0.11	0.09	0.07
SF-277	19.68	0.60	19.68	191.14	26.82	10.68	4.84	0.46	0.14	0.10	0.06	0.03
SF-278	6.19	0.52	6.19	85.02	8.84	3.06	1.23	0.08	0.02	0.01	0.01	0.00
SF-289	8.46	1.08	8.41	29.81	10.04	6.03	3.89	1.06	0.55	0.44	0.34	0.23
SF-294	0.61	1.00	0.61	2.39	0.74	0.42	0.26	0.06	0.03	0.03	0.02	0.01
SF-296	1.42	1.00	1.41	5.54	1.71	0.98	0.61	0.15	0.07	0.06	0.04	0.03
SF-305	6.13	1.00	6.10	23.97	7.38	4.25	2.64	0.65	0.31	0.25	0.19	0.12
SF-343	1.03	0.86	1.02	5.03	1.28	0.67	0.39	0.08	0.03	0.03	0.02	0.01
SF-UN	0.73	1.50	0.71	1.81	0.82	0.57	0.42	0.16	0.10	0.09	0.07	0.05

5.5 Preliminary economic assessment of the 70+ promising sites

5.5.1 Objectives

The objective of the economic analysis is to compare the relative economic performance of energy generation from the 70+ promising potential hydropower sites.

5.5.2 Methodology

The potential hydropower sites will be compared based on their costs per kWh produced, expressed in terms of Levelized Cost of Energy (LCOE) which is a stream of equal payments, normalized over expected energy production periods that would allow a project owner to recover all costs, an assumed return on investment, over a predetermined life span.

The LCOE is defined from investment costs (CAPEX - Capital Expenditure), operating costs (OPEX - Operational Expenditure) and the expected production of energy.

The investment costs (CAPEX) are calculated based on a preliminary design of the proposed hydroelectric schemes (based on the site visits, the hydrological study and the local environment) including an estimate of the quantities and the construction costs of the project. The CAPEX include:

- Study and work supervision costs, hereafter called “Studies and engineering costs” which include:
  - Civil works study and supervision costs
  - Electromechanical works study and supervision costs
  - Owner’s development costs
- Civil works and equipment costs, hereafter called “HPP costs”
- Resettlement and environmental impact costs, hereafter called “ESIA costs”

The annual operating costs (OPEX) include:

- Operation and maintenance costs, hereafter called “O&M costs” which include:
  - Fixed operation and maintenance costs (annual scheduled maintenance)
  - Costs related to interim replacement and refurbishments of major items in the course of the project’s life
  - Insurance costs

The expected energy generation is calculated based on the preliminary design of the potential hydroelectric scheme (based on the site visits, the hydrological study and the local environment).

Eventually, the LCOE is then calculated based on expected production and costs from the following formula:

$$LCOE = \frac{NPV(CAPEX + OPEX)}{NPV(Energy\ production)}$$

Where NPV is the net present value obtained by: $NPV(value) = \sum_i \frac{valuer_i}{(1+n)^i}$ where *n* is the discount rate.

The preliminary design of the potential hydropower schemes, their energy performance analysis and eventually the economic modelling is carried out using our internally developed tool *EconEval* customized for the specific context of Tanzania.

5.5.3 Assumptions

The main economic assumptions for the economic modeling of the *LCOE* calculation for the 85 potential promising hydroelectric projects are presented in Table 20 below.

Table 20. Economic modelling assumptions

Economic lifespan of the project	30 years
Decommissioning cost at the end of the economic life	10% of civils works and equipment costs
Engineering (incl. ESIA) and works supervision **Owner's development costs**	10% of civils works and equipment costs 2% of civils works and equipment costs
Environmental and social impact mitigation costs	10% of civils works and equipment costs
O&M costs **Interim replacement** **Fixed operation costs**	 0,25%/year of civils works and equipment costs 50 USD/kW/year
Insurance costs	0,10% of civils works and equipment costs per year
Distribution of costs over the project implementation process	Year -2 = 40% Year -1 = 60% Year 0 = Commissioning
Reference date for economic analysis	2015
Costs are expressed in constants	(2015) USD
Escalation costs (inflation)	No escalation costs were applied to capital costs or operating costs.
Financing costs etc.	Financing costs, tax, duties or other Government levees are ignored at this stage but shall be included in the financial analysis that will be done during the detailed studies.
Discount rate	10%

The economic analysis is carried out by considering that the electricity grid absorbs all the energy produced. In other words, the analysis assumes that there is a demand for all the energy generated by the hydroelectric schemes.

5.5.4 Economic Analysis

The results of the economic modelling of the 85 potential hydropower sites is presented in Table 21 in the following chapter.

6 TOP 20 PRIORITIZED SMALL HYDROPOWER PROJECTS

6.1 SELECTION PROCESS AND MULTICRITERIA ANALYSIS

The selection of the top 20 prioritized sites relied on groups of potential hydroelectric projects located in the same geographical area that can supply an existing network (main grid or mini-grid currently supplied by a thermal generator) or supply a pure off-grid load center. This is required since all the sites that are located close to each other will directly compete to supply the same load centers.

The selection process relied on the following criteria:

1. Projects that compete to supply the same load center or grid (projects in the same group);
2. Estimated power capacity between ~300 kW and 10 MW;
3. Exclusion of projects located on seasonal rivers (zero flow during the dry season);
4. Economically attractive with a competitive LCOE (Levelized Cost of Energy);
5. No evidence of major environmental constraint, including solid transport.

The selection process of the top 20 prioritized small hydropower projects was carried out during PHASE 1 and the results have been validated during the workshop held in Dar Es Salaam in March 2015 at The Rural Energy Agency (REA) premises.

6.1.1 Group of projects that compete to supply the same load center or grid

The potential hydroelectric projects are grouped based on their capacity to supply the nearest load center, either to the main grid or to a mini-grid or off-grid.

6.1.2 Estimate power capacity between ~ 300 kW and ~10 MW

The Terms of Reference of this study indicate that “small hydro” shall refer as having a generation capacity between 1 to 10 MW. Nevertheless, REA expressed its wish to include potential sites under 1 MW. The minimum of 300 kW has been agreed upon. That value corresponds to a minimal project size in terms of investment and technical barriers for electro-mechanical equipment under which a private developer will face problems to recover its investment and/or find quality equipment for a reasonable price. Note however that some sites are located in areas where the uncertainty of hydrological data is still rather high, which can have a positive or negative influence on the final installed capacity or production.

6.1.3 Exclusion of projects located on seasonal rivers

Field visits and interviews with locals have highlighted rivers that have zero flow during the dry season even if the hydrological model predicted a minimum flow.

The development of hydroelectric project on rivers that feature dry periods (zero streamflow) during a given period of the year is usually not appropriate for multiple reasons amongst which: (i) no energy generation during several months of the year; (ii) production difficult to predict; (iii) high maintenance costs and (iv) operation and maintenance constraints. This problem is particularly disadvantageous for Mini-Grid as the available thermal capacity must be high enough to balance the production deficit to supply the demand. The problem is even more critical for off-grid systems where there will not be any power supply during the dry season.

6.1.4 Economically attractive with a competitive LCOE (Levelized Cost of Energy);

The proposed projects must be economically attractive compared to other alternatives for the production of electricity. In accordance with the economic constraints of small hydropower development in Tanzania (see Chapter 3) and the competitiveness of the future sites, the Consultant has set a maximum threshold for the Levelized Cost of Energy (LCOE) at:

- < 50 US$/MWh for main Grid connection;
- < ~100 US$/MWh for Mini-Grid connection;
- < 200 US$/MWh for pure off-grid operation (no other source of power).

Those threshold values were discussed and agreed upon with REA and the World Bank during the presentation of the Hydro Mapping Report Phase 1 (approved in April 2015). More information is provided in section 5.2.5.

The potential hydropower projects were compared based on their costs per kWh produced, expressed in terms of Levelized Cost of Energy (LCOE) which is a stream of equal payments, normalized over expected energy production periods that would allow a project owner to recover all costs, an assumed return on investment, over a predetermined life span.

The LCOE has been calculated excluding the cost for the access roads and the transmission lines (which makes a good project or not) which is comparable to the figures collected in the Power System Master Plan (Update 2013) and in the SREP-Investment Plan for Tanzania (2013).

6.1.5 No evidence of major environmental constraint including sediment transport

The first site visits (Site Visit Report 2015 and update 2016) identified obvious constraints that would jeopardize the development of promising potential hydroelectric projects. Those constraints were notably the presence of a protected area or game reserve, the presence of soil instability or even a high solid transport (suspended sediments) even during the dry season.

6.2 PRIORITIZATION PROCESS AND RESULTS

The following figure illustrates the prioritization process to select the top 20 priority small hydropower projects and the results are presented in table below. The selection process was carried out during PHASE 1 and results have been validated during the workshop held in Dar Es Salaam in March 2015 at The Rural Energy Agency (REA) premises. The selection has been slightly reviewed in October 2016 with REA during additional site visits that were commissioned by REA.

Figure 39 Selection process of the 20 prioritized sites

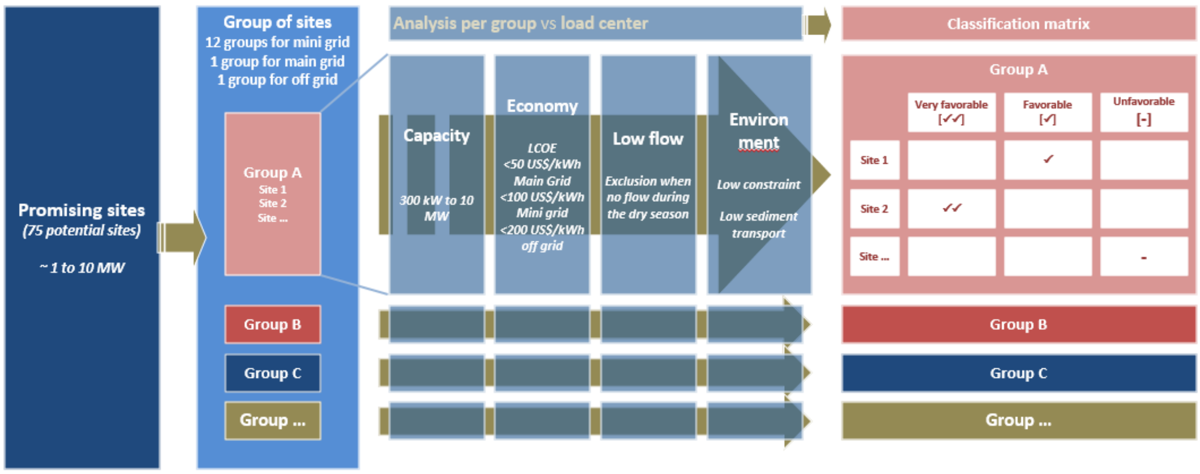


Table 21. Selection of the top 20 prioritized projects (key: ✓✓ = priority site ; ✓= no-priority site ; - = site without interest)

Code	Nom_site	River	Connection	Group	H [m]	Q_eq [m³/s]	P [kW]	E [GWh/y]	LCOE [USD/kWh]	Flow constraint	Environmental constraint	Selection
M-070	Momba II	Momba	Main grid	Group H	355	7,4	21700	161,8	0,030	OK	low	✓✓
M-110	Kitewaka	Kitewaka	Ludewa minigrid	Group G	54	33,5	14960	106	0,043	OK	sediment transport	-
M-113	Kyamato	Kyamato	Bukoba minigrid	Group A	50	0,07	30	0,19	0,524	OK	low	-
M-118	Acheshereo	Acheshereo	Bukoba minigrid	Group A	90	0,3	200	1,34	0,166	OK	low	-
M-119	Lubare	Lubare	Off-grid		125	0,02	20	0,17	1,168	OK	low	-
M-121A	Kitogota I	Kitogota	Bukoba minigrid	Group A	100	2,7	2180	4,28	0,532	OK	low	✓
M-121B	Kitogota Falls	Kitogota	Bukoba minigrid	Group A	25	0,8	160	1,08	0,096	OK	low	✓✓
M-127	Ruhuhu	Ruhuhu	Mbinga minigrid	Group J	15	105,2	13120	87,73	0,028	OK	sediment transport	-
M-221	Mambi	Mambi	Off-grid		152	2,9	3560	30,39	0,043	very low flow during dry season	Upstream irrigation projects	-
M-267A	Ngongi I	Ngongi	Mbinga minigrid	Group J	110	0,3	310	2,12	0,225	OK	sediment transport	-
M-267B	Ngongi II	Ngongi	Mbinga minigrid	Group J	290	0,6	1310	8,91	0,111	OK	sediment transport	-
M-268A	Luwika I	Luwika/Lualala	Mbinga minigrid	Group J	75	0,5	290	1,96	0,154	OK	sediment transport	-
M-268B	Luwika II	Luwika/Lualala	Mbinga minigrid	Group J	750	0,5	3030	20,58	0,146	OK	sediment transport	-
M-277	Luika	Luika	Ludewa minigrid	Group G	58	0,4	200	1,4	0,184	OK	low	✓
M-288	Kelolilo	Kelolilo	Ludewa minigrid	Group G	69	0,7	400	2,85	0,141	OK	low	✓✓
M-295	Myombezi	Myombezi	Off-grid		111	0,1	100	0,89	0,192	OK	low	✓✓
M-297	Lipumba	Mngaka	Mbinga minigrid	Group J	4	2,2	70	0,49	0,161	OK	sediment transport	-
M-298B	Litembo Extension	Ndumbi	Off-grid		25	0,2	50	0,11	1,002	OK	low	-
M-299	Luaita	Luaita	Mbinga minigrid	Group J	70	0,3	200	1,35	0,219	OK	low	✓✓
M-301	Lukarasi shp	Mkurusi	Mbinga minigrid	Group J	27	0,2	40	0,28	0,925	very low flow during dry season	sediment transport	-
M-355A	Mgaka I	Mgaka	Mbinga minigrid	Group J	30	5,3	1300	9,09	0,097	OK	sediment transport	-
M-355B	Mgaka II	Mgaka	Mbinga minigrid	Group J	35	6,6	1900	13,28	0,077	OK	sediment transport	✓
N-002	Kawa	Kawa	Off-grid		260	0,06	130	1,05	0,887	OK	low	-
N-010	Kitandazi II	Mbinga	Mbinga minigrid	Group J	35	1,2	330	2,26	0,148	OK	low	✓✓
N-011	Kingilikiti	Lumeme	Mbinga minigrid	Group J	28	0,7	170	1,16	0,156	OK	low	-
SF-017	Momba I	Momba	Sumbawanga minigrid	Group L	64	11,1	5860	35,69	0,111	OK	low	✓✓

Code	Nom_site	River	Connection	Group	H [m]	Q_eq [m³/s]	P [kW]	E [GWh/y]	LCOE [USD/kWh]	Flow constraint	Environmental constraint	Selection
SF-018	Kalambo Falls	Kalambo	Sumbawanga minigrid	Group L	200	6,3	10360	63,06	0,026	OK	Tourism and transboundary site	✓
SF-019	Lwazi	Lwazi	Sumbawanga minigrid	Group L	120	2,1	2100	12,78	0,042	OK	low	✓✓
SF-020	Mfizi II	Mfizi	Mpanda minigrid	Group K	150	2,5	3040	17,55	0,045	OK	moderate sediment transport	✓✓
SF-022	Luegere	LUEGERE	Kigoma minigrid	Group D	159	14,5	19010	145,35	0,028	OK	low	✓✓
SF-029	Lupapilo	Ruhuhu	Mbinga minigrid	Group J	30	105,5	26230	175,49	0,040	OK	sediment transport	-
SF-041	Kivumilo	UMBA	Main grid	Group H	9	22,1	1640	13,34	0,068	OK	low	✓
SF-052A	Mara I	MARA	Main grid	Group H	25	46,6	9630	61,36	0,089	OK	sediment transport / Bordering of the Serengeti Park	-
SF-052B	Mara II	MARA	Main grid	Group H	45	46,6	17340	110,52	0,061	OK	sediment transport / Bordering of the Serengeti Park	-
SF-056	Manique	MANIQUE	Loliondo Minigrid	Group F	350	5,4	15570	99,23	0,067	zero flow during dry season	sediment transport	-
SF-067	Mponde II	MPONDE	Main grid	Group H	95	5,2	4060	31,55	0,070	zero flow during dry season	sediment transport	-
SF-068	Luwila	LUWILA	Main grid	Group H	120	24	21750	34,66	4,096	zero flow during dry season	sediment transport	-
SF-069	Maparengi	MAPARENGI	Main grid	Group H	150	8,5	10560	82,07	0,038	zero flow during dry season	sediment transport	-
SF-080A	Sasimo I	SASIMO	Main grid	Group H	60	2,2	1070	8,52	0,067	very low flow during dry season	low	-
SF-080B	Sasimo II	SASIMO	Main grid	Group H	110	2,2	1970	15,59	0,045	very low flow during dry season	low	-
SF-082	Lukosi	Lukosi	Main grid	Group H	176	7,7	11210	91,1	0,031	OK	low	✓✓
SF-083	Mlowa	Mlowa	Main grid	Group H	117	2,8	2710	22	0,040	OK	sediment transport	-
SF-091	Bubu II	BUBU	Main grid	Group H	90	23,5	17430	135,47	0,039	zero flow during dry season	sediment transport	-
SF-092	Bubu I	BUBU	Main grid	Group H	35	93,5	21970	35,01	1,862	zero flow during dry season	sediment transport	-
SF-107	Ndembela I	NDEMBELA	Main grid	Group H	100	8,2	6740	52,84	0,043	OK	Low / On going project	✓
SF-108	Ndembela II	NDEMBELA	Main grid	Group H	105	8,9	7720	60,52	0,047	OK	Low / On going project	✓
SF-109	Lyandembela I	Lyandembela	Main grid	Group H	33	6,8	1860	14,61	0,051	OK	Low / On going project	✓
SF-123	Mchakama	Mavuji	Off-grid		5	4,6	190	1,63	0,273	OK	sediment transport	-
SF-143	Wami	Wami	Main grid	Group H	8	168,8	11210	87,1	0,029	High flow out of range	low exept for fishing	✓

CODE	NOM_SITE	RIVER	CONNECTION	GROUP	H [M]	Q_EQ [M³/S]	P [KW]	E [GWH/Y]	LCOE [USD/KWH]	FLOW CONSTRAINT	ENVIRONMENTAL CONSTRAINT	SELECTION
SF-145	Mkalamo	MSANGAZI	Off-grid		20	16,6	420	17,58	0,081	very low flow during dry season	sediment transport	-
SF-153	Ndurumo	NDURUMO	Main grid	Group H	85	8,7	6080	47,22	0,055	zero flow during dry season	sediment transport	-
SF-172	Ruchugi	Ruchugi	Kasulu minigrid	Group B	13	15,6	1680	11,4	0,319	OK	sediment transport	-
SF-178	Mgambazi	MGAMBAZI	Kigoma Minigrid	Group D	90	3,9	2870	21,93	0,037	OK	low	✓✓
SF-187	Muyovozi	Muyovozi	Kibundo minigrid	Group C	40	12	3990	27,11	0,051	OK	low	✓✓
SF-189	Lupa	Lupa	Main grid	Group H	82	24,1	16360	124,98	0,024	OK	sediment transport	✓
SF-206	Chulu	Chulu	Sumbawanga minigrid	Group L	800	0,3	2240	13,81	0,105	OK	low	✓✓
SF-207	Kilida	Kilida	Sumbawanga minigrid	Group L	500	0,4	1530	9,4	0,102	OK	sediment transport	-
SF-208	Mfizi I	Mfizi	Mpanda minigrid	Group K	40	2,3	770	4,47	0,074	OK	sediment transport	✓
SF-211	Lwiche	Lwiche	Sumbawanga minigrid	Group L	519	5,8	24240	44,78	0,310	OK	sediment transport	-
SF-212	Muze	Muze	Sumbawanga minigrid	Group L	420	1,2	4060	24,96	0,065	OK	sediment transport	✓
SF-213	Nyembe	Nyembe	Sumbawanga minigrid	Group L	684	2,7	14760	27,16	0,556	OK	low	-
SF-214A	Kalambo I	Kalambo	Sumbawanga minigrid	Group L	20	5,1	840	5,14	0,056	OK	low	✓✓
SF-214B	Kalambo II	Kalambo	Sumbawanga minigrid	Group L	20	5,2	850	5,19	0,073	OK	low	✓✓
SF-217	Samvya	Samvya	Sumbawanga minigrid	Group L	85	2,2	1570	9,58	0,074	OK	low	✓✓
SF-219	Kianda	Kianda	Sumbawanga minigrid	Group L	700	0,2	1270	7,71	0,112	OK	sediment transport	-
SF-266	Muhuwezi	Muhuwezi	Tunduru minigrid	Group M	105	3,1	2680	16,81	0,094	OK	moderate sediment transport	✓✓
SF-271	Mihima	Mihima Namangale	Masasi minigrid	Group I	104	0,7	590	3,99	0,066	very low flow during dry season	low	✓
SF-277	Mbagala	Mbagala	Masasi minigrid	Group I	40	10,7	3530	20,8	0,077	OK	moderate sediment transport	✓✓
SF-278	Mfizi III	Mfizi	Mpanda minigrid	Group K	30	3,1	760	4,39	0,15	OK	sediment transport	✓
SF-289	Lyandembela II	Lyandembela	Main grid	Group H	33	6	1650	12,92	0,047	OK	Low / On going project	✓
SF-294	Kigogo	Kigogo	Main grid	Group H	562	0,4	1930	15,01	0,036	OK	low	✓✓
SF-296	Vambanungwi	Vambanungwi	Main grid	Group H	110	1	890	6,89	0,045	OK	sediment transport	-

CODE	NOM_SITE	RIVER	CONNECTION	GROUP	H [M]	Q_EQ [M³/S]	P [KW]	E [GWH/Y]	LCOE [USD/KWH]	FLOW CONSTRAINT	ENVIRONMENTAL CONSTRAINT	SELECTION
SF-305	Mponde I	MPONDE	Main grid	Group H	16	17	1780	2,83	3,851	zero flow during dry season	sediment transport	-
SF-343	Samba	Samba	Off-grid		92	0,075	60	0,47	1,255	OK	low	-
SF-UN	Mbawa	Mbawa	Off-grid		350	0,2	450	3,87	0,526	OK	sediment transport	-

* Key:

✓✓ : priority site

✓ : no-priority site

- : site without interest

6.3 TARGETED HYDROLOGICAL STUDY FOR THE TOP 20 MOST PROMISING POTENTIAL HYDROPOWER PROJECTS

6.3.1 Introduction

During the Phase 1 workshop held in Dar Es Salaam on the 17th of March 2015, it was decided with REA and the World Bank to not proceed with the installation of hydrological monitoring stations, as it was originally envisaged at the inception of the Study. It was decided instead that the Consultant would improve the hydrological information by carrying out a more detailed hydrological analysis on the 20 prioritized sites in order to further reduce the uncertainties associated with their preliminary design (installed capacity, firm energy generation, economic performance). This chapter presents the dedicated hydrological study that was carried out, including the data collection within the Water Basin Offices across Tanzania.

6.3.2 Objectives and limits

The objective of the preliminary hydrological study is to establish and quantify the meteorological and hydrological characteristics of the top 20 prioritized small hydropower sites in order to estimate the hydrological parameters for the design of the hydroelectric projects as well as for the economic analysis.

The results of the hydrological study presented in this Chapter must be validated by dedicated hydrological monitoring campaigns. Indeed, the results of the preliminary hydrological study are indicative only and are not intended to be used for design purposes.

Estimates of the hydrological parameters relies on the data available for each hydroelectric site. Given the variability of the data availability and quality, three approaches were developed.

Furthermore, a rainfall analysis has been performed at the country scale to highlight the spatial and temporal variation of precipitations across the country. Results are also presented for the catchments of the top 20 prioritized site.

6.3.3 Sources of data

6.3.3.1 Rainfall data

Historical daily rainfall data were obtained from three sources of information: (i) satellite imagery from Climate Hazards Group InfradRed Precipitation (CHIRPS), (ii) the WorldClim database and (iii) rain gauges from "Système d'Informations Environnementales sur les Ressources en Eau et leur Modélisation" (SIEREM).

Climate Hazards Group InfradRed Precipitation (CHIRPS) - Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS, http://chg.geog.ucsb.edu/data/chirps/) is a 30+ year quasi-global rainfall dataset. Spanning 50°S-50°N (and all longitudes), starting in 1981 to near-present, CHIRPS incorporates 0.05° resolution satellite imagery with in-situ station data to create gridded rainfall time series for trend analysis and seasonal drought monitoring. Daily time-series have been extracted for each prioritized site and flow monitoring station catchments. The daily value extracted is the mean of the precipitation that falls on the entire catchment.

WorldClim - WorldClim gridded dataset (version 2.0) were generated through interpolation of average monthly climate data from major climate databases. These data is available for Tanzania on a monthly time step, a spatial resolution of about 30 arc-second (approx. 1km²) and are representatives for the period from approximately 1970 to 2000.

Système d'Informations Environnementales sur les Ressources en Eau et leur Modélisation (SIEREM) - The HydroSciences Montpellier laboratory (HSM) has developed an information system (SIEREM) on the whole of Africa continent which contains several types of environmental variables. This is the largest environmental information system on the African continent with 13,000 measurement stations, 33,000 time-series, or more than 117 million records, for the period 1837 to 2015. The hydro climatological data are coupled with spatial data: 201 contours of watersheds, 2,962 rivers and rivers. The recovery of the hydrological archives has made it possible to enrich SIEREM. More than 1,342 photos have been collected in 391 georeferenced albums. The SIEREM site allows free access to all this information except for the raw measurement data that is the property of the African national services. Unfortunately, no data from the rain gauge stations located in the study area was available.

6.3.3.2 Hydrological data

Historical daily hydrological data were obtained from two sources of information: (i) data collection in the Tanzanian Water Basin Offices and (ii) the Global Runoff Data Center (GRDC).

Figure 40. Flow monitoring system on the Samvya River at Yunga, Sumbawanga, Tanzania.

Data collection in the Tanzanian Water Basin Offices - The Consultant has undertaken collection of hydrological and meteorological data within the nine Water Basin Offices across Tanzania between January and March 2017. During that mission, the Consultant met with hydrologists from the various Water Basin Offices and collected hydrological data and information relevant for the top 20 prioritized hydroelectric projects.

Global Runoff Data Center (GRDC) - Data from the GRDC were used where information was not available from the Water Basin Offices. The GRDC is an international archive of data up to 200 years old, and fosters multinational and global long-term hydrological studies. The Global Runoff Database at GRDC is a unique collection of river discharge data collected at daily or monthly intervals from more than 9,300 stations in 160 countries. This adds up to around 400,000 station-years with an average record length of 43 years. Some of the flow monitoring stations identified in the data collection from Water Basin Offices are included in the GRDC database, but the datasets collected are generally more complete and accurate.

Summary of the hydrological data acquisition - Table 22 presents the 10 flow monitoring stations with exploitable datasets from the data collection. This list considers the proximity of prioritized sites, the accuracy of the station location, and the period covered by measurements and completeness of the datasets. Others flow monitoring stations datasets have been collected and are stored in a database but they cannot be exploited for this part of the study due to poor quality of the data or important data gaps.

Table 22. List of the flow monitoring stations with exploitable datasets.

Major Basin	Station Name (river + location)	Station Code	Catchment Area [km²]	First Date	Last Date	Daily Data Gap [%]	Altitude (SRTM) [m]	Latitude (WGS84) [°]	Longitude (WGS84) [°]
Lake Victoria	Ngono at Kalebe Bridge	5A3	1,211	01/01/1980	30/06/2016	28.2	1152	-1.471	31.675
Lake Rukwa	Mtembwa at Chipoma	3B15A	6,289	15/12/1974	31/12/1977	1.6	1374	-8.809	32.332
	Mfwizi at Paramawe	3CC3	2,384	9/09/1975	28/03/1980	6.0	1462	-7.283	31.072
	Samvya at Yunga	3B16A	576	18/09/1975	31/03/1979	1.2	1576	-8.418	31.828
	Msaidia at Usevya	3CB2	3,207	16/08/1975	19/09/1979	19.9	957	-7.109	31.170
Lake Nyasa	Kitewaka at Muhumbi D/S	1RB4A	2,121	20/10/1971	30/11/2016	41.3	817	-10.258	34.798
Ruvumu	Ruvuma at Mahiga	1Q7	5,486	12/02/1972	30/04/1994	7.7	680	-11.313	35.354
Lake Tanganyika	Kalambo at Kapozwa	4H1	3,242	21/07/1975	24/12/1997	53.2	1178	-8.594	31.241
	Luegele at Lubalisi	4D1	1,341	18/06/1975	31/12/1988	11.5	876	-5.891	30.016
	Moyowosi at Kanyoni	4AD2	3,509	1/04/1988	20/05/2014	81.7	1161	-3.190	31.034

6.3.3.3 Evapotranspiration data

CLIMWAT 2.0 for CROPWAT is a joint publication of the Water Development and Management Unit and the Climate Change and Bioenergy Unit of FAO. It offers observed agro-climatic data of over 5,000 stations worldwide distributed as shown below. CLIMWAT provides long-term monthly mean values of seven climatic parameters, namely:

- Mean daily maximum temperature in °C
- Mean daily minimum temperature in °C
- Mean relative humidity in %
- Mean wind speed in km/day
- Mean sunshine hours per day
- Mean solar radiation in MJ/m²/day
- Monthly rainfall in mm/month
- Monthly effective rainfall in mm/month
- Reference evapotranspiration calculated with the Penman-Monteith method in mm/day.

Figure 41. CLIMWAT stations in Tanzania and surroundings

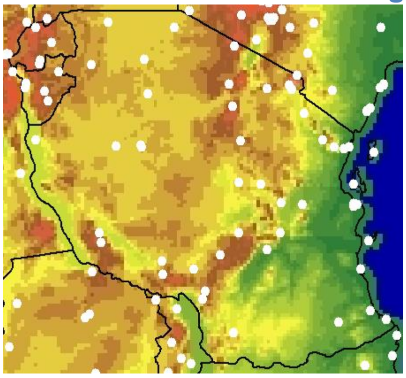


Table 23. List of CLIMWAT stations used for estimation of the evapotranspiration data

STATION NAME (LOCATION)	ELEVATION [M]	LATITUDE (WGS84) [°]	LONGITUDE (WGS84) [°]	PRIORITIZED SITE CODE
Biharamulo	1480	-2.63	31.31	SF187
Bukoba	1137	-1.33	31.81	M121B
Igeri	2250	-9.66	34.66	M288
Kigoma	885	-4.88	29.63	SF178
Mbala (Zambia)	1673	-8.85	31.33	M070
				SF017
				SF022
				SF214A
				SF214B
				SF217
Moshi	831	-3.35	37.33	M245
Songea	1067	-10.68	35.58	N010
Sumbawanga	1710	-7.95	31.6	SF020
Iringa	1428	-7.66	35.75	SF082

6.3.4 Hydrological Modelling

6.3.4.1 Methodologies

The methodology used for the estimation of the parameters varies for each site and depends on the availability and the quality of streamflow datasets. Three methodologies have been developed:

(i) the frequency analysis of *observed streamflow data*,

(ii) the frequency analysis of synthetic streamflows generated on the basis of precipitation data through *hydrological modelling*,

(iii) and the *regionalization* method based on the extrapolation of existing hydrological information from similar river catchments.

Observed streamflow data - If the observed streamflow data cover a sufficient period and is of good quality, a frequency analysis can be performed on the streamflow dataset.

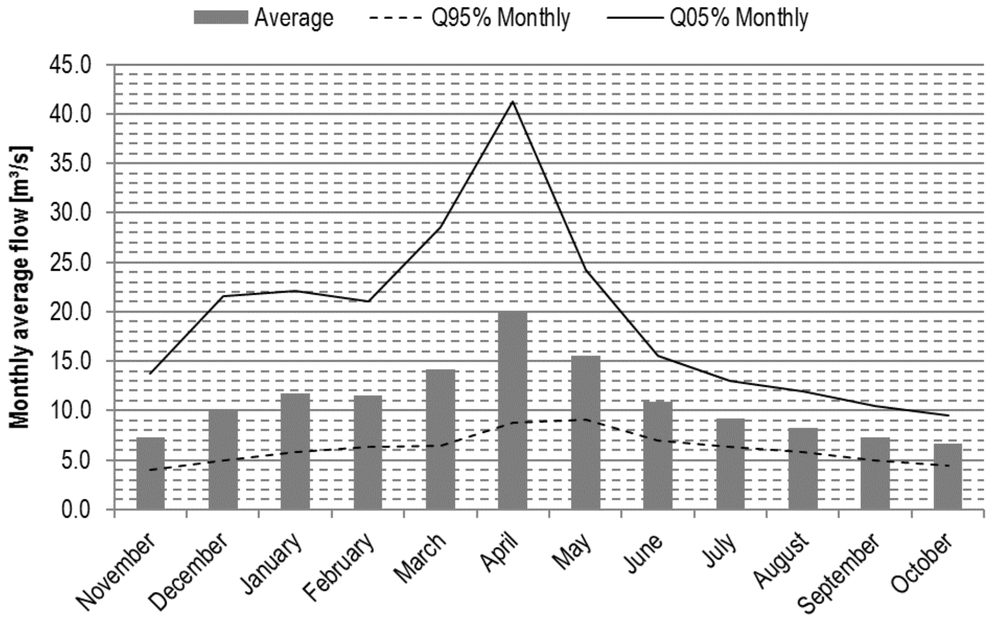
The pre-processing was completed in two steps:

(i) Data gaps were filled by linear interpolation (< 15 days missing) or average interannual data (> 15 days missing).

(ii) Spatial extrapolation of the observed streamflows at the hydrological monitoring station to the site of interest was made based on the ratio of the catchments area.

The frequency analysis consists in different statistics including the monthly and annual averages, the flow duration curve, and the flood estimation and their probability of occurrence.

Figure 42. Monthly statistics of observed streamflow data



Hydrological modelling - The frequency analysis of synthetic streamflows is the same than the frequency analysis of observed streamflows except that the flows are generated through a hydrological modelling in order to extent the time-series period.

Given the characteristics of the data available (daily datasets with gaps), the hydrological model selected was a daily lumped rainfall-runoff model called GR4J (in French: modèle du Génie Rural à 4 paramètres Journalier, https://webgr.irstea.fr/en/modeles/journalier-gr4j-2/).

The inputs of the model are:

- daily precipitation (obtained from CHIRPS satellite imagery or SIEREM rain gauge stations)
- daily evapotranspiration (obtained from CLIMWAT agroclimatic stations)
- daily observed streamflow (obtained from data collection in the Tanzanian Water Basin Offices or GRDC flow monitoring stations)

The rainfall-runoff relation is established by four parameters based on the aforementioned inputs. The model parameters model are adjusted to fit observed streamflow data (model calibration).

Once the model is calibrated, the synthetic streamflows can be generated from the daily precipitation and evapotranspiration data. As these data are available for the period of 1981-2017, the synthetic streamflows can be simulated for the same period.

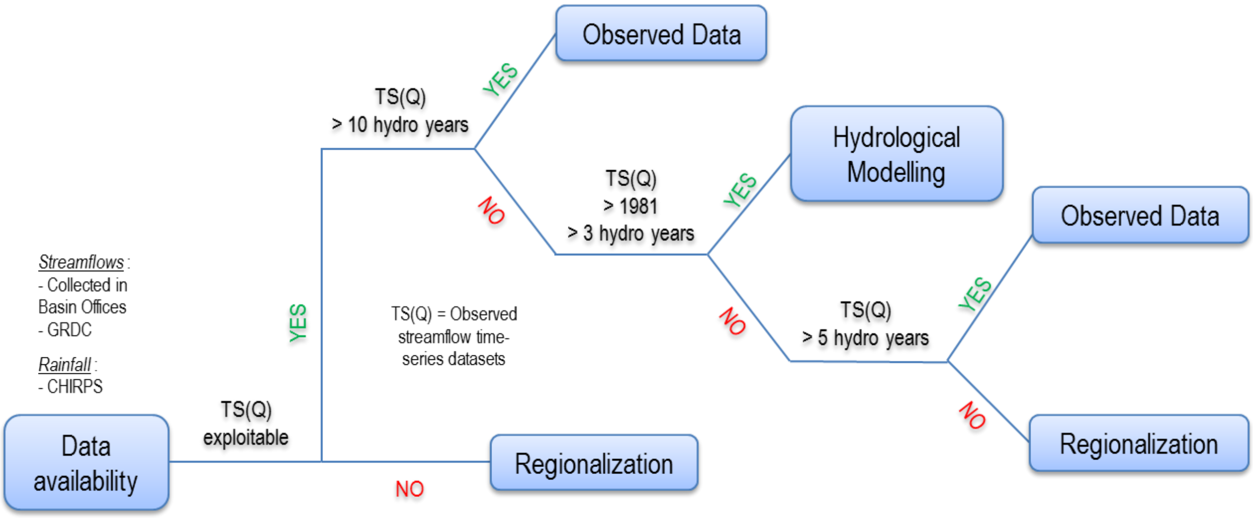
The hydrological modelling is only applicable if the time-series of observed streamflow period covers at least three consecutive high-quality hydrological years(20) after 1981 (first year of the CHIRPS data).

[20] A hydrological year is defined as the 12-month period beginning after the dry season. In Tanzania, the hydrological year begins on November 1 and ends on October 31.

Regionalization - The regionalization is detailed in section 5.4 of this report.

Method selection - For each site, the method has been determined using the following process (Figure 43):

Figure 43. Flow chart for selecting the appropriate hydrological analysis methodology.



(i) The first step consists to analyze the exploitability of the observed streamflow data collected depending on the quality of the time-series dataset (TS(Q)). If the time-series dataset is too poor or is missing, the regionalization method is selected.

(ii) If the time-series dataset is exploitable, the second criterion is the period covered. If this period is greater than 10 consecutive high-quality dataset years, it is considered sufficient to perform a frequency analysis directly on the observed streamflow data.

(iii) If the period covered by the time-series is less than ten years, the criterion necessary to generate synthetic streamflow based on precipitation data is analyzed: the time-series dataset period must cover at least 3 consecutive high-quality hydrological years[20] after 1981, first year of satellite daily rainfall dataset used for the hydrological modelling (CHIRPS rainfall data). In this case, a frequency analysis is performed on the synthetic streamflow data.

(iv) If the hydrological modelling cannot be carried out, the last criterion to determine if the regionalization method should be used is the time-series dataset period again. In this case, it is considered that at least 5consecutive high-quality hydrological years is a criterion acceptable to perform a frequency analysis directly on the observed streamflow data.

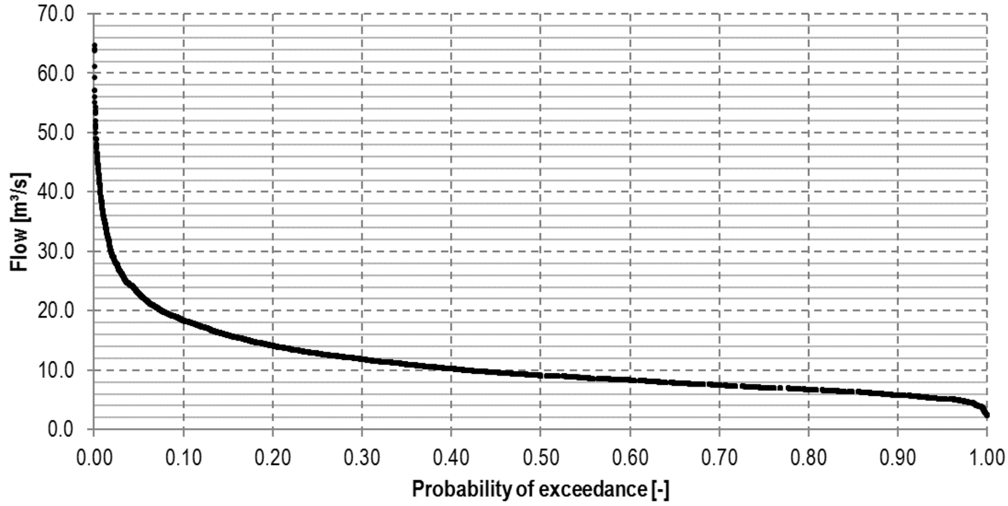
6.3.4.2 Key outputs

Flow duration curve - Among the hydrological parameters, the determination of the flow duration curve is essential to know the availability of the flows in the stream for the hydroelectric project. Indeed, this curve shows the percentage of time that flow in a stream is likely to equal or exceed some specified value of interest.

For the *observed streamflow data* and *hydrological modelling* methods, the flow duration curve is made directly applying a probability function P(X>x) on the time-series of observed or synthetic streamflow data. This function determines the probability of exceedance of each flow reaching the hydroelectric project.

For the *regionalization* method, the flow duration curve results directly from the extrapolation of the two Weibull law parameters. This extrapolation depends on the location of the hydroelectric site relative to the existing gauging stations.

Figure 44. Flow duration curve constructed from observed streamflow data.



Floods - The flood study is equally important for design calculations of structures and equipment such as spillways or floodgates but also for temporary infrastructure such as cofferdams and temporary diversions during the construction period. The flood study will focus on 10 years and 100 years return period. These floods will be used respectively for the construction and exploitation phases.

For the *observed streamflow data* and *hydrological modelling* methods, the flood estimation was carried out by a statistical extrapolation of the observed or synthetic maximum flows. Three frequency analysis methods commonly used in hydrology have been applied:

- Log-normal law(21): this law is advocated by some hydrologists who justify it by arguing that the appearance of a hydrological event results from the combined action of a large number of factors that multiply. Consequently, the random variable follows a log-normal distribution. Indeed, the product of variables is reduced to the sum of the logarithms of these variables and the central-limit theorem makes it possible to assert the log-normality of the random variable.

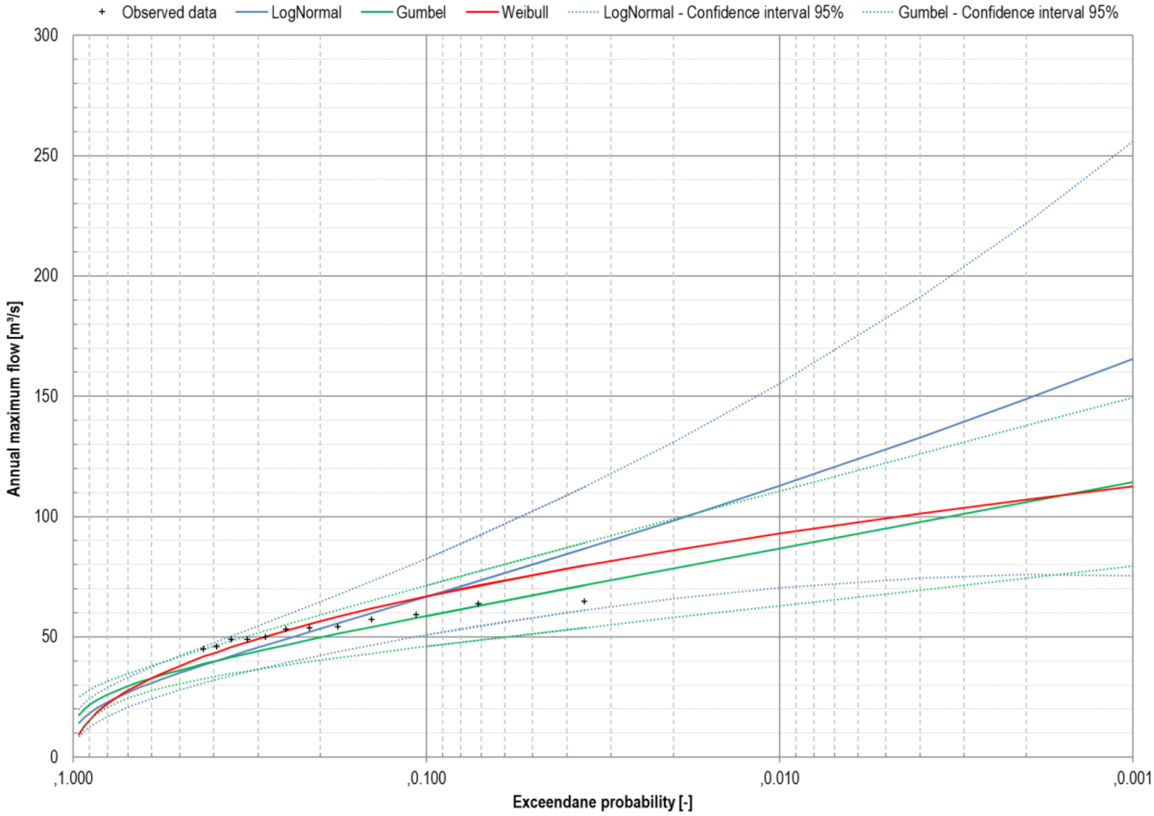
- Gumbel law or exponential double law(21): this law is the limit form of the distribution of the maximum value of a sample of values. Since the annual maximum of a variable is considered to be the maximum of 365 daily values, this law must be able to describe the series of annual maxima.

- Law of Weibull(22): this law of probability, associated with the laws of the extreme values, lends itself well to the study of events such as the floods, the maximum or minimum precipitations, the low flows,...

[21] Translated from Musy A. (2005). Hydrologie générale.

[22] Translated form Perreault, L., & Bobée, B. (1992). Loi Weibull à deux paramètres : Propriétés mathématiques et statistiques : Estimation des paramètres et des quantiles Xt de période de retour T (No. R351). INRS-Eau. http://espace.inrs.ca/1158/1/R000351.pdf

Figure 45. Flood frequency analysis



For the *regionalization* method, the estimation of the flood was not possible due to the lack of relevant data.

6.3.4.3 Remarks

The following remarks are worth noting regarding the hydrological modelling that have been performed:

- The rainfall data used to generate the synthetic streamflows come from CHIRPS satellite imagery. First, the method used to estimate the rainfall from satellite imagery contains unquantifiable uncertainties. Moreover, the value used as input in the hydrological modelling is the spatial average of the precipitation that falls on the entire catchment. This value does not represent the spatial variability of the precipitation within the catchment.
- The daily time step implies some uncertainties in the parameters estimation. For example in the flood analysis, the most important flows observed during the floods occur only during a few hours and does not appear in average values.
- Uncertainties come directly from the observed data. First, the streamflows are defined from an interpolated rating curve established by the relation between the water level measured at the flow monitoring station and often only few streamflow measurements. Moreover, the time-series include some gaps that must be filled for the frequency analysis by linear interpolation (< 15 days missing) or average interannual data (> 15 days missing).
- Due to the lack of data, flood analysis sometimes relies on short time-series (minimum 5 hydrological years) while it is based on the frequency of maximum flows.

- The location of the flow monitoring stations is not always well known. That may result in uncertainties in the calculation of the catchment and does affect directly the parameters estimates that relies on catchment ratio.

- The times-series period used for the parameters estimation sometimes dates from long time ago (60'-80'). Since, the hydromorphological characteristics of the catchments may have changed (land use, reservoir…) what has a direct impact on the hydrological parameters estimation. This remark remains valid for the climatic conditions that have likely evolved over time.

6.3.5 Analysis of spatial and temporal distribution of precipitations

This analysis aims at highlighting the spatiotemporal variability of precipitations across Tanzania. It relies on the monthly precipitations data available from the WorldClim dataset.

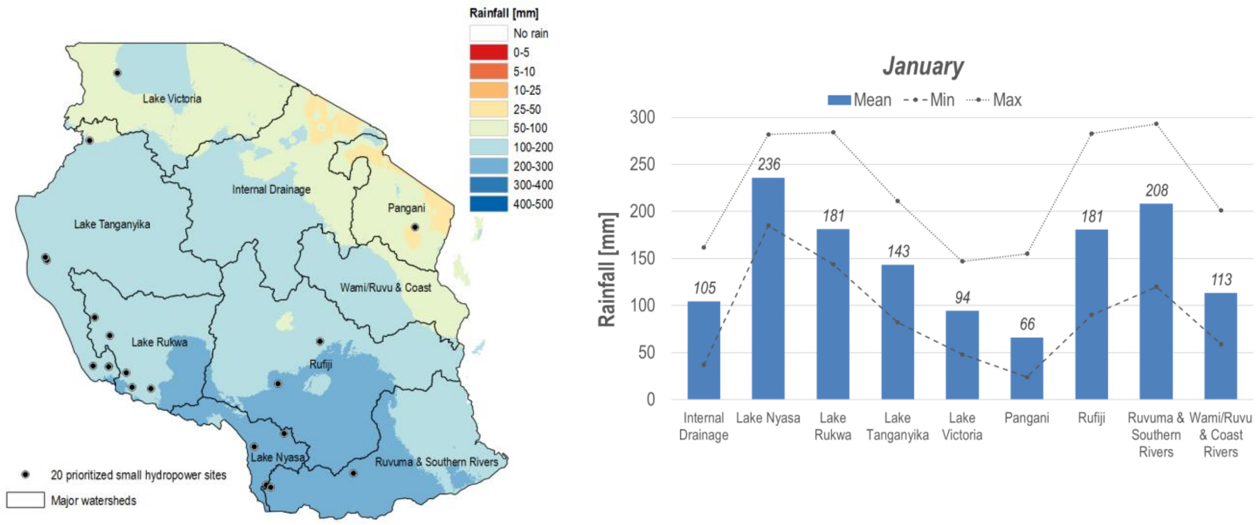
Figure 46 below presents the spatial and temporal distribution of the monthly long-term average precipitations. For each month of the year, the map shows the spatial variability of the monthly precipitations while the bar chart highlights the monthly precipitations by water management basin. The analysis reveals that the country features high spatial and temporal variability of the precipitations:

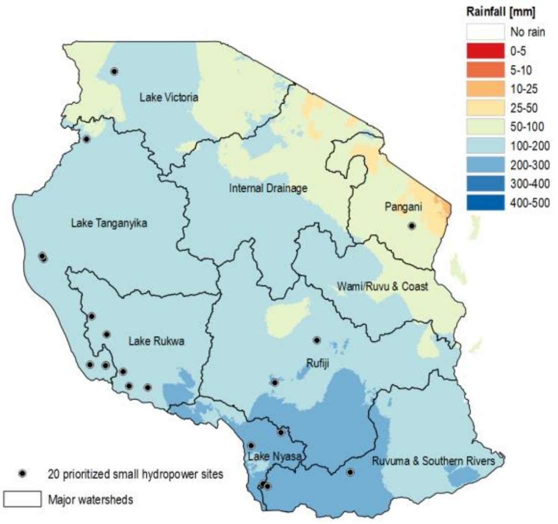
- Central and Western areas have monthly precipitations ranging from 0 mm (dry season) to 200 mm (wet season) with a long-term annual average between 500 and 1,000 mm (up to 1,500 mm in the mountainous areas);

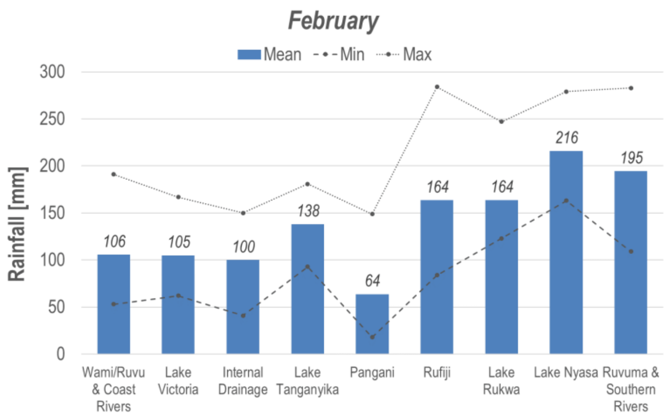
- Northern and Eastern coastal areas record monthly precipitations from 25 mm (dry season) to 400 mm (wet season) with a long-term annual average between 800 and 1,700 mm (Lake Victoria);

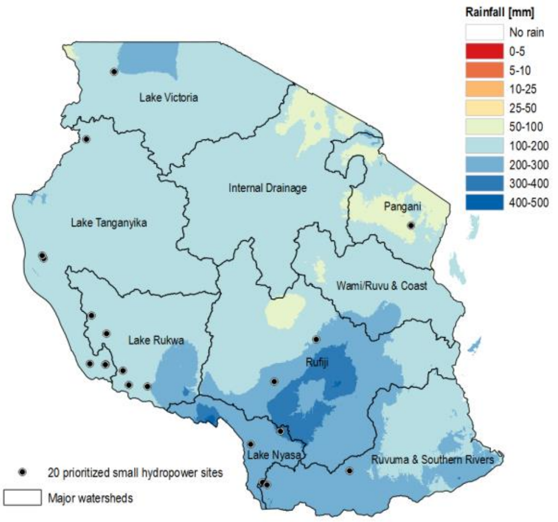
- The Southern region experience an extreme variability of monthly precipitations varying from less than 5 mm (dry season) to 400 mm (wet season).

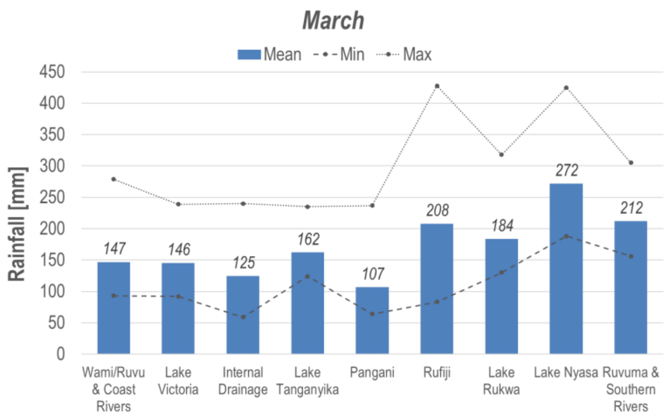
Figure 46. Spatial and temporal distribution of the monthly long-term average precipitations

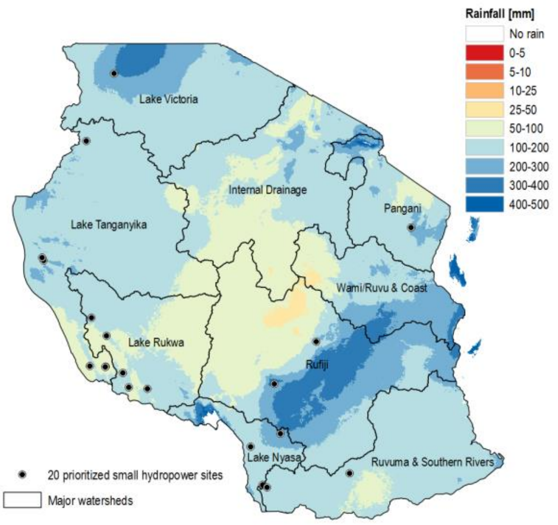


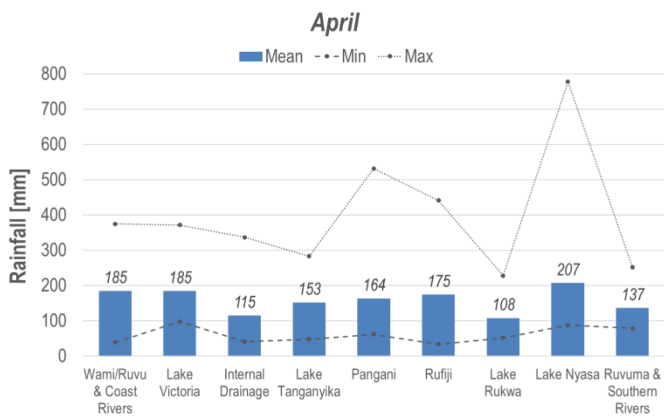

Rainfall [mm]
No rain
0-5
5-10
10-25
25-50
50-100
100-200
200-300
300-400
400-500
Lake Victoria
Internal Drainage
Pangani
Lake Tanganyika
Wami/Ruvu & Coast
Lake Rukwa
Rufiji
Lake Nyasa
Ruvuma & Southern Rivers
20 prioritized small hydropower sites
Major watersheds

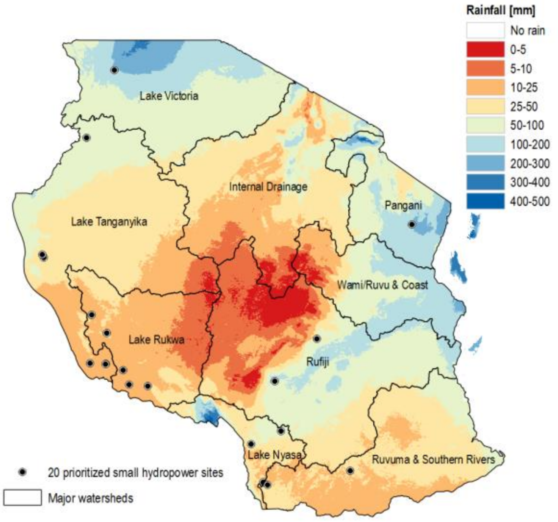

February
Mean
Min
Max
Rainfall [mm]
300
250
200
150
100
50
0
106
105
100
138
64
164
164
216
195
Wami/Ruvu & Coast Rivers
Lake Victoria
Internal Drainage
Lake Tanganyika
Pangani
Rufiji
Lake Rukwa
Lake Nyasa
Ruvuma & Southern Rivers

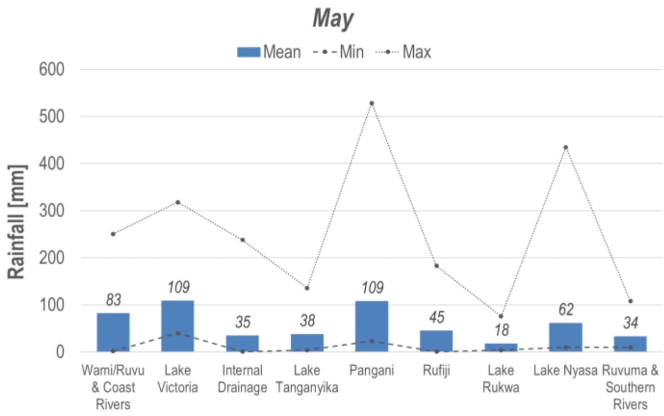

Rainfall [mm]
No rain
0-5
5-10
10-25
25-50
50-100
100-200
200-300
300-400
400-500
Lake Victoria
Internal Drainage
Pangani
Lake Tanganyika
Wami/Ruvu & Coast
Lake Rukwa
Rufiji
Lake Nyasa
Ruvuma & Southern Rivers
20 prioritized small hydropower sites
Major watersheds

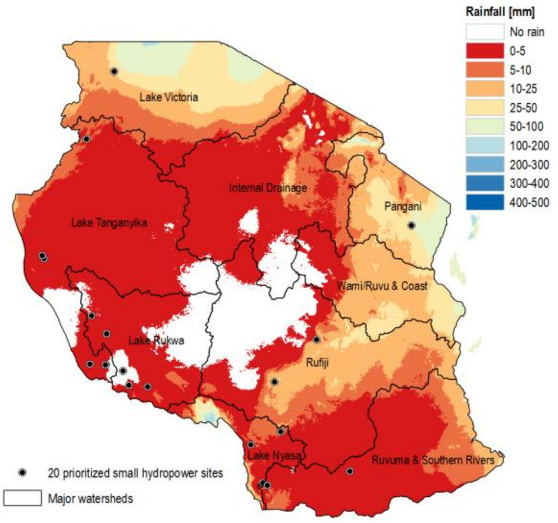

March
Mean
Min
Max
Rainfall [mm]
450
400
350
300
250
200
150
100
50
0
147
146
125
162
107
208
184
272
212
Wami/Ruvu & Coast Rivers
Lake Victoria
Internal Drainage
Lake Tanganyika
Pangani
Rufiji
Lake Rukwa
Lake Nyasa
Ruvuma & Southern Rivers

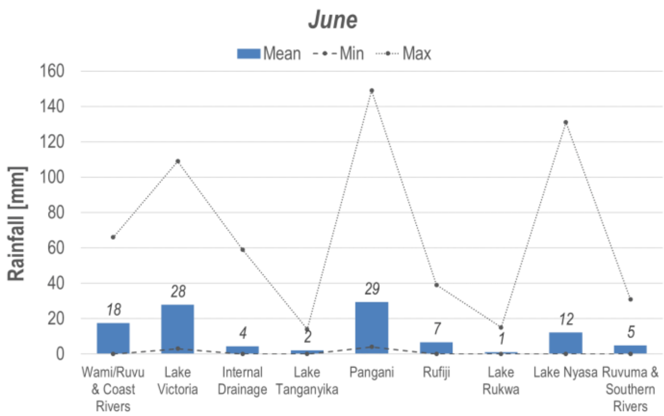

Rainfall [mm]
No rain
0-5
5-10
10-25
25-50
50-100
100-200
200-300
300-400
400-500
Lake Victoria
Internal Drainage
Pangani
Lake Tanganyika
Wami/Ruvu & Coast
Lake Rukwa
Rufiji
Lake Nyasa
Ruvuma & Southern Rivers
20 prioritized small hydropower sites
Major watersheds

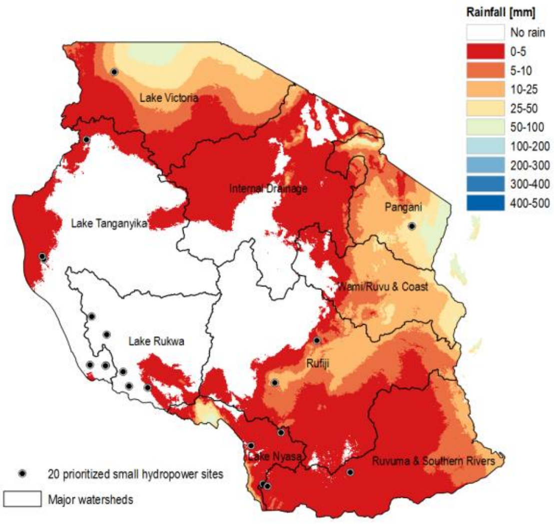

April
Mean
Min
Max
Rainfall [mm]
800
700
600
500
400
300
200
100
0
185
185
115
153
164
175
108
207
137
Wami/Ruvu & Coast Rivers
Lake Victoria
Internal Drainage
Lake Tanganyika
Pangani
Rufiji
Lake Rukwa
Lake Nyasa
Ruvuma & Southern Rivers

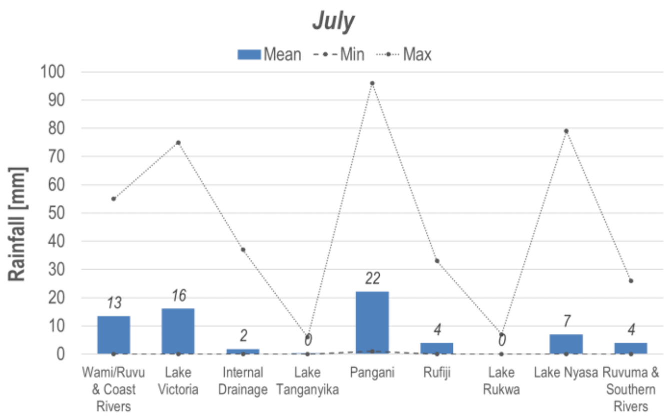

Rainfall [mm]
No rain
0-5
5-10
10-25
25-50
50-100
100-200
200-300
300-400
400-500
Lake Victoria
Internal Drainage
Pangani
Lake Tanganyika
Wami/Ruvu & Coast
Lake Rukwa
Rufiji
Lake Nyasa
Ruvuma & Southern Rivers
20 prioritized small hydropower sites
Major watersheds

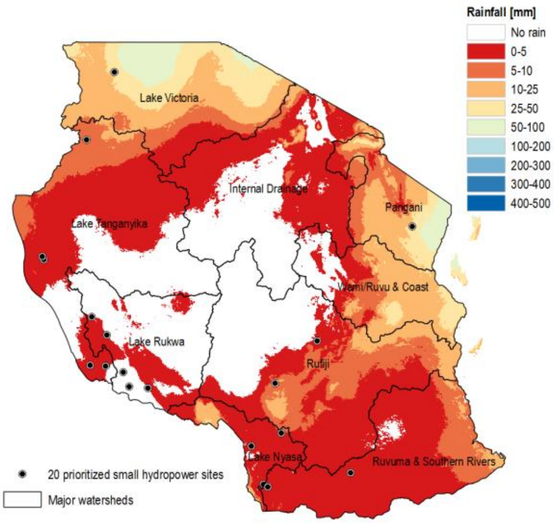

May
Mean
Min
Max
Rainfall [mm]
600
500
400
300
200
100
0
83
109
35
38
109
45
18
62
34
Wami/Ruvu & Coast Rivers
Lake Victoria
Internal Drainage
Lake Tanganyika
Pangani
Rufiji
Lake Rukwa
Lake Nyasa
Ruvuma & Southern Rivers

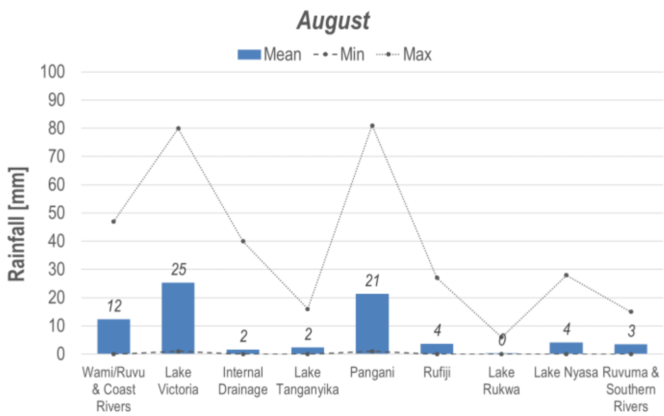

Rainfall [mm]
No rain
0-5
5-10
10-25
25-50
50-100
100-200
200-300
300-400
400-500
Lake Victoria
Internal Drainage
Pangani
Lake Tanganyika
Wami/Ruvu & Coast
Lake Rukwa
Rufiji
Lake Nyasa
Ruvuma & Southern Rivers
20 prioritized small hydropower sites
Major watersheds

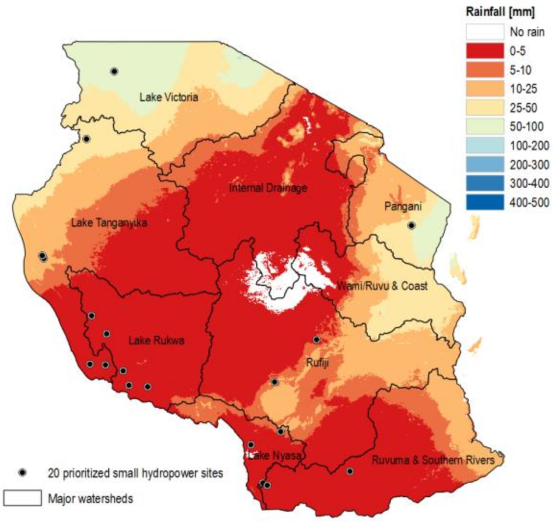

June
Mean
Min
Max
Rainfall [mm]
160
140
120
100
80
60
40
20
0
18
28
4
2
29
7
1
12
5
Wami/Ruvu & Coast Rivers
Lake Victoria
Internal Drainage
Lake Tanganyika
Pangani
Rufiji
Lake Rukwa
Lake Nyasa
Ruvuma & Southern Rivers

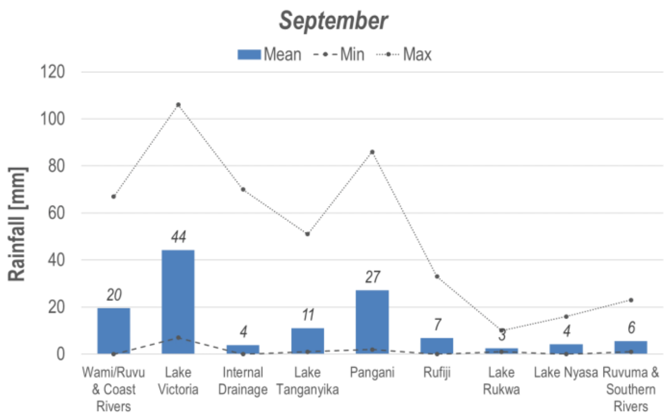

Rainfall [mm]
No rain
0-5
5-10
10-25
25-50
50-100
100-200
200-300
300-400
400-500
Lake Victoria
Internal Drainage
Pangani
Lake Tanganyika
Wami/Ruvu & Coast
Lake Rukwa
Rufiji
Lake Nyasa
Ruvuma & Southern Rivers
20 prioritized small hydropower sites
Major watersheds

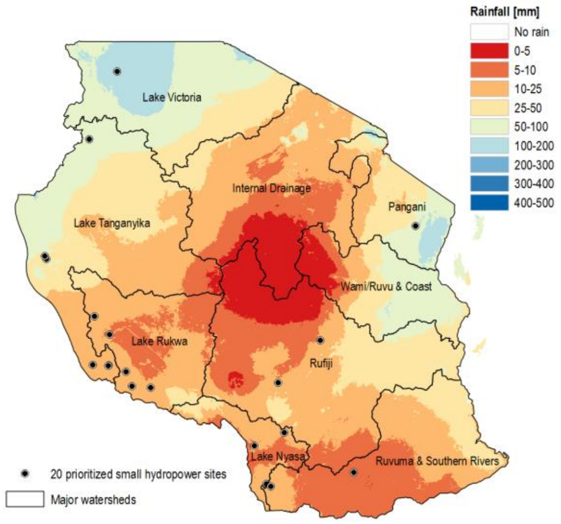

July
Mean
Min
Max
Rainfall [mm]
100
90
80
70
60
50
40
30
20
10
0
13
16
2
0
22
4
0
7
4
Wami/Ruvu & Coast Rivers
Lake Victoria
Internal Drainage
Lake Tanganyika
Pangani
Rufiji
Lake Rukwa
Lake Nyasa
Ruvuma & Southern Rivers

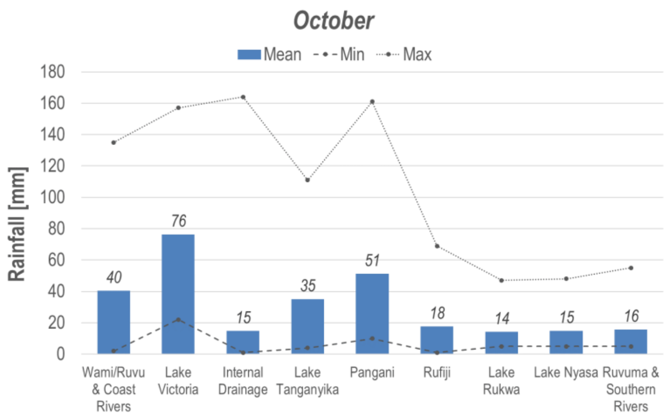

Rainfall [mm]
No rain
0-5
5-10
10-25
25-50
50-100
100-200
200-300
300-400
400-500
Lake Victoria
Internal Drainage
Pangani
Lake Tanganyika
Wami/Ruvu & Coast
Lake Rukwa
Rufiji
Lake Nyasa
Ruvuma & Southern Rivers
20 prioritized small hydropower sites
Major watersheds

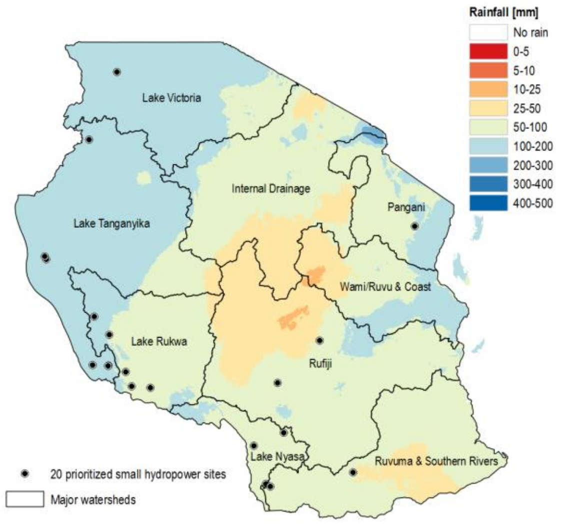

August
Mean
Min
Max
Rainfall [mm]
100
90
80
70
60
50
40
30
20
10
0
12
25
2
2
21
4
0
4
3
Wami/Ruvu & Coast Rivers
Lake Victoria
Internal Drainage
Lake Tanganyika
Pangani
Rufiji
Lake Rukwa
Lake Nyasa
Ruvuma & Southern Rivers

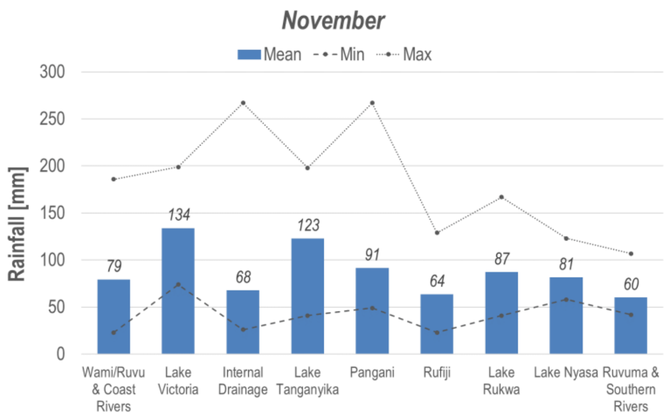

Rainfall [mm]
No rain
0-5
5-10
10-25
25-50
50-100
100-200
200-300
300-400
400-500
Lake Victoria
Internal Drainage
Pangani
Lake Tanganyika
Wami/Ruvu & Coast
Lake Rukwa
Rufiji
Lake Nyasa
Ruvuma & Southern Rivers
20 prioritized small hydropower sites
Major watersheds

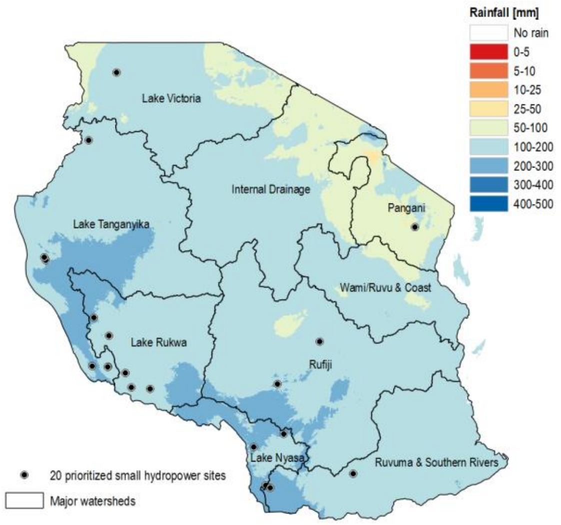

September
Mean
Min
Max
Rainfall [mm]
120
100
80
60
40
20
0
20
44
4
11
27
7
3
4
6
Wami/Ruvu & Coast Rivers
Lake Victoria
Internal Drainage
Lake Tanganyika
Pangani
Rufiji
Lake Rukwa
Lake Nyasa
Ruvuma & Southern Rivers


Rainfall [mm]
No rain
0-5
5-10
10-25
25-50
50-100
100-200
200-300
300-400
400-500
Lake Victoria
Internal Drainage
Pangani
Lake Tanganyika
Wami/Ruvu & Coast
Lake Rukwa
Rufiji
Lake Nyasa
Ruvuma & Southern Rivers
20 prioritized small hydropower sites
Major watersheds


October
Mean
Min
Max
Rainfall [mm]
180
160
140
120
100
80
60
40
20
0
40
76
15
35
51
18
14
15
16
Wami/Ruvu & Coast Rivers
Lake Victoria
Internal Drainage
Lake Tanganyika
Pangani
Rufiji
Lake Rukwa
Lake Nyasa
Ruvuma & Southern Rivers


Rainfall [mm]
No rain
0-5
5-10
10-25
25-50
50-100
100-200
200-300
300-400
400-500
Lake Victoria
Internal Drainage
Pangani
Lake Tanganyika
Wami/Ruvu & Coast
Lake Rukwa
Rufiji
Lake Nyasa
Ruvuma & Southern Rivers
20 prioritized small hydropower sites
Major watersheds


November
Mean
Min
Max
Rainfall [mm]
300
250
200
150
100
50
0
79
134
68
123
91
64
87
81
60
Wami/Ruvu & Coast Rivers
Lake Victoria
Internal Drainage
Lake Tanganyika
Pangani
Rufiji
Lake Rukwa
Lake Nyasa
Ruvuma & Southern Rivers


Rainfall [mm]
No rain
0-5
5-10
10-25
25-50
50-100
100-200
200-300
300-400
400-500
Lake Victoria
Internal Drainage
Pangani
Lake Tanganyika
Wami/Ruvu & Coast
Lake Rukwa
Rufiji
Lake Nyasa
Ruvuma & Southern Rivers
20 prioritized small hydropower sites
Major watersheds

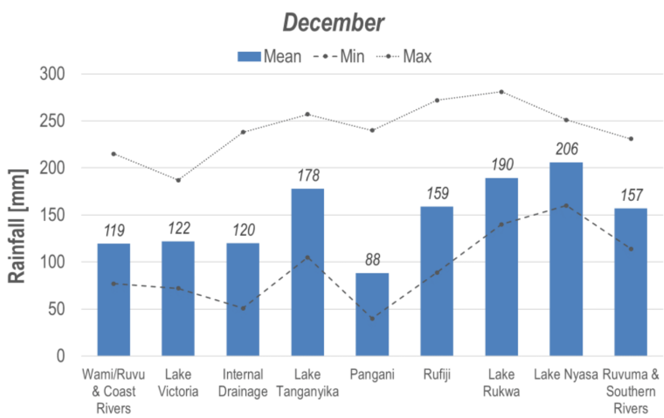
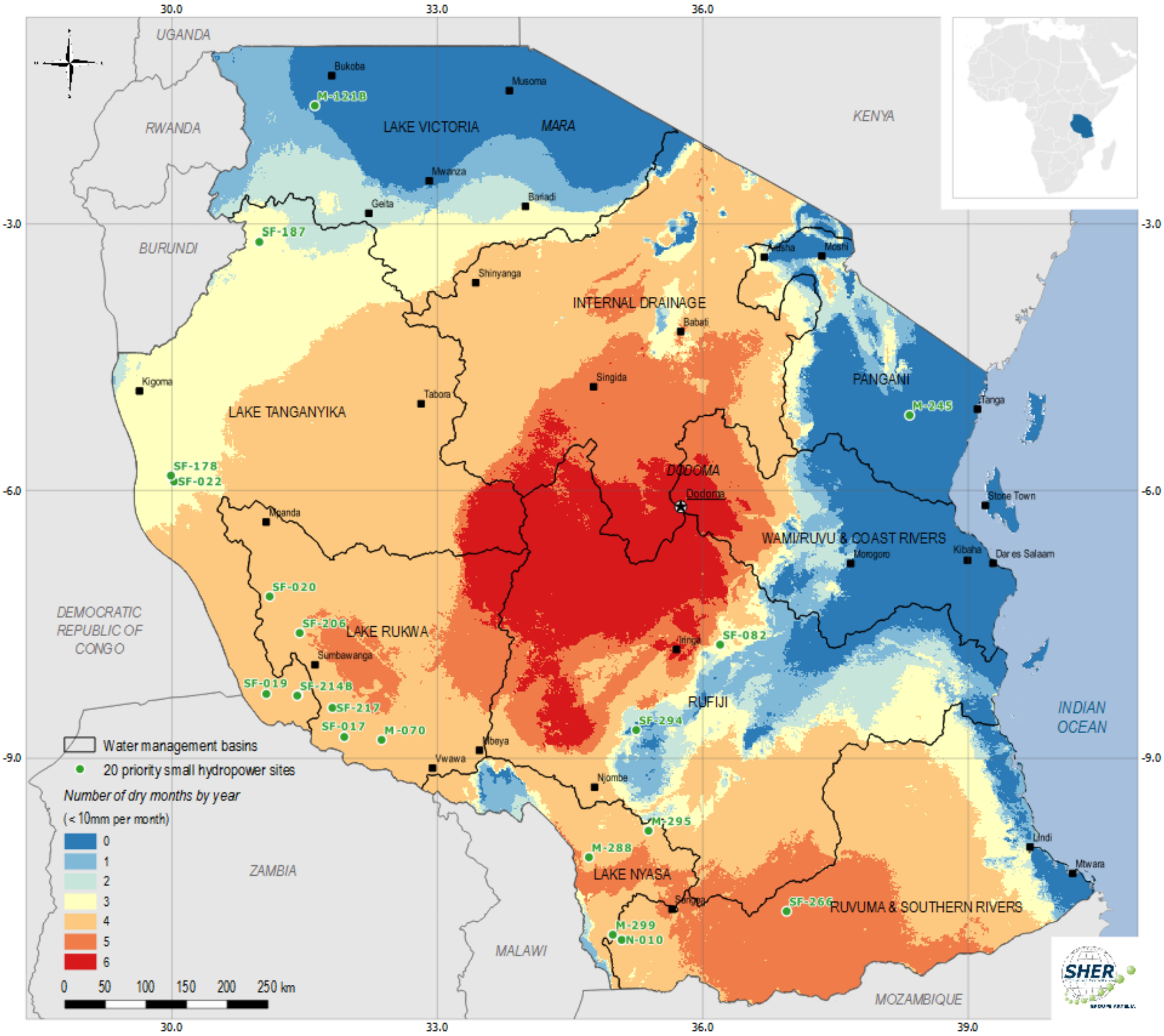

December
Mean
Min
Max
Rainfall [mm]
300
250
200
150
100
50
0
119
122
120
178
88
159
190
206
157
Wami/Ruvu & Coast Rivers
Lake Victoria
Internal Drainage
Lake Tanganyika
Pangani
Rufiji
Lake Rukwa
Lake Nyasa
Ruvuma & Southern Rivers

Figure 47 shows the duration of the dry periods across the country with the number of month with monthly precipitations below 10 mm/month (on average). It reveals that abundant annual precipitations across the country are unevenly distributed during the year: some regions feature high precipitations during the wet season and an extended dry period with very small amount of rain. Sixty percent (60%) of the country (548,290 km²) experience at least four months with precipitations below 10 mm/month every year (on average). Forty percent (40%) of the country (380,000 km²) experience at least four months with precipitations below 5 mm/month every year (on average).

Most of the areas with extended dry periods are mainly in the center (Dodoma, Iringa, Mbeya, Sumbawanga, Tabora) and in the south (Songea, Tunduru) of the country. The situation is less severe in the Northern (around Lake Victoria) and Eastern oceanic zones.

Those regions are more likely to feature seasonal rivers and streams that are less favorable for hydropower development.

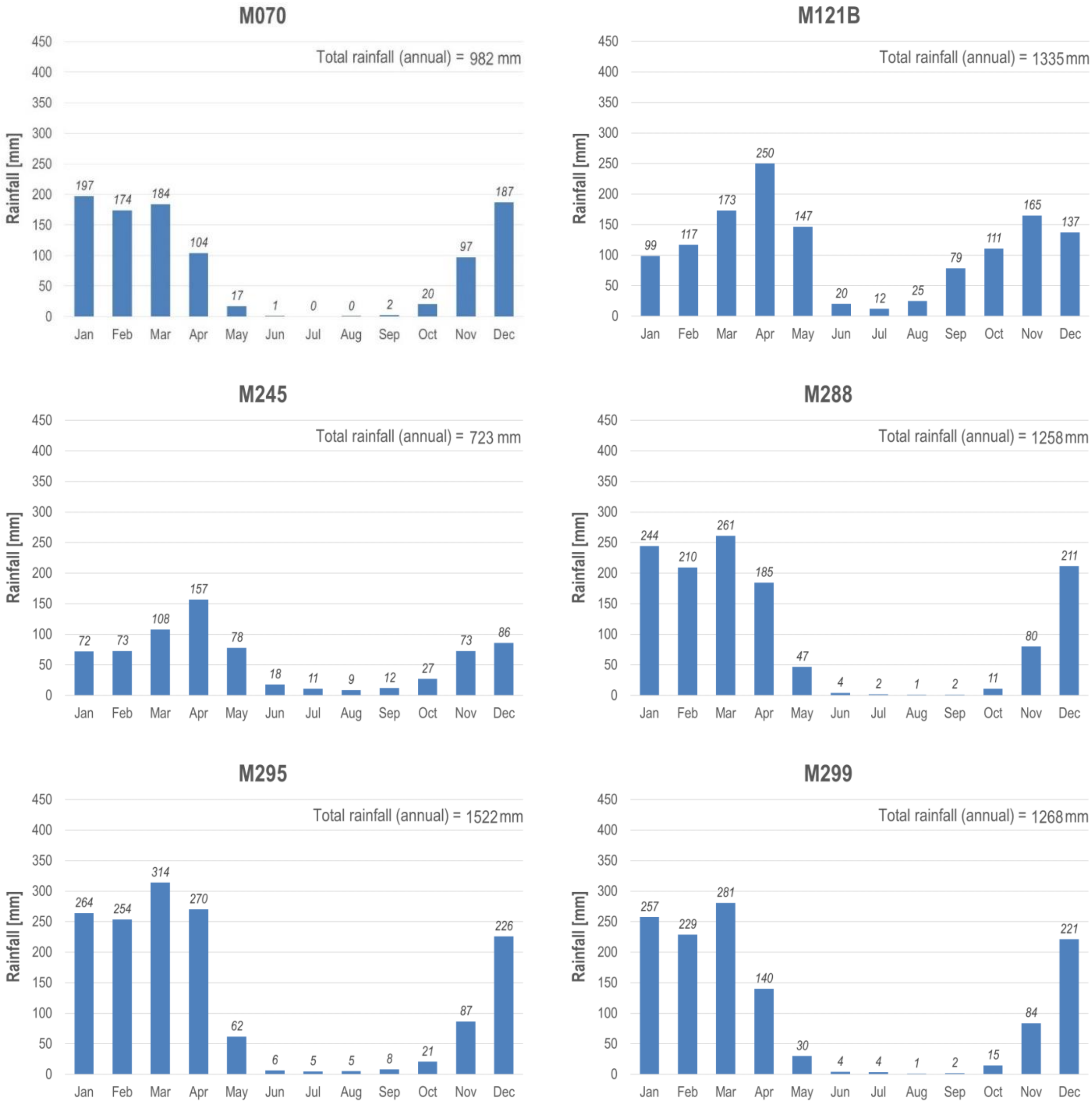
Figure 47. Spatial distribution of areas with extended periods with less than 10 mm per month.

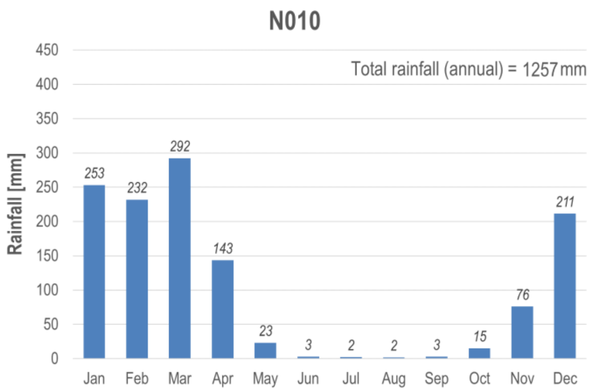


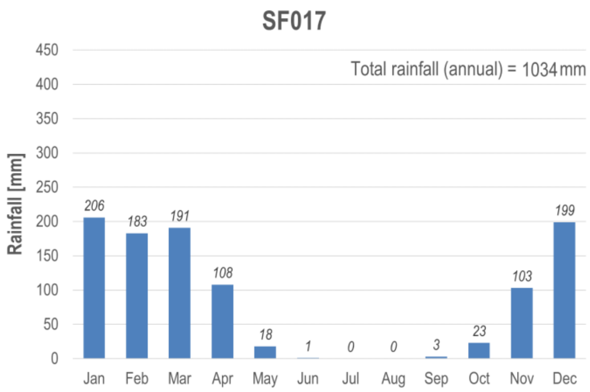
The analysis has been also applied to the river catchments of the top 20 prioritized small hydropower projects. Most of the sites (17/20) are located in regions with at least three months with precipitations below 10 mm/month. The ratio becomes 13 catchments over 17 considering at least 4 months with precipitations below 10mm/month.

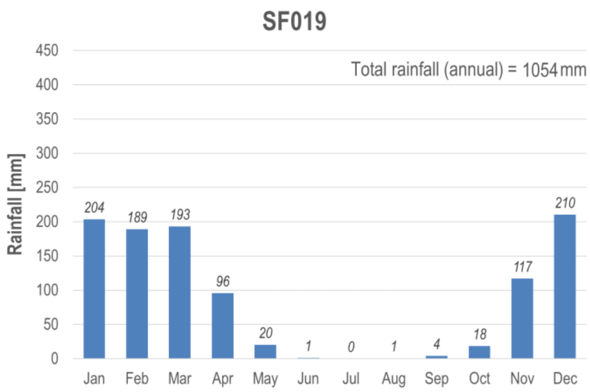
Figure 48 below presents the bar charts of the average monthly precipitations over the catchments of the top 20 prioritized potential hydropower projects.

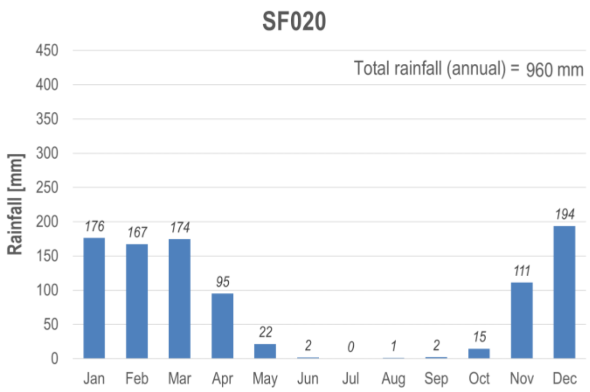
Figure 48. Monthly precipitations over the catchments of the top 20 prioritized potential hydroelectric projects.

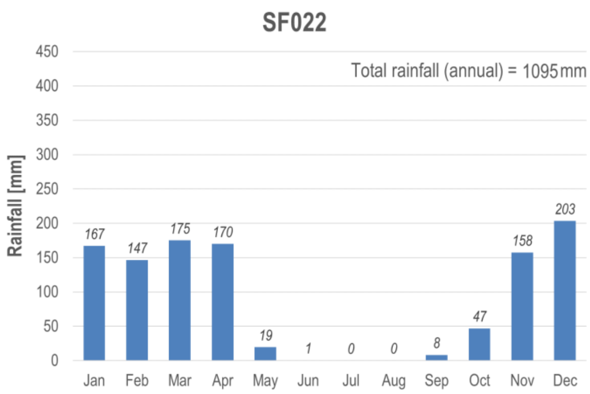


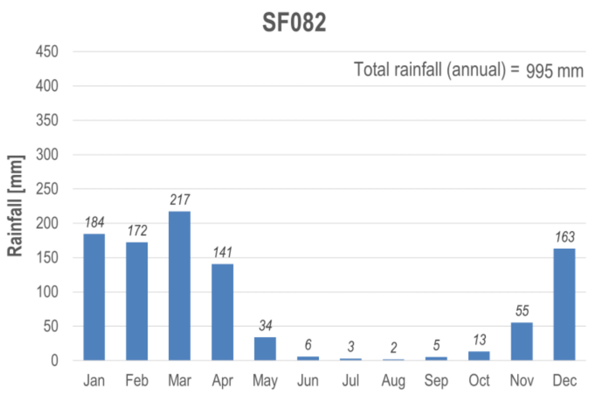

N010
Total rainfall (annual) = 1257mm
Rainfall [mm]
253 232 292 143 23 3 2 2 3 15 76 211
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

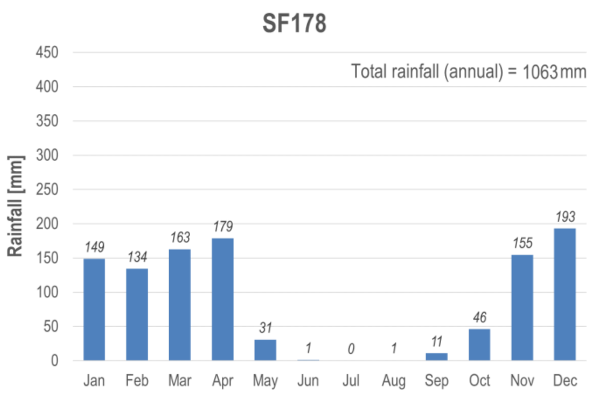

SF017
Total rainfall (annual) = 1034mm
Rainfall [mm]
206 183 191 108 18 1 0 0 3 23 103 199
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

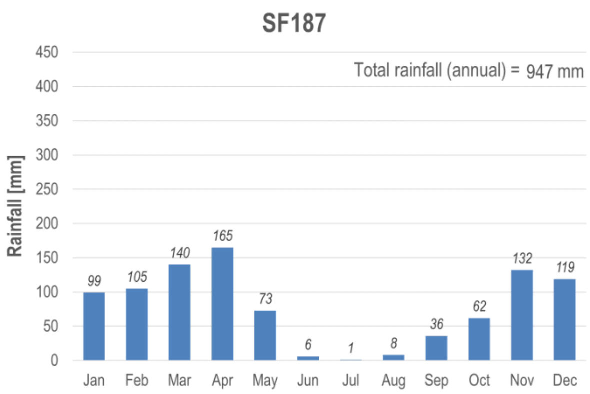

SF019
Total rainfall (annual) = 1054mm
Rainfall [mm]
204 189 193 96 20 1 0 1 4 18 117 210
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

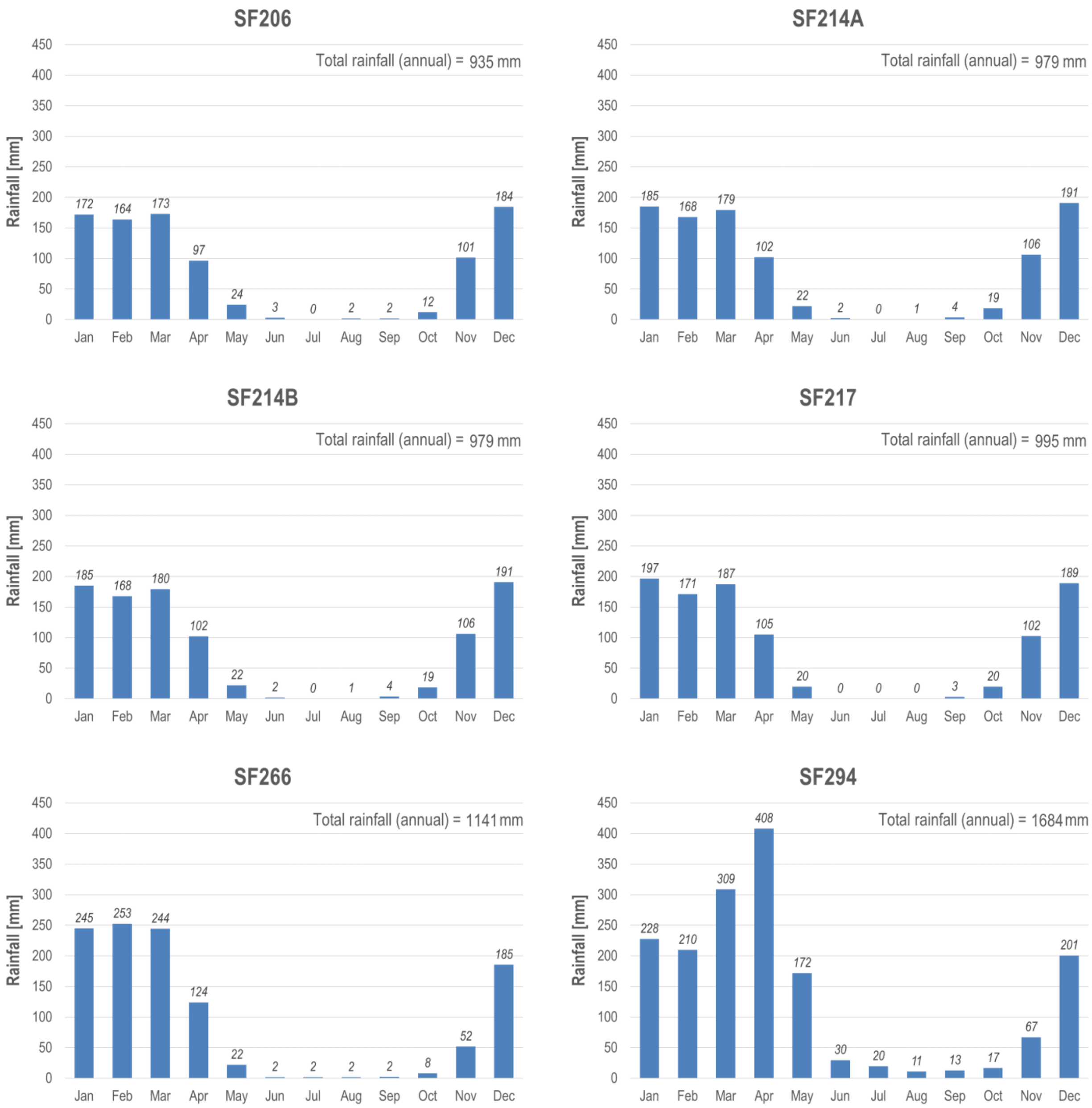

SF020
Total rainfall (annual) = 960 mm
Rainfall [mm]
176 167 174 95 22 2 0 1 2 15 111 194
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec


SF022
Total rainfall (annual) = 1095mm
Rainfall [mm]
167 147 175 170 19 1 0 0 8 47 158 203
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec


SF082
Total rainfall (annual) = 995 mm
Rainfall [mm]
184 172 217 141 34 6 3 2 5 13 55 163
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec


SF178
Total rainfall (annual) = 1063mm
Rainfall [mm]
149 134 163 179 31 1 0 1 11 46 155 193
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec


SF187
Total rainfall (annual) = 947 mm
Rainfall [mm]
99 105 140 165 73 6 1 8 36 62 132 119
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec



6.3.6 Results

The methodologies used to estimate the hydrological features at the top 20 prioritized potential hydropower projects are presented in Table 24 below:

Table 24. List of the 20 prioritized sites with the method selected to estimate the hydrological parameters and criteria of selection.

SITE CODE	FLOW MONITORING STATION	CATCHMENT RATIO	DISTANCE [KM]	METHOD	CRITERIA AND REMARKS
M070	Mtembwa at Chipoma	102%	+/- 10 (downstream)	REG	• Basin Offices: time-series period from 1974 to 1977 • < 1981: no CHIRPS satellite images • No SIEREM gauging station data available • < 5 high-quality hydrological years
M121B	Ngono at Kalebe	10%	+/- 30 (upstream)	HM	• Basin Offices: time-series period from 1978 to 2016 (30% of daily data gap) • < 10 consecutive high-quality hydrological years

					• > 1981: CHIPRS satellite images available
M245	Pangani at Korogwe			OBS	• Water basin: no data collected • GRDC: time-series period from 1959 to 1977 (<1% of daily data gap) • > 10 consecutive high-quality hydrological years • Nyumba ya Mungu reservoir constructed upstream in 1967
M288	Kitewaka at Muhumbi	5%	+/- 30 (upstream)	HM	• Basin Offices: time-series period from 1971 to 2016 (41% of daily data gap) • < 10 consecutive high-quality hydrological years • > 1981: CHIPRS satellite images available
M295	Rutikira at New R.Bridge			REG	• Basin Offices: no data collected • GRDC: time-series period from 1976 to 2002 • Catchment ratio <1%: impossible to use observed data from this station • No other streamflow data available
M299	?			REG	• Basin Offices: no data collected • No streamflow data available
N010	Ruvuma at Mahinga	3%	+/- 60 (upstream)	OBS	• Basin Offices: time-series period from 1972 to 1994 (8% of daily data gap) • > 10 consecutive high-quality hydrological years
SF017	Mtembwa at Chipoma	29%		REG	• Basin Offices: time-series period from 1974 to 1977 (2% of daily data gap) • < 1981: no CHIRPS satellite images • No SIEREM gauging station data available • < 5 high-quality hydrological years
SF019	?			REG	• Basin Offices: no data collected • No streamflow data available
SF020	Mfwizi at Paramawe	107%	+/- 15 (downstream)	OBS	• Basin Offices: time-series period from 1975 to 1980 (8% of daily data gap) • < 1981: no CHIRPS satellite images • No SIEREM gauging station data available • > 5 high-quality hydrological years
SF022	Luegele at Lubalisi	99%	2 (upstream)	HM	• Basin Offices: time-series period from 1975 to 1988 (12% of daily data gap) • < 10 consecutive high-quality hydrological years • > 1981: CHIPRS satellite images available
SF082	Lukosi at Mtandika	46%		OBS	• Basin Offices: time-series period from 1959 to 1987 (3% of daily data gap) • > 10 consecutive high-quality hydrological years
SF178	Luegele at Lubalisi	44%		HM	• Basin Offices: no data collected • No streamflow data available • Catchment similar and nearby to SF022 catchment: hydrological modelling with SF178 inputs andSF022 optimization parameters
SF187	Muyovozi at Kanyoni	78%	8.5 (upstream)	REG	• Basin Offices: data collected unexploitable • No other streamflow data available
SF206	?			REG	• Basin Offices: no data collected • No streamflow data available
SF214A	Kalambo at Kapozwa	41%	+/- 80 (upstream)	OBS	• Basin Offices: waterlevel data collected (unexploitable) • GRDC: time-series period from 1975 to 1980 (<1% of daily data gap) • < 1981: no CHIRPS satellite images • No SIEREM gauging station data available • > 5 high-quality hydrological years
SF214B	Kalambo at Kapozwa	42%	+/- 80 (upstream)	OBS	• Basin Offices: waterlevel data collected (unexploitable) • GRDC: time-series period from 1975 to 1980 (<1% of daily data gap) • < 1981: no CHIRPS satellite images • No SIEREM gauging station data available • > 5 high-quality hydrological years
SF217	Samvya at Yunga	99%	2.5 (upstream)	REG	• Basin Offices: time-series period from 1975 to 1979 (1% of daily data gap) • < 1981: no CHIRPS satellite images • No SIEREM gauging station data available • < 5 high-quality hydrological years
SF266	?			REG	• Basin Offices: no data collected

					• No streamflow data available
SF294	Kigogo Ruaha at Lugema (Mshongo)			REG	• Basin Offices: data collected unexploitable • No other streamflow data available

In total: 10 sites use the *regionalization* method, 6 sites uses the *observed streamflow data* method and 4 sites use the *hydrological modelling* method.

6.4 ADDITIONAL SITE INVESTIGATIONS

The Site Investigation Report is delivered in the frame of PHASE 2 (Ground-based data collection) and aims at providing an overview, at reconnaissance level, of the top 20 prioritized potential small hydropower sites in Tanzania.

The data and information collected during the site investigations of the 20 potential hydroelectric projects were used to prepare a preliminary layout for each site including a preliminary bill of quantities and investment costs. The preliminary design of the potential hydropower schemes, their energy performance analysis and eventually the economic modelling are detailed in dedicated project fiches consolidated in the Site Investigation Report. It contains detailed project sheets for the top 20 prioritized sites.

The findings presented in the Site Investigation Report are based on high-level technical site investigations described in the following sections.

6.4.1 Site visits by the Consultant's Team of Experts

Reconnaissance were undertaken by hydropower experts.

6.4.2 Topographic surveys

The objective of the topographic survey on the 20 prioritized sites is to confirm the available gross head and identify the best feasible option for the waterway.

The topographic survey was carried out by remote sensing. An eBee Plus drone equipped with a specific camera designed for photogrammetric mapping was used.

Outputs from drone survey are (1) a high resolution orthophotography (0.1m resolution) and (2) a Digital Surface Model (DSM). The DSM includes the vegetation cover, but it gives an excellent overview of the topographical features of the site of interest. Contour lines are calculated from the DSM.

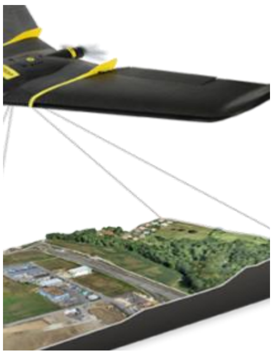
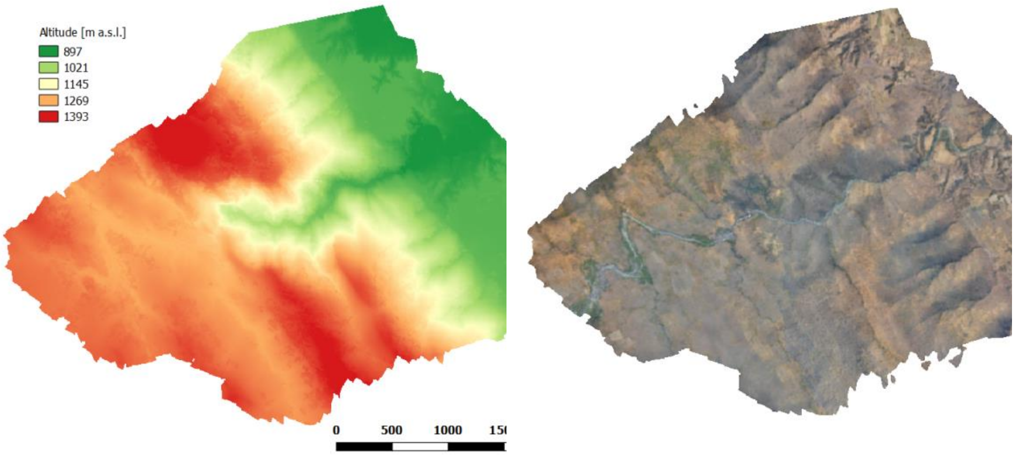


Figure 49. *eBee Plus* drone equipped with a camera for the topographical survey.

Figure 50. Digital Surface Model (DSM) and orthophotography from drone survey at M070 site.



6.4.3 Characterization of the surface geology

The Consultant carried out the additional site visits of the 20 prioritized sites with a geologist. The objective was to assess the geological conditions and the types of materials existing in the region, as well as to give an initial overview of the geotechnical properties of these materials. Recommendations are also formulated regarding the need for further studies and investigations if necessary.

6.4.4 Identification of socio-economic and environmental context

The Consultant carried out the additional site visits of the 20 prioritized sites with a socio-environmental Expert who gave an overview of the socio-environmental context of the project area. The Expert also determined the potential impacts of the proposed scheme on the project area. Where appropriate, the analysis highlights the elements that should be taken into account in future studies to ensure that appropriate mitigation measures are taken. The expert paid a special attention to the World Bank safeguard policies that could be triggered during the planning process.

The World Bank has developed a series of operational policies (OP), or safeguards, to help identify, avoid, and minimize social and environmental impacts. These operational polices and safeguards are prerequisites to accessing the World Bank funding assistance to address certain environmental and social risks for specific development projects.

6.4.5 Dedicated hydrological study.

The targeted hydrological study based on data collection within the Water Basin Offices and hydrological modelling is described in section 8.3.

Figure 51. Location of the top 20 prioritized potential hydropower projects

7 PREFEASIBILITY STUDIES OF FOUR HYDROELECTRIC PROJECTS

7.1 INTRODUCTION AND OBJECTIVES

A Technical Memo was delivered to REA and the World Bank in the frame of PHASE 2 (Ground-based data collection), in September 2017. It aims at providing advices to the Rural Energy Agency and the World Bank for the selection of the four (4) potential hydroelectric projects to be studied at prefeasibility level by the Consultant, SHER Ingénieurs-Conseils.

As per the Terms of References of the Study (*Revised Terms of References for the Phase II and III of the Project, September 24, 2014*), the prefeasibility studies covered the following aspects:

- Review of the existing data and GIS information;
- Additional site visit to the four sites and main load centers/national grid connection by relevant sector experts;
- Additional topographic and geotechnical surveys, update of the hydrology, and assessments of environmental and social impact to reach study results at pre-feasibility level;
- Preparation of a conceptual design and drawings at pre-feasibility level; Schematic Layout of Hydro Powerhouse, weir or dam (when applicable), waterways and Transmission Lines to the main load centers / national grid connection;
- Preparation of a Budgetary Cost Estimate, including costs for environmental and social costs, and Electricity Generation Estimate for a range of installed capacities;
- Preliminary economic analysis.

In compliance with our Terms of References, the selection of the four sites was be made amongst the list of the top 20 prioritized hydroelectric projects presented in the Site Investigation Report. The location of the 20 potential hydroelectric projects is shown in Figure 51 below and their key technical features and economic performances are presented in Table 25.

Table 25. Key features of the top 20 prioritized small potential hydropower sites

		Hydrology					Project features at firm design flow ($Q_{90\%}$)						Project features at median design flow ($Q_{50\%}$)					
Atlas Code	Site Name	River	Catchment [km²]	Firm flow $Q_{90\%}$ [m³/s]	Median flow $Q_{50\%}$ [m³/s]	Gross head [m]	Power [MW]	Energy [GWh/y]	CAPEX (incl. lines & access) [M$]	LCOE (incl. lines & access) [$/kWh]	CAPEX (without lines & access) [M$]	LCOE (without lines & access) [$/kWh]	Power [MW]	Energy [GWh/y]	CAPEX (incl. lines & access) [M$]	LCOE (incl. lines & access) [$/kWh]	CAPEX (without lines & access) [M$]	LCOE (without lines & access) [$/kWh]
M-070	Momba II	Momba	6418	0.44	7.43	358	1.28	10.40	47.13	0.49	18.29	0.19	21.67	125.20	123.50	0.11	94.66	0.08
M-121B	Kitogota Falls	Kitogota	121	0.37	0.77	30	0.09	0.73	1.66	0.25	1.00	0.15	0.18	1.31	1.91	0.16	1.25	0.11
M245	Mandera's Waterfall	Pangani	44928	12.82	21.97	43	4.38	36.84	17.19	0.05	16.23	0.05	7.59	56.50	24.52	0.05	23.45	0.05
SF-020	Mfizi II	Mfizi	2544	0.00	1.21	153	0.00	0.00	20.47	-	2.82	-	1.49	8.28	26.38	0.35	8.73	0.12
SF-022	Luegere	Luegere	1332	1.59	4.56	114	1.40	11.86	24.70	0.23	8.24	0.08	4.15	27.65	51.33	0.20	17.99	0.07
SF-178	Mgambazi	Mgambazi	592	0.75	2.08	57	0.34	2.90	19.66	0.73	4.95	0.19	0.92	6.19	20.70	0.36	5.99	0.11
SF-187	Muyovozi	Muyovozi	2720	3.43	12.04	30	0.71	5.92	13.98	0.26	4.55	0.08	2.73	18.19	20.82	0.12	11.39	0.07
SF-214A	Kalambo I	Kalambo	1335	0.36	1.88	17	0.05	0.42	5.13	1.33	1.91	0.50	0.25	1.53	5.87	0.41	2.64	0.19
SF-214B	Kalambo II	Kalambo	1348	0.36	1.90	20	0.05	0.44	5.84	1.44	1.78	0.44	0.30	1.83	6.82	0.40	2.75	0.16
SF-217	Samvya	Samvya	1849	0.18	2.24	126	0.18	1.47	17.12	1.26	3.05	0.23	2.22	13.11	25.25	0.21	11.18	0.09
M-288	Kelolilo	Mganbanyayu	105	0.47	1.09	79	0.29	2.43	4.34	0.19	1.99	0.09	0.68	4.71	6.63	0.15	4.27	0.10
M-295	Myombezi	Myombezi	35	0.12	0.30	94	0.09	0.76	7.51	1.07	1.23	0.18	0.23	1.58	8.21	0.56	1.93	0.13
M-299	Luaita	Luaita	55	0.10	0.35	30	0.02	0.20	0.54	0.29	0.34	0.18	0.09	0.57	0.73	0.14	0.53	0.10
N-010	Kitandazi II	Mbinga	183	0.18	0.64	26	0.04	0.31	1.87	0.65	0.74	0.26	0.13	0.85	2.20	0.28	1.08	0.14
SF-017	Momba I	Momba	1849	0.90	11.13	4	0.02	0.18	4.72	2.76	0.98	0.57	0.29	1.79	5.73	0.35	1.99	0.12
SF-019	Lwazi	Lwazi	515	0.17	2.12	167	0.23	1.86	10.42	0.60	3.45	0.20	2.77	16.32	21.06	0.14	14.10	0.09
SF-082	Lukosi	Lukosi	1535	5.78	9.10	103	4.76	40.30	20.85	0.06	16.38	0.05	7.59	57.33	28.32	0.05	23.63	0.05
SF-206	Chulu	Chulu	99	0.03	0.35	829	0.20	1.64	16.36	1.08	6.30	0.42	2.39	14.14	55.54	0.43	45.48	0.35
SF-266	Muhuwesi	Muhuwesi	640	0.38	3.10	83	0.25	2.01	10.95	0.59	4.31	0.23	1.91	11.69	17.50	0.16	10.86	0.10
SF-294	Kigogo	Kigogo	52	0.06	0.42	539	0.25	2.08	11.45	0.60	7.76	0.40	1.86	11.44	23.02	0.22	19.33	0.18

7.2 DESCRIPTION OF THE SELECTION CRITERIA

This section presents the criteria for the selection of the projects that will be studied at prefeasibility level. These criteria are based on the additional information and data available following the field investigations (Phase 2), notably the results of the topographic survey, surface geology, socio-environmental aspects and hydrological studies based of the data collected in the Water Basin Offices of Tanzania.

Important note: It is important to note that the uncertainties on the baseline data for assessing the actual potential of a site are variable. The main source of uncertainty relates to the hydrology of the rivers of interest. Indeed, for many of the potential hydroelectric sites studied in this study, there is little or no accurate information on their hydrological regime. These hydrological characteristics play a major role in the calculation of the technical and economic parameters of the hydroelectric schemes as well as their development planning and type of connection for the evacuation of the energy produced.

7.2.1 Criterion 1 - Installed capacity between 300 kW and 10 MW

The Terms of Reference of this study indicate that “small hydro” shall refer as having a generation capacity between 1 to 10 MW. Nevertheless, REA expressed its wish to include potential sites under 1 MW. The minimum of 300 kW has been agreed upon. That value corresponds to a minimal project size in terms of investment and technical barriers for electro-mechanical equipment under which a private developer will face problems to recover its investment and/or find quality equipment for a reasonable price. Note however that some sites are located in areas where the uncertainty of hydrological data is still rather high, which can have a positive or negative influence on the final installed capacity or production.

7.2.2 Criterion 2 - Favorable hydrological conditions: Q90% > 0.2m³/s

The development of hydroelectric project on rivers that feature dry periods (zero streamflow) during a given period of the year is usually not appropriate for multiple reasons amongst which: (i) no energy generation during several months of the year; (ii) production difficult to predict; (iii) high maintenance costs and (iv) operation and maintenance constraints. This problem is particularly disadvantageous for Mini-Grid as the available thermal capacity must be high enough to balance the production deficit to supply the demand. The problem is even more critical for off-grid systems where there will not be any power supply during the dry season.

Given the hydrological uncertainties and based on our similar experience in other countries across the world, the minimum threshold of 200 L/s at $Q_{90\%}$ is proposed. This means that the river at the site of interest must have a minimum of 200 L/s at least 90% of the time over a year. Given the uncertainties, this criterion ensures that the river is not dry during a period longer than one month a year.

7.2.3 Criterion 3 - Competitive economic performance: Levelized Cost of Energy thresholds

The proposed projects must be economically attractive compared to other alternatives for the production of electricity. In accordance with the economic constraints of small hydropower development and the competitiveness of the future sites, the Consultant has set a maximum threshold for the Levelized Cost of Energy (LCOE) at:

- < 50 US$/MWh for main Grid connection;
- < ~100 US$/MWh for Mini-Grid connection;
- < 200 US$/MWh for pure off-grid operation (no other source of power).

Those threshold values were discussed and agreed upon with REA and the World Bank during the presentation of the Hydro Mapping Report (approved in April 2015).

The potential hydropower projects were compared based on their costs per kWh produced, expressed in terms of Levelized Cost of Energy (LCOE) which is a stream of equal payments, normalized over expected energy production periods that would allow a project owner to recover all costs, an assumed return on investment, over a predetermined life span.

The LCOE has been calculated excluding the cost for the access roads and the transmission lines (which makes a good project or not) which is comparable to the figures collected in the Power System Master Plan (Update 2013) and in the SREP-Investment Plan for Tanzania (2013).

7.2.4 Criterion 4 - No evidence of major social and environmental constraints, including solid transport

The first site visits (Site Visit Report 2015 and update 2016) identified obvious constraints that would jeopardize the development of promising potential hydroelectric projects. Those constraints were notably the presence of a protected area or game reserve, the presence of soil instability or even a high solid transport even during the dry season.

Secondly, the additional investigations carried out by the Team of Experts in environmental and social impact assessment identified the operational policies (OPs) of the World Bank that could be triggered for the development of the top 20 prioritized hydroelectric projects.

Environmental and social constraints have been classified into three categories:

- "*Low*": few environmental and / or social constraints identified at this stage of the study;
- "*Medium*": mitigation measures exist for identified environmental and / or social constraints;
- "*High*": the identified environmental and / or social constraints could jeopardize the development of the project.

The "*High*" category is considered as an exclusion criterion in the multicriteria analysis.

7.2.5 Criterion 5 - No evidence of major geological constraints

The additional field investigations carried out by the Team of Geologists provided additional information for the description of the surface geology of the various sites and thus to identify if there were major geological constraints for the development of these sites. These constraints have been classified into two categories:

- "*Low*": No evidence of major geological constraints or easily manageable, identified at this stage of study;

- "*High*": the identified geological constraints could prevent the development of the project or may result in significantly increase of the project costs.

The "*High*" category is considered an exclusion criterion in the multicriteria analysis.

7.3 MULTICRITERIA ANALYSIS

The aforementioned criteria were applied to the set of the top 20 prioritized hydroelectric projects. The results of the multicriteria are presented in Table 26 below.

Table 26. Results of the multicriteria analysis for the selection of the four sites eligible for the prefeasibility studies.

SITE IDENTIFICATION				CRITERION 1	CRITERION 2 Low flow	CRITERION 3 LCOE		CRITERION 4 Environmental and/or Social		CRITERION 5 Geology	ELIGIBLE SITES FOR PREFEASIBILITY STUDIES
Code Atlas	Site Name	River	Region	Power @Q50% [MW]	Firm flow (Q90%) [m^3/s]	LCOE (without lines and access) [$/MWh]	National Grid / Mini-grid / Off-grid	Solid Transport [Low / Medium / High]	Social / Environmental constraint [Low / Medium / High]	Geological Risk [Low / Medium / High]	
M-070	Momba II	Momba	Mbeya	21.67	0.44	83.3	National Grid	Low	Low	High	-
M-121B	Kitogota Falls	Kitogota	Kagera	0.18	0.37	105.1	Bukoba Mini-Grid	Low	Low	Low	-
M245	Mandera's	Pangani	Tanga	7.59	12.82	46.1	National Grid	Low	Low	Low	✓
SF-020	Mfizi II	Mfizi	Rukwa	1.49	0.00	115.4	Mpanda Mini-Grid	Low	Low	Low	-
SF-022	Luegere	Luegere	Kigoma	4.15	1.59	71.7	Kigoma Mini-Grid	Low	Low	Low	✓
SF-178	Mgambazi	Mgambazi	Kigoma	0.92	0.75	105.9	Kigoma Mini-Grid	Low	Medium	Low	-
SF-187	Muyovozi	Muyovozi	Kigoma	2.73	3.43	69.0	Kibundo Mini-Grid	Low	Low	Low	✓
SF-214A	Kalambo I	Kalambo	Rukwa	0.25	0.36	187.6	Sumbawanga Mini-Grid	Low	Low	Low	-
SF-214B	Kalambo II	Kalambo	Rukwa	0.30	0.36	163.4	Sumbawanga Mini-Grid	Low	Low	Low	-
SF-217	Samvya	Samvya	Rukwa	2.22	0.18	93.7	Sumbawanga Mini-Grid	Low	Low	Low	✓
M-288	Kelolilo	Mganban	Iringa	0.68	0.47	99.2	Ludewa Mini-Grid	Low	Low	Low	✓
M-295	Myombezi	Myombez	Ruvuma	0.23	0.12	132.9	Off-grid	Low	Low	Low	-
M-299	Luaita	Luaita	Ruvuma	0.09	0.10	102.6	Mbinga Mini-Grid	Low	Low	Low	-
N-010	Kitandazi II	Mbinga	Ruvuma	0.13	0.18	137.6	Mbinga Mini-Grid	Low	Low	Low	-
SF-017	Momba I	Momba	Rukwa	0.29	0.90	121.6	Sumbawanga Mini-Grid	Low	Low	Low	-
SF-019	Lwazi	Lwazi	Rukwa	2.77	0.17	94.9	Sumbawanga Mini-Grid	Medium	Low	Low	-
SF-082	Lukosi	Lukosi	Iringa	7.59	5.78	45.8	National Grid	Low	Low	Low	✓
SF-206	Chulu	Chulu	Rukwa	2.39	0.03	348.6	Sumbawanga Mini-Grid	Medium	Low	Low	-
SF-266	Muhuwesi	Muhuwesi	Ruvuma	1.91	0.38	101.8	Tunduru Mini-Grid	Low	Low	Low	✓
SF-294	Kigogo	Kigogo	Iringa	1.86	0.06	184.0	National Grid	Low	High	Low	-

7.4 Conclusions and Recommendations

The multicriteria analysis reveals that seven (7) potential hydropower projects are eligible to be studied at prefeasibility level in the context of this study: M-245 (Mandera's Waterfall), SF-022 (Luegere), SF-187 (Muyovozi), SF-217 (Samvya), M-288 (Kelolilo), SF-082 (Lukosi) and SF-266 (Muhuwesi).

Following meetings held in Dar Es Salaam on the 26th and 27th of September 2017 with the Rural Energy Agency, the Ministry of Energy and Minerals, the World Bank and the Consultant, it appears that (i) feasibility studies have been performed recently for M-245 (Mandera's Waterfall) and SF-082 (Lukosi) and (ii) water uses for irrigation purposes might be problematic for the development of the M-245 (Mandera's Waterfall) hydroelectric project. As a consequence, it has been jointly decided to exclude those two (2) sites from the list of eligible candidates for the prefeasibility studies.

Hence, it was agreed that five (5) potential hydroelectric projects are eligible for the prefeasibility studies: SF-022 (Luegere), SF-187 (Muyovozi), SF-217 (Samvya), M-288 (Kelolilo), and SF-266 (Muhuwesi).

Those five candidates hydroelectric projects are expected to supply energy to five different Mini-Grids, as highlighted in Table 26.

Details on those five sites, including pictures, are available in the *Site Investigation Report*.

Based on the recommendations presented in this Technical Memo and the discussions held in Dar Es Salaam on the 26th and 27th of September 2017 with the Rural Energy Agency, the Ministry of Energy and Minerals, the World Bank and the Consultant, the Tanzanian stakeholders of the Study have finalized the selection process internally.

On the 4th of October 2017, it was decided by REA to proceed with the prefeasibility studies of the following four sites:

- SF 217 - Samvya
- SF 022 - Luegere
- SF 187 - Muyowozi
- SF 266 - Muhuwesi

7.5 KEY OUTCOMES OF THE PREFEASIBILITY STUDIES

The following sections present the key conclusions of the prefeasibility studies.

It is important to note that the conclusions of the four economic analyses are conditioned to the validation of the flow duration curves estimated in the hydrological studies. This validation can only be achieved by hydrological monitoring of the various rivers. This hydrological monitoring should include not only the continuous water level monitoring but also the gauging operations of the rivers for the establishment of validated rating curves.

Beyond the development of the four hydroelectric projects, it is strongly recommended that the Government of Tanzania further develop the existing hydrological monitoring network for its rivers with high hydropower potential in order to better understand the available water resources and thus promote the development of hydroelectric projects across the country. It is only in a context of reduced uncertainties through reliable, recent and long-term records (more than 20 years) that technical parameters and economic and financial analyzes of hydroelectric developments can be defined accurately, enabling optimization of their design and their flood control infrastructure (temporary and permanent).

7.5.1 Muyovosi hydroelectric project (SF187)

The hydrological study revealed that the Muyovozi River is characterized by a good guaranteed low-flow which should be confirmed by hydrological monitoring of the River.

The preliminary investigation of the surface geology concludes that the site is favorable for the construction of the project as long as appropriate mitigation measures are put in place. The site has no major problems of stability and leakages. Further investigations will however have to be undertaken in further studies.

Preliminary socio-environmental studies show that the development of the Muyovozi project has no major impacts that cannot be mitigated by appropriate measures.

The economic analysis reveals that the construction costs of the 33kV transmission line to Kibondo (or Lusahunga) mini-grid are high. However, those costs will be significantly reduced in the near future with the construction of the 400kV transmission line between Nyakanazi and Kigoma at horizon 2020, as proposed in the Power Supply Master Plan (2016). The Muyovozi hydroelectric project is an economically attractive scheme with a LCOE of 0.0897 US$/kWh if the costs of the costs of the transmission line and access roads are excluded. The Muyovozi Project features a production costs significantly lower than the standardized small power projects (SPPs) tariff for hydro between 2MW and 3MW, as approved by EWURA in 2016 (0.108 US$/kWh).

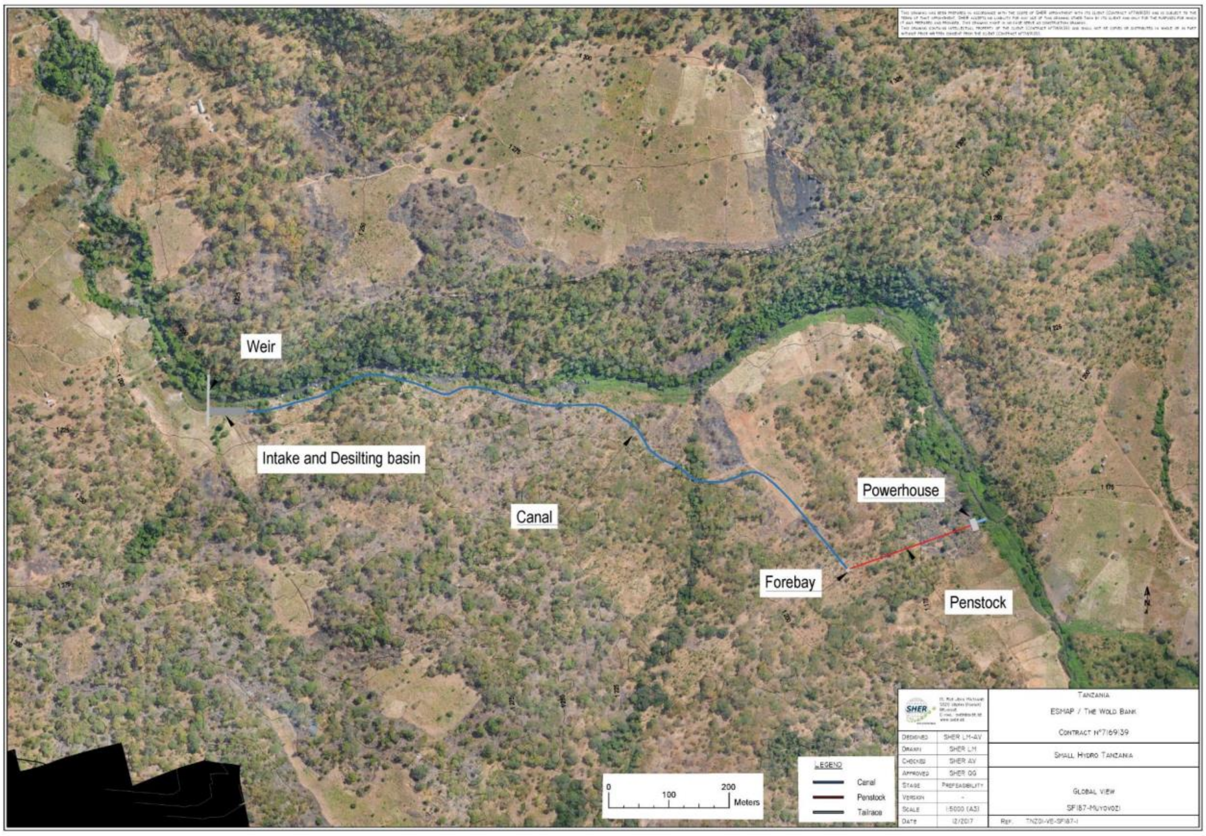
Table 27 below summarizes the key features of the proposed layout of the Muyovozi hydroelectric scheme.

Table 27. Key features of the Muyovosi hydroelectric project.

Feature	Parameter	Value	Units
Location	Region	Kigoma	-
	River	Muyovozi	-
Hydrology	Catchment area	2 720.00	km²
	Median streamflow (Q50%)	12.04	m³/s
	Firm streamflow (Q95%)	2.12	m³/s
	Design flow	11.44	m³/s
	Design flood (100 years)	624	m³/s
Diverting structure	Structure type	Gravity weir (Overflowing section : Trapezoidal)	-
	Material used	Concrete	-
	Overflowing section crest length	40	m
	Total structure length	85	m
	Overflowing section height	3.00	m
	Non-overflowing section height	8.80	m
	Crest elevation	1 192.00	masl
	Slab elevation	1 189.00	masl
Gated flushing channel	Invert elevation	1 189.00	masl
	Number of bays	2.00	pce
	Gate section	1.6 x 2	m x m
Intake	Number of bays	4	pce
	Invert elevation	1 189.50	masl
	Equipment	Trash rack (manual cleaning)	-
Desilting structure	Yes		
	Number of basins	3.00	pce
	Water level	1 192.00	masl
Waterway	Headrace canal length	1 147	m
Canal	Headrace canal section	2.8 x 3.2	m x m
	Average slope	0.001	m / m
Forebay	Yes	-	-
	Water level	1 190.85	masl
Penstock	Number of penstock(s)	1	pce
	Length	226	m
	Diameter	1.70	m
Powerhouse and electrical / electromechanical equipments	Floor elevation	1 165.00	masl
	Gross head	27.00	m
	Number of units	2	pce
	Turbine type	Kaplan	-
	Operating discharge per unit	5.72	m³/s
	Total installed capacity	2 270	kW
	Average annual energy generation	15.00	GWh/year
Access road	Length of road to build	2 200	m
	Length of road to rehabilitate	3 700	m
Transmission lines	Length	60 (Kibondo) or 50 (Lusahunga)	km
	Voltage	33	kV
Economic data	CAPEX - without access road and transmission lines	9.78	M$

	LCOE - without access road and transmission lines	0.09	$/kWh
	CAPEX - access road and transmission lines included	17.38 (Kibondo) or 16.41 (Lusahunga)	M$
	LCOE - access road and transmission lines included	0.16 (Kibondo) or 0.15 (Lusahunga)	$/kWh

Figure 52. Proposed layout for the Muyovosi hydroelectric project



7.5.2 Muhuwesi hydroelectric project (SF266)

The hydrological study (based on regional data) revealed that the Muhuwesi River is characterized by a reasonable guaranteed low-flow that shall be confirmed by hydrological monitoring of the River. Indeed, the dry season in the study area features five months with precipitations below 5 mm per month (on average).

The preliminary investigation of the surface geology concludes that the site is favorable for the construction of the project as long as appropriate mitigation measures are put in place. The site has no major problems of stability and leakages. Further investigations will however have to be undertaken in further studies.

Preliminary socio-environmental studies show that the development of the Muhuwesi project has no major impacts that cannot be mitigated by appropriate measures.

The economic analysis reveals that the construction costs of the 33kV transmission line to Tunduru mini-grid are reasonable (8km). However, the transmission system evolves continuously with the planning and construction of new electrification projects. Moreover, the Power Supply Master Plan (2016) propose the construction of a 400 kV transmission line between Songea and Tunduru at horizon 2030 which would ensure the electricity production stability supplied by the Muhuwesi hydroelectric scheme. The costs of building new access to the site are significant in the total budget.

The Muhuwesi hydroelectric project is an economically attractive scheme with a LCOE of 0.11 US$/kWh if the costs of the costs of the transmission line and access roads are excluded. The Muhuwesi Project features a production costs significantly lower than the standardized small power projects (SPPs) tariff for hydro between 1MW and 2MW, as approved by EWURA in 2016 (0.115 US$/kWh).

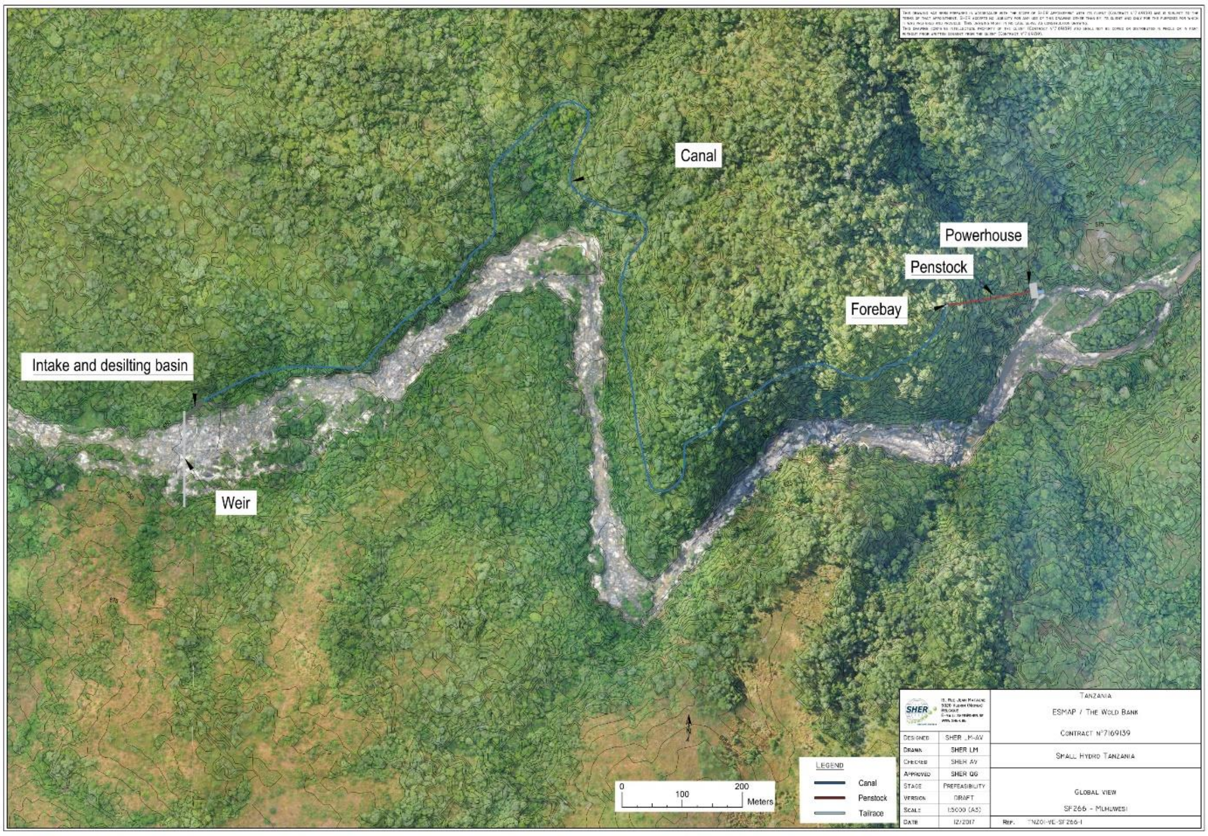
Table 28 below summarizes the key features of the proposed layout of the Muhuwesi hydroelectric scheme.

Table 28. Key features of the Muhuwesi hydroelectric project.

FEATURE	PARAMETER	VALUE	UNITS
Location	Region	Ruvuma	-
	River	Muhuwesi	-
Hydrology	Catchment area	640	km²
	Median streamflow (Q50%)	3.10	m³/s
	Firm streamflow (Q95%)	0.17	m³/s
	Design flow	2.94	m³/s
	Design flood (100 years)	376	m³/s
Diverting structure	Structure type	Gravity weir (Overflowing section : Creager)	-
	Material used	Concrete	-
	Overflowing section crest length	130	m
	Total structure length	140	m
	Overflowing section height	3.00	m
	Non-overflowing section height	5.25	m
	Crest elevation	642.00	masl
	Slab elevation	639.00	masl
Gated flushing channel	Invert elevation	639.00	masl
	Number of bays	2.00	pce
	Gate section	1 x 1.5	m x m
Intake	Number of bays	2	pce
	Invert elevation	639.50	masl
	Equipment	Trash rack (manual cleaning)	-
Desilting structure	Yes	-	-
	Number of basins	2.00	pce
	Water level	642.00	masl
Waterway	Headrace canal length	2 280	m
Canal	Headrace canal section	1.8 x 2.1	m x m
	Average slope	0.001	m / m
Forebay	Yes	-	-
	Water level	639.72	masl
Penstock	Number of penstock(s)	1	pce
	Length	170	m
	Diameter	0.80	m
Powerhouse and electrical / mechanical works	Floor elevation	561.00	masl
	Gross head	81.00	m
	Number of units	2	pce
	Turbine type	Pelton	-
	Operating discharge per unit	1.47	m³/s
	Total installed capacity	1 820	kW
	Average annual energy generation	10.90	GWh/year

Access road	Length of road to build	10 900	m
	Length of road to renovate	0	m
Transmission lines	Length	8	km
	Voltage	33	kV
Economic data	CAPEX - without access road and transmission lines	8.62	M$
	LCOE - without access road and transmission lines	0.11	$/kWh
	CAPEX - access road and transmission lines included	14.58	M$
	LCOE - access road and transmission lines included	0.18	$/kWh

Figure 53. Proposed layout for the Muhuwesi hydroelectric project



7.5.3 Luegere hydroelectric project (SF022)

The hydrological study revealed that the Luegere River is characterized by a good guaranteed low-flow that should be confirmed by hydrological monitoring of the River.

The preliminary investigation of the surface geology concludes that from a geological point of view the site is favorable for the construction of the project as long as the appropriate mitigation measures are put in place. The site has no major problems of stability and leakages. Further studies will however have to be undertaken in further studies.

Preliminary socio-environmental studies show that the development of the Luegere project has no major impacts that cannot be mitigated by appropriate measures.

The economic analysis reveals that the construction costs of the 33kV transmission line to the Kigoma mini-grid are high. However, those costs will be significantly reduced in the near future with the construction of the 400kV transmission line between Kigoma and Mpanda at horizon 2020, as proposed in the Power Supply Master Plan (2016).

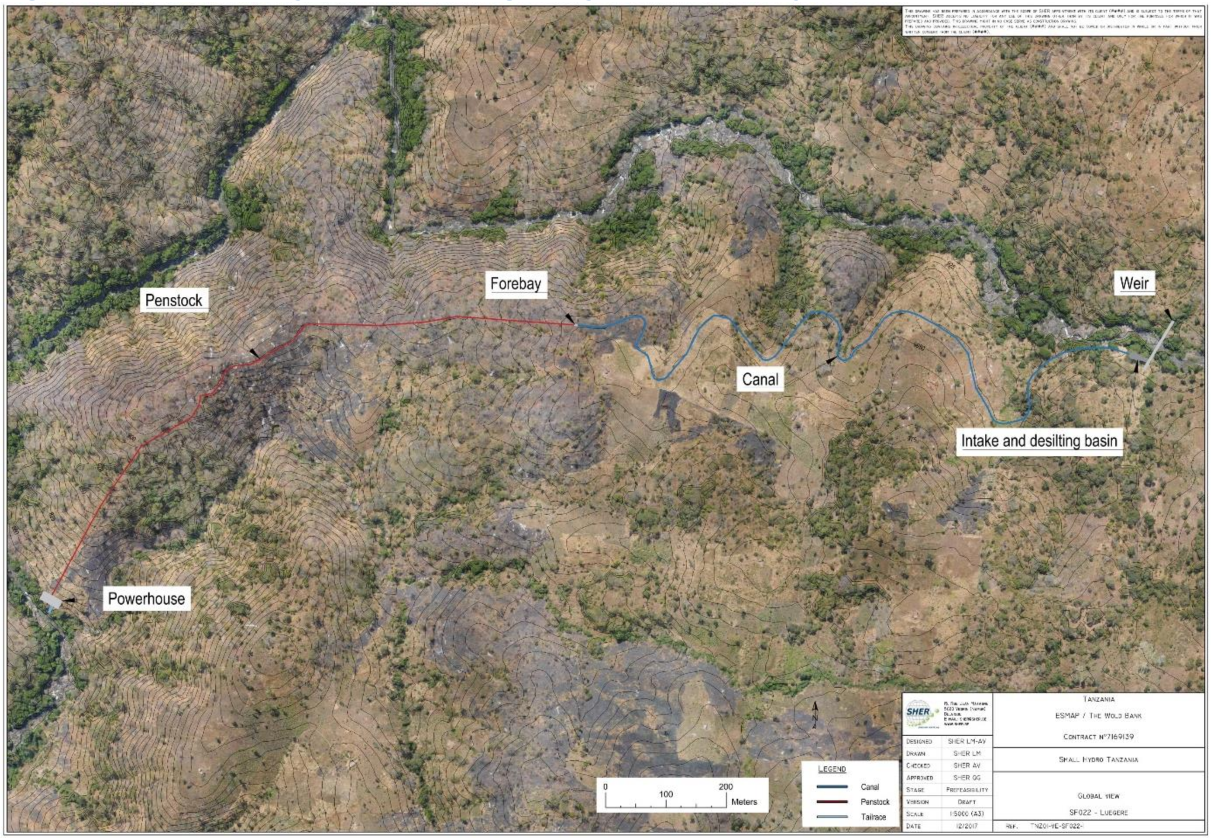
The Luegere hydroelectric project is an economically attractive scheme with a LCOE of 0.05 US$/kWh if the costs of the transmission line costs and access roads are excluded. The Luegere Project features a production costs significantly lower than the standardized small power projects (SPPs) tariff for hydro between 5MW and 6MW, as approved by EWURA in 2016 (0.095 US$/kWh).

Table 29. Key features of the Luegere hydroelectric project.

FEATURE	PARAMETER	VALUE	UNITS
Location	Region	Kigoma	-
	River	Luegere	-
Hydrology	Catchment area	1,317	km²
	Median streamflow (Q50%)	4.56	m³/s
	Firm streamflow (Q95%)	1.41	m³/s
	Design flow	4.33	m³/s
	Design flood (100 years)	220	m³/s
Diverting structure	Structure type	Gravity weir (Overflowing section : Creager)	-
	Material used	Concrete	-
	Overflowing section crest length	50	m
	Total structure length	70	m
	Overflowing section height	4.50	m
	Non-overflowing section height	7.15	m
	Crest elevation	943.00	masl
	Slab elevation	938.50	masl
Gated flushing channel	Invert elevation	938.50	masl
	Number of bays	2.00	pce
	Gate section	1.4 x 1.5	m x m
Intake	Number of bays	2	pce
	Invert elevation	941.00	masl
	Equipment	Trash rack (manual cleaning)	-
Desilting structure	Yes		
	Number of basins	2.00	pce
	Water level	943.00	masl
Waterway	Headrace canal length	1 420	m
Canal	Headrace canal section	2 x 2.3	m x m
	Average slope	0.001	m / m
Forebay	Yes	-	-
	Water level	941.58	masl
Penstock	Number of penstock(s)	1	pce
	Length	1 110	m
	Diameter	1.20	m
Powerhouse and electrical / electromechanical equipment	Floor elevation	786.00	masl
	Gross head	157.00	m
	Number of units	3	pce
	Turbine type	Pelton	-
	Operating discharge per unit	1.44	m³/s
	Total installed capacity	5 340	kW
	Average annual energy generation	34.40	GWh/year
Access road	Length of road to build	9,000	m
	Length of road to rehabilitate	0	m

Transmission lines	Length	85	km
	Voltage	33	kV
Economic data	CAPEX - without access road and transmission lines	13.14	M$
	LCOE - without access road and transmission lines	0.05	$/kWh
	CAPEX - access road and transmission lines included	24.97	M$
	LCOE - access road and transmission lines included	0.10	$/kWh

Figure 54. Proposed layout for the Luegere hydroelectric project



7.5.4 Samvya hydroelectric project (SF217)

The hydrological study (based on regional data) revealed that the Samvya River is characterized by a severe low-flow period. Hydrological monitoring of the river shall confirm that the river is not seasonal. Indeed, the dry season in the study area features four months with precipitations below 5 mm per month (on average).

The preliminary investigation of the surface geology concludes that the site is favorable for the construction of the project as long as appropriate mitigation measures are put in place. The site has no major problems of stability and leakages. Further investigations will however have to be undertaken in further studies.

Preliminary socio-environmental studies show that the development of the Samvya project has no major impacts that cannot be mitigated by appropriate measures.

The economic analysis reveals that the construction costs of the 33kV transmission line to Mpui are reasonable (9km). However, the cost associated with the access roads remain high. The Samvya hydroelectric project is an economically attractive scheme with a LCOE of 0.09 US$/kWh if the costs of the costs of the transmission line and access roads are excluded. The Samvya Project features a production costs significantly lower than the standardized small power projects (SPPs) tariff for hydro between 1MW and 2MW, as approved by EWURA in 2016 (0.115 US$/kWh).

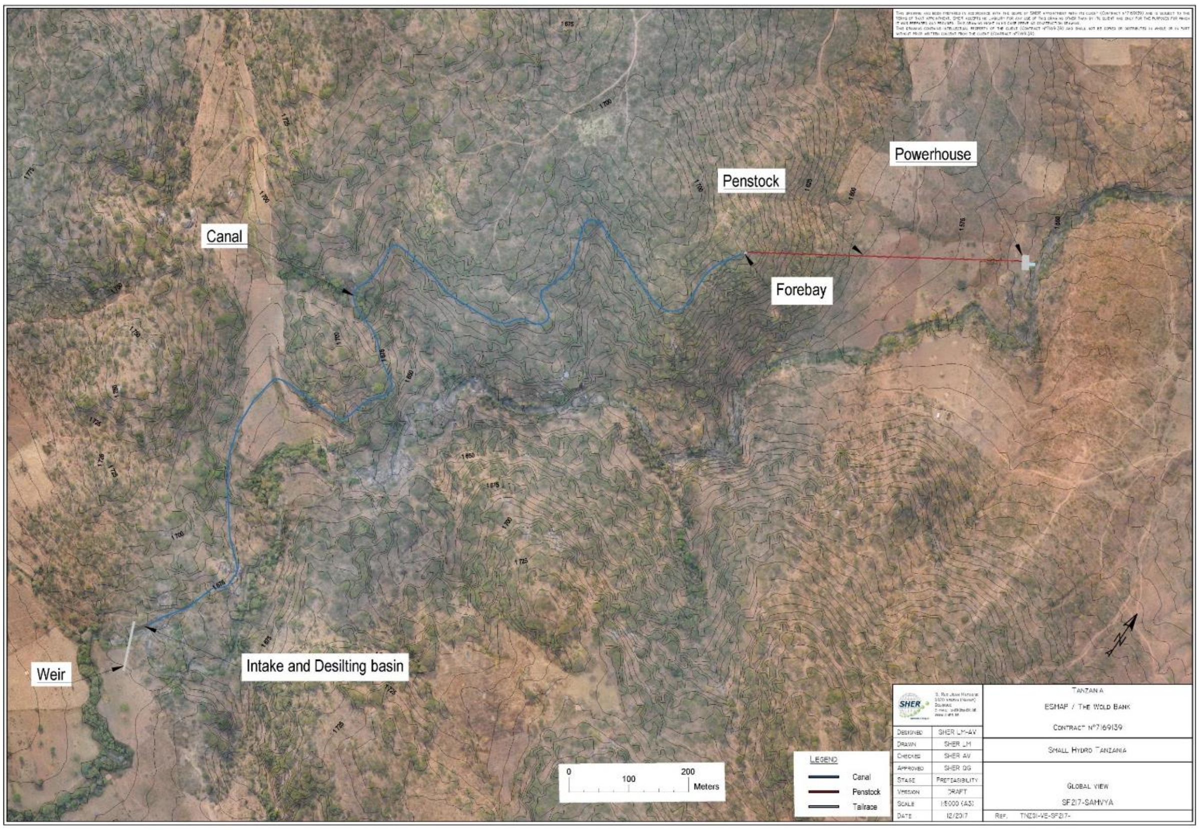
Table 30 below summarizes the key features of the proposed layout of the Samvya hydroelectric scheme.

Table 30. Key features of the Samvya hydroelectric project.

FEATURE	PARAMETER	VALUE	UNITS
Location	Region	Rukwa	-
	River	Samvya	-
Hydrology	Catchment area	565	km²
	Median streamflow (Q50%)	2.24	m³/s
	Firm streamflow (Q95%)	0.07	m³/s
	Design flow	2.13	m³/s
	Design flood (100 years)	114	m³/s
Diverting structure	Structure type	Gravity weir (Overflowing section : Creager)	-
	Material used	Concrete	-
	Overflowing section crest length	30	m
	Total structure length	75	m
	Overflowing section height	3.00	m
	Non-overflowing section height	5.50	m
	Crest elevation	1 673.00	masl
	Slab elevation	1 670.00	masl
Gated flushing channel	Invert elevation	1 670.00	masl
	Number of bays	2.00	pce
	Gate section	1 x 1.2	m x m
Intake	Number of bays	2	pce
	Invert elevation	1 671.50	masl
	Equipment	Trash rack (manual cleaning)	-
Desilting structure	Yes	-	-
	Number of basins	2.00	pce
	Water level	1 673.00	masl
Waterway	Headrace canal length	1 955	m
Canal	Headrace canal section	1.7 x 1.9	m x m
	Average slope	0.001	m / m
Forebay	Yes	-	-
	Water level	1 671.05	masl
Penstock	Number of penstock(s)	1	pce
	Length	500	m
	Diameter	0.80	m
Powerhouse and electrical / electromechanical equipment	Floor elevation	1 555.00	masl
	Gross head	118.00	m
	Number of units	2	pce
	Turbine type	Pelton	-
	Operating discharge per unit	1.06	m³/s
	Total installed capacity	1 940	kW
	Average annual energy generation	11.10	GWh/an
Access road	Length of road to build	7000	m
	Length of road to renovate	3000	m
Transmission lines	Length	9	km

	Voltage	33	kV
Economic data	CAPEX - without access road and transmission lines	7.49	M$
	LCOE - without access road and transmission lines	0.09	$/kWh
	CAPEX - access road and transmission lines included	11.45	M$
	LCOE - access road and transmission lines included	0.14	$/kWh

Figure 55. Proposed layout for the Samvya hydroelectric project



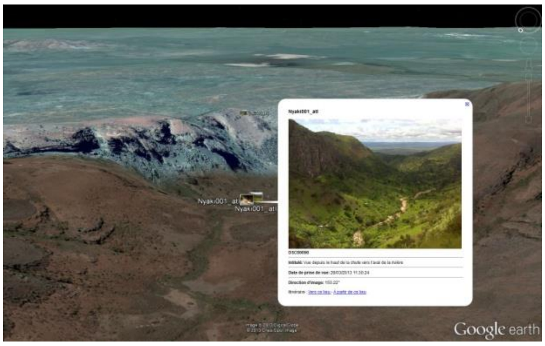
8 TRAINING AND CAPACITY BUILDING

A key output of the Small Hydro Mapping Study is the delivery of the GIS and associated spatial database of potential hydropower projects. Training sessions (2 days) dedicated to the concepts of spatial information and geographical information system was held in Dar Es Salaam in April 2015.

Every session started with a theoretical introduction and a demonstration followed by practical exercises. The sessions focused on the following aspects:

The first session target a non-technical audience including decision-makers and managers:

- General presentation of the Google Earth small hydropower database for managers and technical staff - presentation of the capabilities of the GIS database.



The following sessions target engineers and technical staff:

- Software installation, introduction to GIS, introduction to the main layers and shapefiles,
- Consult and update (editing) of the database,
- Updating the database from Google Earth data, from GPS data,
- According to the participants level, the last session might be focused on
    - more exercises on layers, consulting and editing the database
    - creating maps
    - possibilities of GIS for hydropower studies (presentation)

Twelve persons from the Ministry of Energy and Minerals, REA, SHP Centre Tanzania, EWURA and TANESCO have attended the training session. The list of attendees is presented in Appendix 7.

Figure 56. Training session on GIS

9 CONCLUSIONS

The Study focuses exclusively on potential sites in the range of capacities between 0.3 and 10 MW. All the information related to the hydropower sector in Tanzania having geographical coordinates has been compiled into a Geographic Information System (GIS). The spatial database of potential hydropower sites is the result of the consolidation of information from various sources: it contains a total of 455 potential hydropower sites amongst which 278 coming from the literature and 177 newly identified by SiteFinder, a spatial analysis tool that identify river stretches featuring a high hydropower potential based on rainfall and topography data (tool developed by SHER Ingénieurs-Conseils).

In collaboration with The Rural Energy Agency (REA) and the associated entities, a portfolio of 85 hydropower projects meeting the criteria of the study has been identified. The multicriteria analysis considered the following parameters: the power capacity range corresponding to the terms of reference of the study (up to 10 MW), hydrological constraints, economic performance of the projects (based on their levelized cost of energy) and finally the potential environmental and social impacts.

In total, 85 promising sites have been visited between March 2014 and January 2015, from which 82 have a confirmed potential for hydropower development. The data acquired during the sites visits are included in dedicated reports: "*Sites Visits Report - Potential Sites"* and "*Sites Visits Report - Existing sites"*.

Amongst those 82 promising projects a subset of 20 was selected and constitutes the list of the top 20 prioritized hydroelectric projects for short-term development in Tanzania. Additional field investigations (surface geology, topography, hydrology and socio-environment) were carried out on the top 20 prioritized projects: (i) Additional site visits by experts in hydropower design; (ii) Topographic surveys based on the processing of ortho-photogrammetric images acquired by drone; (iii) Characterization of the surface geology; (iv) Description of the socio-economic and environmental context; (v) Visit of the nine Water Basins Offices for hydrological data collection in order to perform additional hydrological modelling. The reconnaissance and field investigations took place between September 2016 and July 2017. The data and information collected during the site investigations of the top 20 prioritized potential hydroelectric projects were used to prepare a preliminary layout for each site including a preliminary bill of quantities and investment costs. The preliminary design of the potential hydropower schemes, their energy performance analysis and eventually the economic modelling are detailed in dedicated project fiches consolidated in the "*Site Investigations Report"*.

Alongside to the potential hydropower sites selection process, the hydrological study revealed that, in general, available hydrological data in Tanzania are sparse and / or non-existent for some catchments. For the vast majority of the potential hydropower projects in this study, there is no or little accurate information on their hydrological regime. Therefore, the Consultant developed and applied a methodology to estimate the statistical characteristics of river flows at sites of interest, based on data available at other gauging stations in Tanzania. A confidence index to the hydrological estimates was also attributed to each site.

The Study reveals that the small hydropower potential of Tanzania is good and largely untapped. Opportunities exist in all power capacity ranges. The development of this potential is however hampered by the size of the country and the poor state of the road network and tracks in remote areas. Soil degradation and erosion is worrying and may question the feasibility of some hydraulic projects. This context of catchment degradation and suspended sediments management must be considered in every future development of hydropower projects, whether large or small. Any new infrastructure development must be part of an Integrated Watershed Resources Management (IWRM) process in order to preserve the natural water resources of Tanzania in a sustainable way.

Without technical or economic considerations, the small hydro potential in Tanzania consists of more than 400 potential sites from 0.3 to 10 MW. Eighty-two (82) potential projects were visited with a cumulated capacity of approximately 162 MW (confirmed small hydropower potential).

Small hydro projects have the advantage of a faster development process (~2.5 to 4 years), a better progression in meeting the increasing electricity demand and a more easily available funding compared to the large hydro. The latter requires a longer development process, complex financial closure and may encounter severe socio-environmental constraints. Given the opportunity to replace expensive and polluting production from thermal power plants and the future increase in energy demand on the main grid and mini-grids, small hydro projects remain appealing even when a larger project is developed.

Expansion of the existing power grids should continue, as planned in the Power System Master Plan 2016. The development should rely on accurate and transparent mapping highlighting the priorities and timeframes for their development. Consequently, the economic attractiveness of remote hydropower projects could strongly increase due to the expected reduced costs associated with the transmission lines and access roads. Those remote projects could hence become competitive compared to thermal production.

In the light of a growing energy demand, the future development plans will have to integrate all the known and studied hydropower sites distributed across the country, the most promising hydropower projects selected in this study and the other renewable energy sources (solar, wind, ...) which will constitute a complete portfolio of renewable energy projects.

In a context of climate change and high seasonal variabilities of streamflow in the rivers, development of reservoir projects should be further analyzed to provide more flexibility of the power system. Also, cascade development of hydropower projects (including an upstream reservoir for daily or seasonal regulation) are particularly relevant in Tanzania. Economy of scale, particularly in terms of access roads and transmission lines, are possible for such projects.

It is important to note that the results are conditioned to the validation of the flow duration curves estimated in the hydrological studies. This validation can only be achieved by hydrological monitoring of the various rivers. This hydrological monitoring should include not only the continuous water level monitoring but also the gauging operations of the rivers for the establishment of validated rating curves. It is strongly recommended that the Government of Tanzania further develop the existing hydrological monitoring network for its rivers with high hydropower potential in order to better understand the available water resources and thus promote the development of hydroelectric projects across the country. It is only in a context of reduced uncertainties through reliable, recent and long-term records (more than 20 years) that technical parameters and economic and financial analyzes of hydroelectric developments can be defined accurately, enabling optimization of their design and their flood control infrastructure (temporary and permanent).

10 APPENDICES

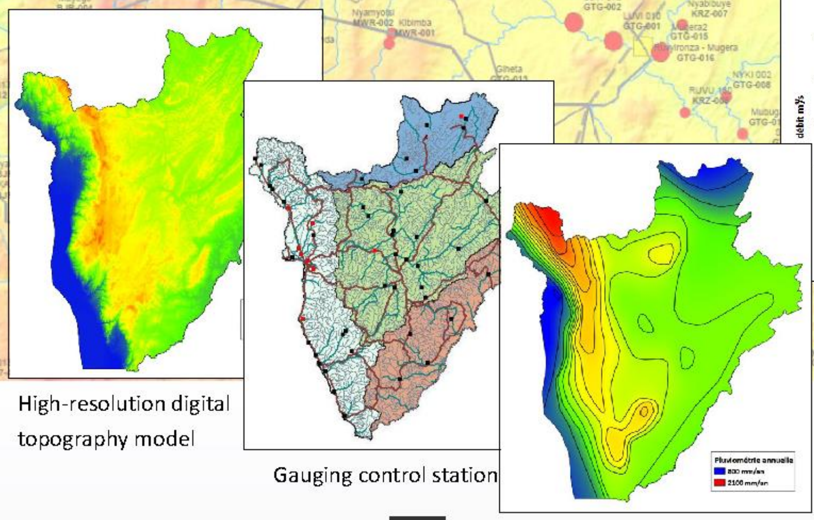
10.1 APPENDIX 1 : SITEFINDER TOOL

SiteFinder

a large-scale hydropower potential detection tool developed by SHER

SHER developed a dedicated tool called "*SiteFinder*". This software aims at detecting sites with hydropower potential in a specific area or a whole country.

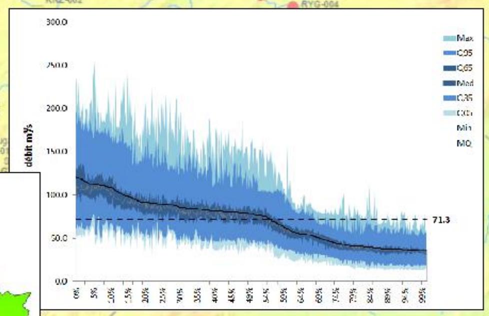
"*SiteFinder*" is fed by DEM models (Digital Elevation Model, a digital topographic model), such as SRTM* or ASTER**; by a map showing the spatial distribution of the average annual rainfall in the area or by the average rivers discharge, which are used for model calibration.



High-resolution digital topography model

Gauging control station

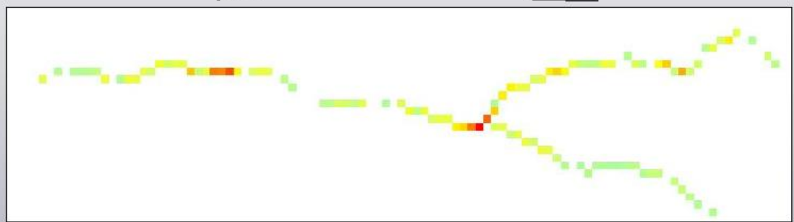
spatial distribution of average annual precipitation

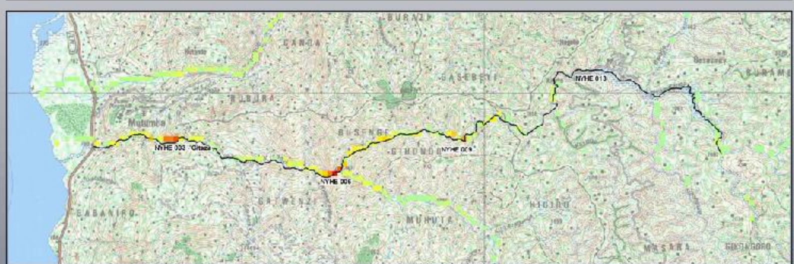


Hydrological variogram

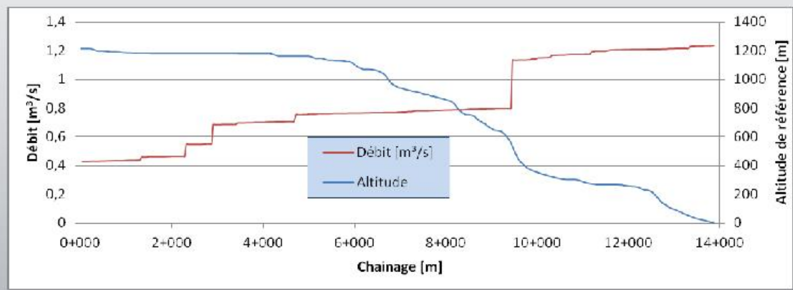
SiteFinder

The software simulates the surface runoff on the selected area (medium or large scale) and computes the total runoff volume at each point of the rivers and streams. The average river discharge is then calculated by linear regression using a set of data coming from control gauging stations. The average power per linear length is then computed on each point of the river stream taking into account the available head.

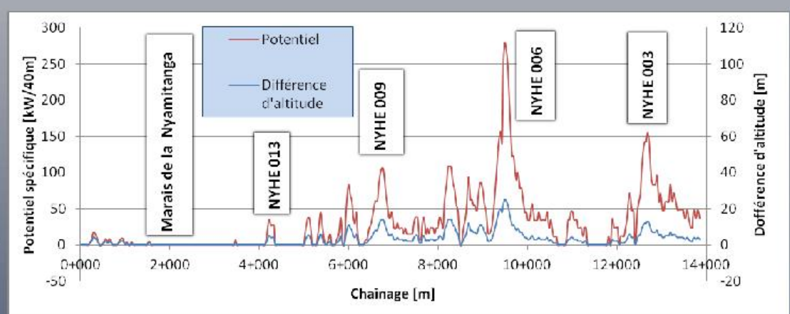




SiteFinder mapping example on the Nyamitanga River
(red points show the highest river power potential per km)



Graph showing the altitude and discharge on the river



Head and specific power alongside the stream

* SRTM : The Shuttle Radar Topography Mission is an international project spearheaded by the U.S. National Geospatial-Intelligence Agency (NGA) and the U.S. National Aeronautics and Space Administration (NASA).
** ASTER : Advanced Spaceborne Thermal Emission and Reflection Radiometer. Global Digital Elevation Model (GDEM) is a joint operation between NASA and Japan's Ministry of Economy, Trade and Industry (METI), the Global Digital Elevation Model is the most complete mapping of the earth ever made, covering 99% of its surface

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YOUR PARTNER FOR HYDROPOWER **MAPPING**

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10.3 Appendix 3 : Content of the 455 potential sites database

- 383 potential sites

Hydro-Atlas code	Site name	Region	Disctrict	Ward	Latitude [Decimal degrees]	Longitude [Decimal degrees]	River	Gross head estimated [m]	Design flow estimated [m³/s]	Installed power estimated [MW]	Source	Author of the site reference	Reference
M-001	Ninga	Njombe	Njombe	Ninga	-9.033	35.049	Lifufuma	60	1.2	0.9	Bibliography	Emmanuel Michael	Pre-Feasibility Assessment for Potential Mini-hydropower Demonstration sites under GEF4 Project in Tanzania
M-002	Utalingoro	Njombe	Njombe Urban	Utalingolo	-9.397	34.7	Ruhuji	68	0.55	0.3	Bibliography	Emmanuel Michael	Pre-Feasibility Assessment for Potential Mini-hydropower Demonstration sites under GEF4 Project in Tanzania
M-003	Chala	Rukwa	Nkasi	Chala	-7.588	31.279	Ntangayika	160	0.1	0.13	Bibliography	Emmanuel Michael	Pre-Feasibility Assessment for Potential Mini-hydropower Demonstration sites under GEF4 Project in Tanzania
M-004	Boimanda	Njombe	Njombe Urban	Luponde	-9.65	34.754	Lupali	20	2	0.325	Bibliography	Emmanuel Michael	Pre-Feasibility Assessment for Potential Mini-hydropower Demonstration sites under GEF4 Project in Tanzania
M-005	Uliwa	Njombe	Njombe Urban	Iwungilo	-9.591	34.898		50	1	0.7	Bibliography	Emmanuel Michael	Pre-Feasibility Assessment for Potential Mini-hydropower Demonstration sites under GEF4 Project in Tanzania
M-006	Ludilu	Njombe	Makete	Lupila	-9.532	34.357	Salala	82	0.15	0.098	Bibliography	Emmanuel Michael	Pre-Feasibility Assessment for Potential Mini-hydropower Demonstration sites under GEF4 Project in Tanzania
M-007	Tandala	Njombe	Makete	Ukwama	-9.447	34.274	Ijangala	20	2.5	0.407	Bibliography	Emmanuel Michael	Pre-Feasibility Assessment for Potential Mini-hydropower Demonstration sites under GEF4 Project in Tanzania
M-008	Tandala	Njombe	Makete	Tandala	-9.392	34.261	Ijangala	40	2	0.687	Bibliography	Emmanuel Michael	Pre-Feasibility Assessment for Potential Mini-hydropower Demonstration sites under GEF4 Project in Tanzania
M-009	Tulila - Chipole	Ruvuma	Songea Rural	Muhuruku	-11.096	35.279	Ruvuma	20	20	3.25	Bibliography	Emmanuel Michael	Pre-Feasibility Assessment for Potential Mini-hydropower Demonstration sites under GEF4 Project in Tanzania
M-015	Zigi	Tanga	Muheza	Amani	-5.105	38.641		84	0.35	0.167	Bibliography	CAMCO	Technical Assessment for Potential Community-based Micro-hydropower potential in Muheza, Korogwe & Lushoto Districts
M-016	Dodwe	Tanga	Muheza	Amani	-5.101	38.646		25	0.366	0.036	Bibliography	CAMCO	Technical Assessment for Potential Community-based Micro-hydropower potential in Muheza, Korogwe & Lushoto Districts
M-017	Mkusu	Tanga	Lushoto	Vuga	-4.905	38.328		56	0.11	0.042	Bibliography	CAMCO	Technical Assessment for Potential Community-based Micro-hydropower potential in Muheza, Korogwe & Lushoto Districts
M-018	Kidabwa	Tanga	Korogwe	Dindira	-4.966	38.418		101	0.23	0.149	Bibliography	CAMCO	Technical Assessment for Potential Community-based Micro-hydropower potential in Muheza, Korogwe & Lushoto Districts
M-019	Kwamdimu	Tanga	Korogwe	Vugiri	-5.105	38.427		15	0.1	0.01	Bibliography	CAMCO	Technical Assessment for Potential Community-based Micro-hydropower potential in Muheza, Korogwe & Lushoto Districts
M-020	Kwesasa	Tanga	Lushoto	Mponde	-4.924	38.406		33	0.057	0.013	Bibliography	CAMCO	Technical Assessment for Potential Community-based Micro-hydropower potential in Muheza, Korogwe & Lushoto Districts
M-021	Mkolo	Tanga	Lushoto	Mayo	-4.843	38.524		20	0.3	0.031	Bibliography	CAMCO	Technical Assessment for Potential Community-based Micro-hydropower potential in Muheza, Korogwe & Lushoto Districts
M-022	Kwabululu	Tanga	Korogwe	Mpale	-5.044	38.445		100	0.45	0.249	Bibliography	CAMCO	Technical Assessment for Potential Community-based Micro-hydropower potential in Muheza, Korogwe & Lushoto Districts
M-023	Kwenyashi	Tanga	Lushoto	Vuga	-4.925	38.388		13	0.1	0.009	Bibliography	CAMCO	Technical Assessment for Potential Community-based Micro-hydropower potential in Muheza, Korogwe & Lushoto Districts
M-025	Lupalalu	Tanga	Lushoto	Funta	-4.93	38.469		100	0.03	0.021	Bibliography	CAMCO	Technical Assessment for Potential Community-based Micro-hydropower potential in Muheza, Korogwe & Lushoto Districts
M-026	Nzovwe	Rukwa	Sumbawanga Rural	Msanda Muungano	-8.008	31.812		1060	0.9	8	Bibliography	DECON, SWECO and Inter-Consult	Feasibility Study of the Rural Electrification (Area Supply)
M-028	Lower Pininyi	Arusha	Ngorongoro	Pinyinyi	-2.291	35.916					Bibliography	DECON, SWECO and Inter-Consult	Feasibility Study of the Rural Electrification (Area Supply)
M-029	Upper Pininyi	Arusha	Ngorongoro	Pinyinyi	-2.208	35.863					Bibliography	DECON, SWECO and Inter-Consult	Feasibility Study of the Rural Electrification (Area Supply)

M-030	Nakatuta	Ruvuma	Songea Rural	Muhuruku	-11.335	35.367					Bibliography	DECON, SWECO and Inter-Consult	Feasibility Study of the Rural Electrification (Area Supply)
M-031	Sunda Falls	Ruvuma	Tunduru	Misechela	-11.369	37.824	Ruvuma	14	52	6	Bibliography	DECON, SWECO and Inter-Consult	Feasibility Study of the Rural Electrification (Area Supply)
M-032	Darakuta	Manyara	Mbulu	Nambisi	-3.967	35.62	Nambis (or Kou)	352	0.75	0.68	Bibliography	Intec - Entec - Skat	Feasibility Study of Six Mini-Hydropower Projects (MHP) in Tanzania -Inception Report
M-033	Ihalula	Njombe	Njombe Urban	Utalingolo	-9.418	34.614		25	0.5	0.3	Bibliography	Intec - Entec - Skat	Feasibility Study of Six Mini-Hydropower Projects (MHP) in Tanzania -Inception Report
M-034	Lingatunda	Ruvuma	Songea Rural	Mahanje	-9.925	35.282		183	0.8	3	Bibliography	Intec - Entec - Skat	Feasibility Study of Six Mini-Hydropower Projects (MHP) in Tanzania -Inception Report
M-035	Luswisi	Songwe	Ileje	Lubanda	-9.336	33.481		200	3	4	Bibliography	Intec - Entec - Skat	Feasibility Study of Six Mini-Hydropower Projects (MHP) in Tanzania -Inception Report
M-036	Mlangali	Njombe	Ludewa	Mlangali	-9.708	34.523	Macheke	42	1.4	0.7	Bibliography	Intec - Entec - Skat	Feasibility Study of Six Mini-Hydropower Projects (MHP) in Tanzania -Inception Report
M-037	Mwoga	Kigoma	Kasulu Township Authority	Muhunga	-4.542	30.002		200	0.4	0.3	Bibliography	Intec - Entec - Skat	Feasibility Study of Six Mini-Hydropower Projects (MHP) in Tanzania -Inception Report
M-038	Mkoyo	Kilimanjaro	Same	Myamba	-4.437	38.023	Mkoyo	255	0.34	0.63	Bibliography	TATEDO	Potential hydropower sites in the Pare Mountains
M-039	Saseni I	Kilimanjaro	Same	Mpinji	-4.407	37.97	Saseni	200	0.214	0.31	Bibliography	TATEDO	Potential hydropower sites in the Pare Mountains
M-040	Saseni II	Kilimanjaro	Same	Kirangare	-4.431	37.999	Saseni	80	0.248	0.15	Bibliography	TATEDO	Potential hydropower sites in the Pare Mountains
M-041	Saseni III	Kilimanjaro	Same	Kirangare	-4.443	38.018	Saseni	105	0.512	0.4	Bibliography	TATEDO	Potential hydropower sites in the Pare Mountains
M-044	Yongoma I	Kilimanjaro	Same	Lugulu	-4.339	38.008	Yongoma	150	0.31	0.15	Bibliography	TATEDO	Potential hydropower sites in the Pare Mountains
M-045	Yongoma II	Kilimanjaro	Same	Lugulu	-4.364	38.032	Yongoma	460	0.21	0.7	Bibliography	TATEDO	Potential hydropower sites in the Pare Mountains
M-047	Higililu I	Kilimanjaro	Same	Vuje	-4.269	38.017	Higililu	140	0.29	0.17	Bibliography	TATEDO	Potential hydropower sites in the Pare Mountains
M-048	Higililu II	Kilimanjaro	Same	Bombo	-4.277	38.025	Higililu	460	0.94	0.66	Bibliography	TATEDO	Potential hydropower sites in the Pare Mountains
M-049	Nakombo I	Kilimanjaro	Same	Mshewa	-4.18	37.921	Nakombo	310	0.07	0.15	Bibliography	TATEDO	Potential hydropower sites in the Pare Mountains
M-050	Nakombo II	Kilimanjaro	Same	Mshewa	-4.168	37.931	Nakombo	610	0.25	1.13	Bibliography	TATEDO	Potential hydropower sites in the Pare Mountains
M-053	Chome	Kilimanjaro	Same	Chome	-4.283	37.882	Chome	320	0.045	0.11	Bibliography	TATEDO	Potential hydropower sites in the Pare Mountains
M-054	Namtumbo	Ruvuma	Namtumbo	Rwinga	-10.457	36.175	Mtonya	3	1.5	0.038	Bibliography	Dar Es Salaam Institute of Technology	THE REPORT ON PRE-FEASIBILITY STUDY OF SMALL HYDROPOWER POTENTIAL SCHEMES IN RUVUMA AND IRINGA REGIONS-TANZANIA
M-055	Malindindo	Ruvuma	Mbinga	Kambarage	-11.11	34.838	Wogawoga	38	0.5	0.158	Bibliography	Dar Es Salaam Institute of Technology	THE REPORT ON PRE-FEASIBILITY STUDY OF SMALL HYDROPOWER POTENTIAL SCHEMES IN RUVUMA AND IRINGA REGIONS-TANZANIA
M-057	Macheke	Njombe	Ludewa	Mlangali	-9.706	34.524		23	1.5	0.288	Bibliography	Dar Es Salaam Institute of Technology	THE REPORT ON PRE-FEASIBILITY STUDY OF SMALL HYDROPOWER POTENTIAL SCHEMES IN RUVUMA AND IRINGA REGIONS-TANZANIA
M-058	Isigula	Njombe	Ludewa	Mlangali	-9.741	34.613		200	1.2	2	Bibliography	Dar Es Salaam Institute of Technology	THE REPORT ON PRE-FEASIBILITY STUDY OF SMALL HYDROPOWER POTENTIAL SCHEMES IN RUVUMA AND IRINGA REGIONS-TANZANIA
M-059	Mpando	Njombe	Wanging'ombe	Makoga	-9.264	34.608		13	2.5	0.271	Bibliography	Dar Es Salaam Institute of Technology	THE REPORT ON PRE-FEASIBILITY STUDY OF SMALL HYDROPOWER POTENTIAL SCHEMES IN RUVUMA AND IRINGA REGIONS-TANZANIA
M-060	Mugali	Iringa	Mufindi	Isalavanu	-8.29	35.204		20	2	0.333	Bibliography	Dar Es Salaam Institute of Technology	THE REPORT ON PRE-FEASIBILITY STUDY OF SMALL HYDROPOWER POTENTIAL SCHEMES IN RUVUMA AND IRINGA REGIONS-TANZANIA
M-061	Little Ruaha	Iringa	Iringa Rural	Itunundu	-7.364	35.482		77	2	1.28	Bibliography	Dar Es Salaam Institute of Technology	THE REPORT ON PRE-FEASIBILITY STUDY OF SMALL HYDROPOWER POTENTIAL SCHEMES IN RUVUMA AND IRINGA REGIONS-TANZANIA
M-062	Mtombozi	Morogoro	Morogoro Rural	Mtombozi	-7.104	37.748	Mbozi	57	0.8	0.456	Bibliography	Dar Es Salaam Institute of Technology	THE REPORT ON PRE-FEASIBILITY STUDY OF SMAL HYDROPOWER POTENTIAL SCHEMES IN MOROGORO, IRINGA, RUVUMA AND MBEYA REGIONS-TANZANIA
M-063	Ruaha South	Iringa	Mufindi	Kiyowela	-9.037	35.22		8	3.5	0.28	Bibliography	Dar Es Salaam Institute of Technology	THE REPORT ON PRE-FEASIBILITY STUDY OF SMAL HYDROPOWER POTENTIAL SCHEMES IN MOROGORO, IRINGA, RUVUMA AND MBEYA REGIONS-TANZANIA

M-064	Igologolo	Iringa	Mufindi	Kiyowela	-8.948	35.204		9	0.5	0.045	Bibliography	Dar Es Salaam Institute of Technology	THE REPORT ON PRE-FEASIBILITY STUDY OF SMAL HYDROPOWER POTENTIAL SCHEMES IN MOROGORO, IRINGA, RUVUMA AND MBEYA REGIONS-TANZANIA
M-065	Nyalawa	Iringa	Mufindi	Makungu	-8.702	35.229		100	1	1	Bibliography	Dar Es Salaam Institute of Technology	THE REPORT ON PRE-FEASIBILITY STUDY OF SMAL HYDROPOWER POTENTIAL SCHEMES IN MOROGORO, IRINGA, RUVUMA AND MBEYA REGIONS-TANZANIA
M-066	Ilondo	Iringa	Mufindi	Luhanga	-8.633	35.586		79	6	4.74	Bibliography	Dar Es Salaam Institute of Technology	THE REPORT ON PRE-FEASIBILITY STUDY OF SMAL HYDROPOWER POTENTIAL SCHEMES IN MOROGORO, IRINGA, RUVUMA AND MBEYA REGIONS-TANZANIA
M-067	Ruhaha North	Iringa	Mufindi	Kiyowela	-8.753	35.146		8	2.5	0.2	Bibliography	Dar Es Salaam Institute of Technology	THE REPORT ON PRE-FEASIBILITY STUDY OF SMAL HYDROPOWER POTENTIAL SCHEMES IN MOROGORO, IRINGA, RUVUMA AND MBEYA REGIONS-TANZANIA
M-068	Mhangazi	Ruvuma	Namtumbo	Kitanda	-10.118	35.859	Muhangazi	21	1.2	0.252	Bibliography	Dar Es Salaam Institute of Technology	THE REPORT ON PRE-FEASIBILITY STUDY OF SMAL HYDROPOWER POTENTIAL SCHEMES IN MOROGORO, IRINGA, RUVUMA AND MBEYA REGIONS-TANZANIA
M-071	Funta	Tanga	Lushoto	Mponde	-4.909	38.437		110	0.01	0.008	Bibliography	TATEDO	Potential hydropower sites in the Usambara Mountains
M-072	Mkolo II	Tanga	Lushoto	Mayo	-4.843	38.524		20	0.12	0.018	Bibliography	TATEDO	Potential hydropower sites in the Usambara Mountains
M-073	Sine	Tanga	Lushoto	Kwekanga	-4.689	38.326		20	0.15	0.02	Bibliography	TATEDO	Potential hydropower sites in the Usambara Mountains
M-075	Mpalato I	Tanga	Lushoto	Funta	-4.93	38.469		100	0.03	0.02	Bibliography	TATEDO	Potential hydropower sites in the Usambara Mountains
M-076	Lwengera II	Tanga	Lushoto	Mayo	-4.883	38.547		20	0.14	0.02	Bibliography	TATEDO	Potential hydropower sites in the Usambara Mountains
M-077	Lwengera III	Tanga	Lushoto	Maheza ngulu	-4.876	38.557		20	0.14	0.02	Bibliography	TATEDO	Potential hydropower sites in the Usambara Mountains
M-079	Shokoi	Tanga	Lushoto	Mgwashi	-4.767	38.463		180	0.02	0.023	Bibliography	TATEDO	Potential hydropower sites in the Usambara Mountains
M-080	Vuruni	Tanga	Lushoto	Mponde	-4.929	38.403		130	0.03	0.03	Bibliography	TATEDO	Potential hydropower sites in the Usambara Mountains
M-081	Indii I	Tanga	Lushoto	Mtae	-4.459	38.296		120	0.03	0.03	Bibliography	TATEDO	Potential hydropower sites in the Usambara Mountains
M-082	Mkumbi	Tanga	Lushoto	Nkongoi	-4.709	38.492		76	0.05	0.03	Bibliography	TATEDO	Potential hydropower sites in the Usambara Mountains
M-083	Indii I	Tanga	Lushoto	Mtae	-4.471	38.294		160	0.33	0.04	Bibliography	TATEDO	Potential hydropower sites in the Usambara Mountains
M-084	Kidabwa I	Tanga	Korogwe	Dindira	-4.968	38.415		150	0.06	0.07	Bibliography	TATEDO	Potential hydropower sites in the Usambara Mountains
M-085	Kimazi I	Tanga	Lushoto	Ngulwi	-4.824	38.303		120	0.25	0.07	Bibliography	TATEDO	Potential hydropower sites in the Usambara Mountains
M-086	Mkolo I	Tanga	Lushoto	Mayo	-4.839	38.523		80	0.13	0.074	Bibliography	TATEDO	Potential hydropower sites in the Usambara Mountains
M-087	Mkusu II	Tanga	Lushoto	Mbuzii	-4.871	38.345		80	0.13	0.075	Bibliography	TATEDO	Potential hydropower sites in the Usambara Mountains
M-089	Mglumi	Tanga	Lushoto	Makanya	-4.701	38.487		107	0.1	0.08	Bibliography	TATEDO	Potential hydropower sites in the Usambara Mountains
M-090	Mkwuma	Tanga	Lushoto	Makanya	-4.698	38.524		100	0.13	0.09	Bibliography	TATEDO	Potential hydropower sites in the Usambara Mountains
M-091	Bumbuli III	Tanga	Lushoto	Funta	-4.899	38.499		70	0.18	0.09	Bibliography	TATEDO	Potential hydropower sites in the Usambara Mountains
M-092	Umba I	Tanga	Lushoto	Dule "M"	-4.58	38.293		168	0.08	0.1	Bibliography	TATEDO	Potential hydropower sites in the Usambara Mountains
M-093	Mpalato II	Tanga	Lushoto	Tamota	-4.907	38.496		370	0.04	0.11	Bibliography	TATEDO	Potential hydropower sites in the Usambara Mountains
M-094	Lwengera I	Tanga	Lushoto	Mayo	-4.893	38.522		65	0.26	0.12	Bibliography	TATEDO	Potential hydropower sites in the Usambara Mountains
M-095	Kimazi II	Tanga	Lushoto	Ubiri	-4.856	38.322		286	0.08	0.16	Bibliography	TATEDO	Potential hydropower sites in the Usambara Mountains
M-096	Kimazi III	Tanga	Lushoto	Ubiri	-4.866	38.318		140	0.15	0.16	Bibliography	TATEDO	Potential hydropower sites in the Usambara Mountains
M-097	Kidabwa II	Tanga	Lushoto	Mponde	-4.962	38.402		440	0.06	0.19	Bibliography	TATEDO	Potential hydropower sites in the Usambara Mountains
M-098	Kosoi	Tanga	Korogwe	Mombo	-4.897	38.288		720	0.04	0.21	Bibliography	TATEDO	Potential hydropower sites in the Usambara Mountains
M-101	Mkusu I	Tanga	Lushoto	Soni	-4.812	38.394		140	0.35	0.36	Bibliography	TATEDO	Potential hydropower sites in the Usambara Mountains
M-104	Bumbuli I	Tanga	Lushoto	Bumbuli	-4.888	38.473		100	0.54	0.45	Bibliography	TATEDO	Potential hydropower sites in the Usambara Mountains
M-106	Zinui I	Tanga	Lushoto	Mbuzii	-4.887	38.321		260	0.34	0.65	Bibliography	TATEDO	Potential hydropower sites in the Usambara Mountains
M-107	Umba III	Tanga	Lushoto	Mlalo	-4.537	38.368		717	0.12	0.655	Bibliography	TATEDO	Potential hydropower sites in the Usambara Mountains
M-108	Mkolo III	Tanga	Lushoto	Mayo	-4.874	38.512		420	0.2	0.66	Bibliography	TATEDO	Potential hydropower sites in the Usambara Mountains
M-111	Kyamigege	Kagera	Bukoba Urban	Kagondo	-1.312	31.772	Kanoni Stream	10	0.084	0.009	Bibliography	Tanesco	Reconnaissance Study Mini Hydropower Potential in Kagera Region Draft Report
M-112	Gera	Kagera	Bukoba Rural	Katoma	-1.244	31.764	Kiirila river	29	0.213	0.06	Bibliography	Tanesco	Reconnaissance Study Mini Hydropower Potential in Kagera Region Draft Report
M-114	Kemondo Bay	Kagera	Bukoba Rural	Kemondo	-1.479	31.742	Kishala Stream	38	0.135	0.05	Bibliography	Tanesco	Reconnaissance Study Mini Hydropower Potential in Kagera Region Draft Report
M-115	Bulinda	Kagera	Bukoba Rural	Maruku	-1.424	31.788	Kyolelo Stream	15	0.414	0.066	Bibliography	Tanesco	Reconnaissance Study Mini Hydropower Potential in Kagera Region Draft Report

M-117	Rwamailu	Kagera	Karagwe	Ihembe	-1.748	31.133	Rusumo Stream	26	0.105	0.03	Bibliography	Tanesco	Reconnaissance Study Mini Hydropower Potential in Kagera Region Draft Report
M-120	Katanda	Kagera	Karagwe	Kihanga	-1.399	31.159	Katanda stream		0.004		Bibliography	Tanesco	Reconnaissance Study Mini Hydropower Potential in Kagera Region Draft Report
M-122	Kihumulo	Kagera	Muleba	Nshamba	-1.821	31.573	Rwanjelu river at Muguugu	20	0.219	0.059	Bibliography	Tanesco	Reconnaissance Study Mini Hydropower Potential in Kagera Region Draft Report
M-123	Kihumulo	Kagera	Muleba	Biirabo	-1.831	31.574	Igabiro stream at Muguugu	120	0.093	0.104	Bibliography	Tanesco	Reconnaissance Study Mini Hydropower Potential in Kagera Region Draft Report
M-124	Kihumulo	Kagera	Muleba	Biirabo	-1.831	31.574	Rwanjelu-Igabiro Combined	120	0.312	0.349	Bibliography	Tanesco	Reconnaissance Study Mini Hydropower Potential in Kagera Region Draft Report
M-125	Zigi	Tanga	Muheza	Amani	-5.105	38.634		160	0.432	0.9	Bibliography	ENCO	CONSULTANCY SERVICES TO CARRY OUT PRE-FEASIBILITY STUDIES FOR SMALL HYDROPOWER PROJECTS - Final Report Part One: Zigi SHPP
M-126	Nkole	Tanga	Korogwe	Dindira	-5.04	38.441		315	0.812	2	Bibliography	ENCO	CONSULTANCY SERVICES TO CARRY OUT PRE-FEASIBILITY STUDIES FOR SMALL HYDROPOWER PROJECTS - Final Report Part Two: NKOLE SHPP
M-128	Kifanya	Njombe	Njombe Urban	Kifanya	-9.546	35.048		12	0.806	0.082	Bibliography	Tanesco	Reconnaissance Study for Minihydropower Potential Sites Iringa Region Phase II October 2007
M-130	Madope	Njombe	Ludewa	Lugarawa	-9.767	34.673		360	0.154	0.473	Bibliography	Tanesco	Reconnaissance Study for Minihydropower Potential Sites Iringa Region Phase II October 2007
M-134	Idonja Falls	Njombe	Njombe	Matembwe	-9.339	35.154		35	27.905	8.065	Bibliography	Tanesco	Reconnaissance Study for Minihydropower Potential Sites Iringa Region Phase II October 2007
M-135	Fwagi	Iringa	Mufindi	Kasanga	-8.699	35.173		300	0.394	1.019	Bibliography	Tanesco	Reconnaissance Study for Minihydropower Potential Sites Iringa Region Phase II October 2007
M-136	Mhanga	Iringa	Kilolo	Kimala	-8.203	36.054		520	6.002	26.637	Bibliography	Tanesco	Reconnaissance Study for Minihydropower Potential Sites Iringa Region Phase III December 2009
M-137	Ndembela	Iringa	Mufindi	Sadani	-8.233	34.967		50	13.837	5.904	Bibliography	Tanesco	Reconnaissance Study for Minihydropower Potential Sites Iringa Region Phase III December 2009
M-140	Hagafiro	Njombe	Njombe Urban	Yakobi	-9.37	34.836		20	5.868	1.001	Bibliography	Tanesco	Reconnaissance Study for Minihydropower Potential Sites Iringa Region Phase III December 2009
M-141	Hagafiro	Njombe	Njombe Urban	Yakobi	-9.421	34.813		16	5.868	0.801	Bibliography	Tanesco	Reconnaissance Study for Minihydropower Potential Sites Iringa Region Phase III December 2009
M-142	Itidza	Njombe	Njombe Urban	Yakobi	-9.386	34.865		5	0.052	0.002	Bibliography	Tanesco	Reconnaissance Study for Minihydropower Potential Sites Iringa Region Phase III December 2009
M-143	Ruhudji	Njombe	Njombe Urban	Ihanga	-9.356	34.999		360	0.154	0.473	Bibliography	Tanesco	Reconnaissance Study for Minihydropower Potential Sites Iringa Region Phase III December 2009
M-144	Barali	Njombe	Wanging'ombe	Luduga	-9.1	34.5		25	17.453	3.724	Bibliography	Tanesco	Reconnaissance Study for Minihydropower Potential Sites Iringa Region Phase III December 2009
M-145	Kimani Falls	Mbeya	Mbarali	Mapogoro	-8.929	34.214		82	55.043	38.522	Bibliography	Tanesco	Reconnaissance Study for Minihydropower Potential Sites Iringa Region Phase III December 2009
M-146	Great Ruaha	Njombe	Makete	Mfumbi	-8.884	34.096		8	106.187	7.25	Bibliography	Tanesco	Reconnaissance Study for Minihydropower Potential Sites Iringa Region Phase III December 2009
M-147	Mbaral	Mbeya	Mbarali	Lugelele	-8.819	34.391		5	18.465	0.788	Bibliography	Tanesco	Reconnaissance Study for Minihydropower Potential Sites Iringa Region Phase III December 2009
M-149	Yongoma	Kilimanjaro	Same	Lugulu	-4.352	38.034		80	0.14	0.075	Bibliography	Tanesco (Project Description)	NO NAME
M-150	Suma	Mbeya	Rungwe	Suma	-9.259	33.707			0	1.54	Bibliography	IED	RURAL ELECTRIFICATION PLAN SUMA SHP, TANZANIA
M-151	Idunda	Songwe	Ileje	Bupigu	-9.488	33.253	Songwe	75	1.5	0.6	Bibliography	Tanesco	Reconnaissance Study for Mini hydropower Potential Sites in Mbeya Region
M-152	Salala	Mbeya	Mbeya Rural	Isuto	-9.069	33.236	Songwe	230	0.02	0.025	Bibliography	Tanesco	Reconnaissance Study for Mini hydropower Potential Sites in Mbeya Region
M-153	Katela	Mbeya	Rungwe	Kiwira	-9.105	33.571	Kiwira	20	4	0.55	Bibliography	Tanesco	Reconnaissance Study for Mini hydropower Potential Sites in Mbeya Region
M-154	Katela	Mbeya	Rungwe	Kiwira	-9.111	33.561	Kiwira	20	4	0.55	Bibliography	Tanesco	Reconnaissance Study for Mini hydropower Potential Sites in Mbeya Region
M-155	Kibumbe	Mbeya	Rungwe	Kiwira	-9.139	33.538	Kiwira	30	5	1	Bibliography	Tanesco	Reconnaissance Study for Mini hydropower Potential Sites in Mbeya Region
M-156	Kiwira	Mbeya	Rungwe	Nkunga	-9.175	33.533	Kiwira	10	8	0.55	Bibliography	Tanesco	Reconnaissance Study for Mini hydropower Potential Sites in Mbeya Region
M-157	Ibililo	Mbeya	Rungwe	Nkunga	-9.202	33.534	Kiwira	20	10	1.35	Bibliography	Tanesco	Reconnaissance Study for Mini hydropower Potential Sites in Mbeya Region

M-159	Natural Bridge	Mbeya	Rungwe	Nkunga	-9.277	33.547	Kiwira	40	12	2	Bibliography	Tanesco	Reconnaissance Study for Mini hydropower Potential Sites in Mbeya Region
M-160	Igogwe	Mbeya	Rungwe	Kinyala	-9.153	33.52	Kiwira	13	1.2	0.13	Bibliography	Tanesco	Reconnaissance Study for Mini hydropower Potential Sites in Mbeya Region
M-161	Kaporogwe Falls	Mbeya	Rungwe	Kisondela	-9.393	33.613	Kiwira	65	0.26	0.09	Bibliography	Tanesco	Reconnaissance Study for Mini hydropower Potential Sites in Mbeya Region
M-162	Mosiya Falls	Mbeya	Rungwe	Kisondela	-9.359	33.594	Kiwira	100	0.9	0.6	Bibliography	Tanesco	Reconnaissance Study for Mini hydropower Potential Sites in Mbeya Region
M-164	Mbosi	Mbeya	Rungwe	Malindo	-9.34	33.609	Kiwira	120	0.25	0.2	Bibliography	Tanesco	Reconnaissance Study for Mini hydropower Potential Sites in Mbeya Region
M-165	Isuba	Songwe	Rungwe	Ikuti	-9.371	33.588	Kiwira	40	0.4	0.1	Bibliography	Tanesco	Reconnaissance Study for Mini hydropower Potential Sites in Mbeya Region
M-167	Lusalala	Songwe	Ileje	Sange	-9.397	33.521	Kiwira	250	3	5	Bibliography	Tanesco	Reconnaissance Study for Mini hydropower Potential Sites in Mbeya Region
M-174	Kantete Falls	Rukwa	Sumbawanga Rural	Mfinga	-7.59	31.475		145	0.03	0.037	Bibliography	Tanesco	Reconnaissance Study for Mini hydropower Potential Sites Rukwa Region
M-175	Mumba	Rukwa	Sumbawanga Rural	Ilemba	-8.213	31.958		122	0.06	0.063	Bibliography	Tanesco	Reconnaissance Study for Mini hydropower Potential Sites Rukwa Region
M-177	Malagarasi	Kigoma	Uvinza	Ilagala	-5.191	30.083	Malagarasi	25	40	8	Bibliography	SECSD (P) Ltd.	KIGOMA REGION PRE-INVESTMENT REPORT ON MINI HYDROPOWER DEVELOPMENT CASE STUDY ON THE MALAGARASI RIVER
M-177-B	Lower Malagarasi	Kigoma	Uvinza	Ilagala	-5.202	29.909	Malagarasi				Bibliography	SECSD (P) Ltd.	KIGOMA REGION PRE-INVESTMENT REPORT ON MINI HYDROPOWER DEVELOPMENT CASE STUDY ON THE MALAGARASI RIVER
M-177-C	Uvinza	Kigoma	Uvinza	Uvinza	-5.184	30.558	Malagarasi				Bibliography	SECSD (P) Ltd.	KIGOMA REGION PRE-INVESTMENT REPORT ON MINI HYDROPOWER DEVELOPMENT CASE STUDY ON THE MALAGARASI RIVER
M-178	Muhuwesi	Ruvuma	Tunduru	Muhuwesi	-10.861	37.474	Muhuwesi	17	13.5	2	Bibliography	SECSD (P) Ltd.	RUVUMA REGION PRE-INVESTMENT REPORT ON MINI HYDROPOWER DEVELOPMENT CASE STUDY ON THE MUHUWESI RIVER
M-179	Kikuletwa	Manyara	Simanjiro	Naisinyai	-3.484	37.225	Kikuletwa	64	20	11	Bibliography	SECSD (P) Ltd.	KILIMANJARO REGION PRE-INVESTMENT REPORT ON MINI HYDROPOWER DEVELOPMENT CASE STUDY ON THE KIKULETWA RIVER
M-182	Kiwira	Mbeya	Rungwe	Nkunga	-9.234	33.521	Kiwira	40	24	6.4	Bibliography	Eng. Dr. Henry K. Ntale Vala Associates Limited	RECONNAISSANCE MISSION: DEVELOPMENT OF THE PANGANI AND KIWIRA HYDROPOWER SCHEMES
M-186	Mvuha	Morogoro	Morogoro Rural	Mtombozi	-7.133	37.75	River Mvuha	120	0.76	0.68	Bibliography	IED	IREP
M-187	Lumba	Morogoro	Morogoro Rural	Singisa	-7.225	37.633	River Lumba	400	0.57	1.71	Bibliography	IED	IREP
M-188	Mngazi	Morogoro	Morogoro Rural	Singisa	-7.261	37.666	River Mngazi	150	2.07	2.3	Bibliography	IED	IREP
M-189	Lugonga	Morogoro	Morogoro Rural	Singisa	-7.217	37.6	River Lugonga	280	0.55	1.125	Bibliography	IED	IREP
M-190	Mbakana	Morogoro	Mvomero	Kikeo	-7.175	37.55	River Mbakana	60	1.7	0.755	Bibliography	IED	IREP
M-191	Mbakana	Morogoro	Mvomero	Kikeo	-7.258	37.567	River Mbakana and river Lugonga	60	3.6	1.62	Bibliography	IED	IREP
M-192	Mbezi	Morogoro	Morogoro Rural	Tegetero	-6.924	37.733	River Mbezi or Ruvu	100	1.19	0.875	Bibliography	IED	IREP
M-193	Ruvu	Morogoro	Morogoro Rural	Kinole	-6.929	37.784	River Ruvu	100	3.33	2.6	Bibliography	IED	IREP
M-194	Mkindo	Morogoro	Mvomero	Hembeti	-6.219	37.52	River Mkindo	180	2.34	3.26	Bibliography	IED	IREP
M-195	Chombohi	Morogoro	Kilosa	Ulaya	-7.099	36.738	River Chombohi	200	0.59	0.89	Bibliography	IED	IREP
M-197	Kikalo	Morogoro	Kilosa	Uleling'ombe	-7.209	36.554	River Kikalo	260	0.69	1.35	Bibliography	IED	IREP
M-199	Mwega	Morogoro	Kilosa	Malolo	-7.283	36.681	River Mwega	335	1.88	4.85	Bibliography	IED	IREP
M-200	Mgonya	Morogoro	Kilombero	Mchombe	-8.417	35.983	River Mgonya	310	0.88	2.08	Bibliography	IED	IREP
M-202	Mfumbu	Iringa	Kilolo	Kimala	-8.089	36.251	River Mfumbu	140	2.23	2.365	Bibliography	IED	IREP
M-203	Sonjo	Morogoro	Kilombero	Sanje	-7.808	36.905	Rivers Sonjo and Mkula	220	0.69	1.155	Bibliography	IED	IREP
M-205	Kimbi	Iringa	Kilolo	Kimala	-8.276	36.036	River Kimbi	485	1.86	7.691	Bibliography	IED	IREP
M-206	Mlimba	Morogoro	Kilombero	Mlimba	-8.793	35.763	River Mlimba	130	0.07	0.074	Bibliography	IED	IREP

M-207	Yovi	Morogoro	Kilosa	Kisanga	-7.183	36.709	River Yovi	361	0.36	0.995	Bibliography	IED	IREP
M-208	Yovi	Morogoro	Kilosa	Kisanga	-7.183	36.709	River Yovi	361	0.52	1.45	Bibliography	IED	IREP
M-209	Mloo	Dodoma	Mpwapwa	Galigali	-7.096	36.537	River Mloo	30	0.75	0.16	Bibliography	IED	IREP
M-210	Mloo	Dodoma	Mpwapwa	Galigali	-7.096	36.537	River Mloo and Sasima	30	1.15	0.245	Bibliography	IED	IREP
M-214	Mgeta	Morogoro	Mvomero	Bunduki	-7.05	37.644	River Mgeta	270	0.7	1.36	Bibliography	IED	IREP
M-214B	Lumbamwa	Morogoro	Morogoro Rural	Kibungo Juu	-7.024	37.717	LUMBAMWA	35	1.2	0.23	Bibliography	IED	IREP
M-214-C	Dimamba	Morogoro	Mvomero	Hembeti	-6.242	37.505	Dimamba	110	0.5	0.4	Bibliography	IED	IREP
M-215	Diwale	Morogoro	Mvomero	Mhonda	-6.077	37.561	River Diwale	45	3.15	0.88	Bibliography	IED	IREP
M-216	Diwale	Morogoro	Mvomero	Mhonda	-6.077	37.561	River Diwale	45	3.15	0.95	Bibliography	IED	IREP
M-217	Diwale	Morogoro	Mvomero	Mhonda	-6.066	37.556	River Diwale	130	3.15	2.92	Bibliography	IED	IREP
M-218	Diwale	Morogoro	Mvomero	Mhonda	-6.066	37.556	River Diwale	130	3.15	3.18	Bibliography	IED	IREP
M-219	Divue	Morogoro	Mvomero	Sungaji	-6.17	37.576	River Divue	80	1.6	0.955	Bibliography	IED	IREP
M-220	Lubata	Morogoro	Mvomero	Maskati	-6.103	37.425	River Lubata	260	0.27	0.485	Bibliography	IED	IREP
M-223	Nhgunguma	Dodoma	Mpwapwa	Mima	-6.659	36.152	Nhgunguma la river				Bibliography	IED	IREP
M-224	Chilemelem	Dodoma	Mpwapwa	Chitemo	-6.628	36.148	Chilemelem bwi				Bibliography	IED	IREP
M-225	Nyekwa	Dodoma	Mpwapwa	Massa	-6.885	36.435	Nyekwa				Bibliography	IED	IREP
M-226	Mkundi	Dodoma	Mpwapwa	Wotta	-6.833	36.318	Mkundi				Bibliography	IED	IREP
M-227	Chiwa	Iringa	Kilolo	Ukwega	-8.022	36.273	Chiwa-chiwa	100		0.379	Bibliography	IED	IREP
M-229	Mwatasi	Iringa	Kilolo	Mahenge	-7.682	36.199	Mwatasi				Bibliography	IED	IREP
M-231	Lukosi	Iringa	Kilolo	Mahenge	-7.634	36.285	Lukosi				Bibliography	IED	IREP
M-233	Mkwuma	Tanga	Lushoto	Makanya	-4.697	38.523	Mkwuma	100	0.29	0.22	Bibliography	IED	IREP
M-234	Mdando	Tanga	Lushoto	Makanya	-4.64	38.473	Mdando	550	0.23		Bibliography	IED	IREP
M-235	Lwengera	Tanga	Lushoto	Funta	-4.897	38.499	Lwengera	60	0.63	0.26	Bibliography	IED	IREP
M-236	Sigi	Tanga	Tanga	Kiomoni	-5.048	38.997	Sigi	25	4.53		Bibliography	IED	IREP
M-237	Sigi	Tanga	Tanga	Kiomoni	-5.029	38.92	Sigi	20	4.53	0.6	Bibliography	IED	IREP
M-238	Mkongore	Tanga	Handeni	Mgambo	-5.472	38.653	Mkongore	60	0.21	0.32	Bibliography	IED	IREP
M-240	Kimazi	Tanga	Lushoto	Ubiri	-4.849	38.322	Kimazi	230	0.02	0.032	Bibliography	IED	IREP
M-241	Zimui	Tanga	Lushoto	Vuga	-4.877	38.302	Zimui	40	0.97	0.27	Bibliography	IED	IREP
M-242	Lwengera	Tanga	Lushoto	Funta	-4.879	38.484	Lwengera	70	0.7	0.35	Bibliography	IED	IREP
M-243	Mkuzi	Tanga	Lushoto	Vuga	-4.885	38.333	Mkuzi	250	0.02	0.035	Bibliography	IED	IREP
M-244	Mkuzu	Tanga	Lushoto	Soni	-4.847	38.367	Mkuzu or Soni	40	0.69	0.19	Bibliography	IED	IREP
M-246	Mkolo	Tanga	Lushoto	Mayo	-4.84	38.523	Mkolo	20	0.3	0.025	Bibliography	IED	IREP
M-247	Kosoi	Tanga	Lushoto	Vuga	-4.902	38.327	Kosoi (tributary of Mkusu)	56	0.11	0.035	Bibliography	IED	IREP
M-248	Kidabwa	Tanga	Korogwe	Dindira	-4.963	38.417	Kidabwa	101	0.23	0.12	Bibliography	IED	IREP
M-249	Kwenyashi	Tanga	Lushoto	Mponde	-4.922	38.387	Kwenyashi (or Ndeme)	13	0.1	0.007	Bibliography	IED	IREP
M-250	Lwengera	Tanga	Lushoto	Mayo	-4.881	38.55	Lwengera	20	0.22	0.02	Bibliography	IED	IREP
M-251	Kwesasa	Tanga	Lushoto	Mponde	-4.921	38.405	Kwesasa	33	0.057	0.011	Bibliography	IED	IREP
M-252	Dodwe	Tanga	Muheza	Amani	-5.098	38.645	Dodwe	25	0.366	0.03	Bibliography	IED	IREP
M-253	Sigi	Tanga	Muheza	Amani	-5.105	38.64	Sigi	84	0.35	0.135	Bibliography	IED	IREP
M-254	Kwandimu	Tanga	Korogwe	Vugiri	-5.103	38.427	Kwandimu	15	0.1	0.01	Bibliography	IED	IREP
M-255	Kwabululu	Tanga	Korogwe	Mpale	-5.042	38.444	Kwabululu	100	0.45	0.2	Bibliography	IED	IREP
M-256	Lupalalu	Tanga	Lushoto	Funta	-4.927	38.468	Lupalalu (tributary of Mpalato)	100	0.03	0.017	Bibliography	IED	IREP
M-260	Lupilo	Ruvuma	Songea Rural	Magagura	-10.862	35.201	Ruvuma	14	16.9	1.5	Bibliography	REA	List for Feasibility
M-262	Nakatuta	Ruvuma	Nyasa	Liparamba	-11.311	35.35	Ruvuma	68	50.3	15	Bibliography	REA	List for Feasibility

M-266	Lumeme	Ruvuma	Mbinga	Mpapa	-11.147	34.953		301	1.31	4.2	Bibliography	REA	List for Feasibility
M-276	Luganga	Iringa	Iringa Rural	Mlowa	-7.57	35.507	Little Ruaha	70	1.65	1.2	Bibliography	REA	List for Feasibility
M-279	Balali	Njombe	Wanging'ombe	Luduga	-9.04	34.485	BALALI RIVER	25	17.453	3.7	Bibliography	IED	IREP - GIS - base list (SHP Total.shp)
M-281	Filongo	Katavi	Mlele	Litapunga	-6.358	31.416		150		0.04	Bibliography	IED	IREP - GIS - base list (SHP Total.shp)
M-285	Ilundo	Mbeya	Rungwe	Kiwira	-9.163	33.559	Ilundo hydropower project (Rungwe)	30		0.2	Bibliography	IED	IREP - GIS - base list (SHP Total.shp)
M-286	Isigula	Njombe	Ludewa	Makonde	-9.856	34.413	ISIGULA	180		2	Bibliography	IED	IREP - GIS - base list (SHP Total.shp)
M-287	Itidza	Njombe	Njombe Urban	Yakobi	-9.354	34.864	HAGAFIRO RIVER	5	0.052	2.2	Bibliography	IED	IREP - GIS - base list (SHP Total.shp)
M-289	Kikuletwa	Arusha	Meru	Mbuguni	-3.538	36.917		40		8	Bibliography	IED	IREP - GIS - base list (SHP Total.shp)
M-291	Kinko	Tanga	Lushoto	Malindi	-4.657	38.328	Kinko mini hydroplant (Korogwe)	18		0.01	Bibliography	IED	IREP - GIS - base list (SHP Total.shp)
M-292	Kipengere	Njombe	Wanging'ombe	Kipengere	-9.291	34.439				0.006	Bibliography	IED	IREP - GIS - base list (SHP Total.shp)
M-293	Kisinga	Iringa	Kilolo	Irole	-7.833	36			0	0.006	Bibliography	IED	IREP - GIS - base list (SHP Total.shp)
M-303	Lusala	Njombe	Ludewa	Lupanga	-9.69	34.5	MNYERELI RIVER	15	1.225	0.156	Bibliography	IED	IREP - GIS - base list (SHP Total.shp)
M-305	Lwega	Katavi	Mpanda	Mwese	-6.273	30.398	Lwega Small Hydropower Project (Mpanda)	120		2	Bibliography	IED	IREP - GIS - base list (SHP Total.shp)
M-307	Mamba	Katavi	Mlele	Mamba	-7.32	31.366	Mamba hydropower Project (Rukwa)	120		0.155	Bibliography	IED	IREP - GIS - base list (SHP Total.shp)
M-309	Matitima	Ruvuma	Tunduru	Mchoteka	-11.51	36.853	LITUNGURU RIVER	20	0.787	0.247	Bibliography	IED	IREP - GIS - base list (SHP Total.shp)
M-310	Mbangamao	Ruvuma	Mbinga	Mbangamao	-11.016	35.07	MTANDASI	34	2.212	1	Bibliography	IED	IREP - GIS - base list (SHP Total.shp)
M-312	Mgombezi	Ruvuma	Namtumbo	Mgombasi	-10.221	36.058				0.2	Bibliography	IED	IREP - GIS - base list (SHP Total.shp)
M-313	Mhangasi	Njombe	Ludewa	Ludewa	-10.099	34.712	MHANGAZI RIVER	80	0.247	0.168	Bibliography	IED	IREP - GIS - base list (SHP Total.shp)
M-317	Mpete	Rukwa	Sumbawanga Rural	Mfinga	-7.543	31.479	Mpete hydropower Project (Rukwa)	200		0.055	Bibliography	IED	IREP - GIS - base list (SHP Total.shp)
M-320	Mtigalala	Iringa	Kilolo	Udekwa	-7.718	36.193	LUKOSI RIVER	70	9.04	5.401	Bibliography	IED	IREP - GIS - base list (SHP Total.shp)
M-322	Muze	Rukwa	Sumbawanga Rural	Muze	-7.683	31.55	MUZE	80		0.075	Bibliography	IED	IREP - GIS - base list (SHP Total.shp)
M-323	Mwoga	Kigoma	Uvinza	Mganza	-5.057	30.817	KASULU	120		0.3	Bibliography	IED	IREP - GIS - base list (SHP Total.shp)
M-324	Nainyomu	Njombe	Ludewa	Mundindi	-10.015	35.07	MHANGAZI RIVER	60	0.127	0.12	Bibliography	IED	IREP - GIS - base list (SHP Total.shp)
M-326	Ngengedu I	Njombe	Njombe Urban	Ramadhani	-9.322	34.767	HAGAFIRO RIVER	40	1.817	0.62	Bibliography	IED	IREP - GIS - base list (SHP Total.shp)
M-329	Rwanda	Kagera	Biharamulo	Kalenge	-3.328	31.168	MATO STREAM	18	0.048	0.037	Bibliography	IED	IREP - GIS - base list (SHP Total.shp)
M-334	Lugenge	Njombe	Njombe Urban	Lugenge	-9.499	34.563	NgÃ¢â‚¬â„¢hongwa	17	0.06	0.009	Bibliography	IED	IREP - GIS - base list (SHP Total.shp)
M-335	Ikondo	Njombe	Njombe	Ikondo	-9.101	35.268			0		Bibliography	IED	IREP - GIS - base list (SHP Total.shp)

M-342	Songwe	Njombe	Makete	Kitulo	-8.917	33.833	SONGWE RIVER	230	0.02	0.03	Bibliography	IED	IREP - GIS - base list (SHP Total.shp)
M-345	Kiwira	Mbeya	Kyela	Makwale	-9.449	33.927	KIWIRA RIVER	40	0.4	0.1	Bibliography	IED	IREP - GIS - base list (SHP Total.shp)
M-348	Mwena	Mtwara	Masasi	Mwena	-10.511	39.03					Bibliography	IED	IREP - GIS - base list (SHP Total.shp)
M-350	Kawa	Rukwa	Kalambo	Kisumba	-8.499	31.196	KAWA	40	210	0.075	Bibliography	IED	IREP - GIS - base list (SHP Total.shp)
M-352	Msinjewe	Ruvuma	Tunduru	Misechela	-11.283	37.617	MSINJEWE RIVER	4	1.618	0.051	Bibliography	IED	IREP - GIS - base list (SHP Total.shp)
M-353	Mhangazi	Njombe	Ludewa	Mundindi	-10.016	35.07	MHANGAZI RIVER	60	0.254	0.12	Bibliography	IED	IREP - GIS - base list (SHP Total.shp)
M-356	Yungu	Ruvuma	Namtumbo	Ligera	-10.941	36	YUNGU RIVER	20	0.5	0.09	Bibliography	IED	IREP - GIS - base list (SHP Total.shp)
M-358	Zigi	Tanga	Lushoto	Mng'aro	-4.559	38.64	zigi			0.135	Bibliography	IED	IREP - GIS - base list (SHP Total.shp)
M-359	Kidabwa	Tanga	Lushoto	Mnazi	-4.38	38.29	kidabwa			0.12	Bibliography	IED	IREP - GIS - base list (SHP Total.shp)
M-360	Lwengara	Tanga	Lushoto	Mlola	-4.632	38.426	Lwengara			0.02	Bibliography	IED	IREP - GIS - base list (SHP Total.shp)
M-362	Tamota	Tanga	Lushoto	Tamota	-4.941	38.467				0.6	Bibliography	IED	IREP - GIS - base list (SHP Total.shp)
M-364	Itete	Morogoro	Ulanga	Kilosa kwa Mpepo	-9.216	36.123	River Itete				Bibliography	IED	IREP - GIS - own list (SHP Total.shp)
M-365	Mnegeta	Iringa	Kilolo	Kimala	-8.155	36.115	River Mnegeta				Bibliography	IED	IREP - GIS - own list (SHP Total.shp)
M-367	Luwegu	Ruvuma	Namtumbo	Likuyuseka	-9.751	36.348	River Luwegu				Bibliography	IED	IREP - GIS - own list (SHP Total.shp)
M-368	Mgeta	Morogoro	Mvomero	Bunduki	-7.033	37.633	River Mgeta	270	0.75	1.36	Bibliography	IED	IREP - GIS - own list (SHP Total.shp)
M-370	Luwegu	Morogoro	Ulanga	Kilosa kwa Mpepo	-9.741	36.302	River Luwegu				Bibliography	IED	IREP - GIS - own list (SHP Total.shp)
M-372	Kisima	Morogoro	Ulanga	Kilosa kwa Mpepo	-9.227	36.022	River Kisima				Bibliography	IED	IREP - GIS - own list (SHP Total.shp)
M-374	Matisi	Morogoro	Ulanga	Kilosa kwa Mpepo	-9.226	36.075	River Matisi				Bibliography	IED	IREP - GIS - own list (SHP Total.shp)
M-375	Mtambo	Katavi	Mlele	Ugala	-5.976	31.174	Mtambo Sanda	17	13.5	2.4	Bibliography	Norplan	Norwegian support to implementation of small hydropower projects in tanzania assessment and prioritization study
MH-01	Kakono	Kagera	Kyerwa	Murongo	-1.006	30.731	Songwe			58	Bibliography	Sweco	Tanzania Hydropower Sustainability Assessment
MH-02	Masigira	Njombe	Ludewa	Mavanga	-9.865	35.173	Ruhuhu			118	Bibliography	SwedPower - Norconsult	Ruhudji hydropower project
MH-03	Kihanzi II	Morogoro	Kilombero	Chita	-8.585	35.852				120	Bibliography	Sweco	Tanzania Hydropower Sustainability Assessment
MH-04	Mpanga	Morogoro	Kilombero	Masagati	-8.854	35.645	Mpanga			144	Bibliography	SwedPower - Norconsult	Ruhudji hydropower project
MH-05	Taveta	Morogoro	Kilombero	Uchindile	-8.966	35.503	Mnyera			145	Bibliography	Sweco	Tanzania Hydropower Sustainability Assessment
MH-06	Songwe Manolo	Songwe	Ileje	Kafule	-9.608	33.538	Songwe			149	Bibliography	Sweco	Tanzania Hydropower Sustainability Assessment
MH-07	Songwe Sofre	Songwe	Ileje	Ikinga	-9.607	33.659	Songwe			157	Bibliography	Sweco	Tanzania Hydropower Sustainability Assessment
MH-08	Ruhudji	Njombe	Njombe	Idamba	-9.499	35.306	Ruhudji	750		358	Bibliography	Swedpower - Norconsult	Ruhudji hydropower project
MH-08-B	Zanziberi Reservoir	Njombe	Njombe Urban	Ihanga	-9.448	35.275	Ruhudji	750			Bibliography	SwedPower - Norconsult	Ruhudji hydropower project
MH-09	Rumakali	Mbeya	Rungwe	Kisegese	-9.318	33.969				520	Bibliography	SwedPower - Norconsult	Ruhudji hydropower project
MH-10	Stiegler Gorge	Pwani	Rufiji	Mwaseni	-7.795	37.864	Rufiji			1200	Bibliography	Sweco	Tanzania Hydropower Sustainability Assessment
MH-11	Rusumo Falls	Kagera	Ngara	Rusumo	-2.383	30.783	Kagera			90	Bibliography	SNC Lavalin	Regional Rusumo Falls Hydroelectric and Multipurpose Project
SF-004	Chunya	Mbeya	Chunya	Matundasi	-8.557	33.285		120			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-005	Mbeya Rural	Mbeya	Mbeya Rural	Lwanjiro	-8.681	33.349		100			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-006	Mbeya Rural	Mbeya	Mbeya Rural	Mshewe	-8.864	33.248		60			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-007	Mbeya Rural	Songwe	Mbeya Rural	Bonde la Songwe	-8.905	33.22		40			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-008	Mbozi	Songwe	Mbozi	Isansa	-8.77	33.061		160			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania

SF-014	Chunya	Songwe	Chunya	Mbangala	-8.31	32.976		10			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-015	Mbozi	Songwe	Mbozi	Msia	-9.006	32.664		60			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-025	Ileje	Songwe	Ileje	Ikinga	-9.604	33.659		120			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-026	Ileje	Mbeya	Ileje	Kafule	-9.608	33.538		140			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-027	Makete	Njombe	Ludewa	Lumbila	-9.563	34.169		80			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-028	Ludewa	Njombe	Makete	Lupila	-9.684	34.37		400			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-030	Songea Rural	Ruvuma	Songea Rural	Mahanje	-9.959	35.199		220			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-033	Namtumbo	Ruvuma	Namtumbo	Magazini	-11.721	36.614		20			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-044	Simanjiro	Manyara	Simanjiro	Liborsoit	-4.095	37.438		170			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-045	Simanjiro	Kilimanjaro	Same	Mabilioni	-4.595	37.81		30			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-055	Ngorongoro	Arusha	Ngorongoro	Malambo	-2.799	35.601		100			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-057	Monduli	Arusha	Longido	Gelai Meirugoi	-2.755	35.982		200			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-058	Monduli	Arusha	Longido	Gelai lumbwa	-2.377	36.15		60			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-060	Monduli	Arusha	Monduli	Selela	-3.21	36.023		70			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-065	Hanang	Manyara	Hanang	Balagidalalu	-4.578	35.325		50			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-066	Singida Rural	Singida	Singida Rural	Mgori	-4.801	35.011		50			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-076	Iringa Rural	Iringa	Iringa Rural	Malenga Makali	-7.14	36.115		90			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-077	Iringa Rural	Iringa	Iringa Rural	Malenga Makali	-7.212	36.167		70			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-079	Iringa Rural	Iringa	Iringa Rural	Kihorogota	-7.49	35.905		100			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-099	Njombe	Njombe	Njombe	Mfriga	-9.523	35.444		120			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-100	Ulanga	Morogoro	Ulanga	Kilosa kwa Mpepo	-9.577	35.866		60			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-101	Kilombero	Morogoro	Kilombero	Masagati	-9.135	35.765		60			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-106	Mufindi	Iringa	Mufindi	Mpanga	-8.626	35.689		220			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-110	Iringa Rural	Iringa	Kilolo	Irole	-7.868	35.819		20			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-112	Iringa Rural	Iringa	Iringa Rural	Kiwere	-7.635	35.555		100			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-113	Iringa Rural	Iringa	Iringa Rural	Mlowa	-7.565	35.5		200			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-116	Njombe	Njombe	Wanging'ombe	Kidugala	-9.096	34.501		80			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-117	Njombe	Njombe	Wanging'ombe	Luduga	-8.999	34.454		20			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-118	Njombe	Njombe	Wanging'ombe	Luduga	-8.878	34.414		40			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-119	Njombe	Njombe	Wanging'ombe	Luduga	-8.833	34.538		40			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-128	Kiteto	Manyara	Kiteto	Makame	-4.715	36.694		120			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-129	Kiteto	Manyara	Kiteto	Partimbo	-5.291	36.776		100			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-130	Simanjiro	Manyara	Simanjiro	Kitwai	-4.652	36.982		20			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-131	Simanjiro	Manyara	Simanjiro	Kitwai	-4.905	37.261		30			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-132	Simanjiro	Manyara	Simanjiro	Kitwai	-4.9	37.545		30			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-133	Simanjiro	Manyara	Simanjiro	Ruvu Remiti	-4.987	37.758		110			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-134	Kongwa	Dodoma	Kongwa	Sagara	-6.192	36.515		80			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-135	Mpwapwa	Dodoma	Mpwapwa	Kimagai	-6.491	36.502		20			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-136	Kilosa	Morogoro	Kilosa	Kidete	-6.655	36.732		30			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-137	Kilosa	Morogoro	Mvomero	Mvomero	-6.306	37.348		90			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-139	Kilindi	Tanga	Kilindi	Negero	-5.844	37.803		40			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-142	Bagamoyo	Pwani	Bagamoyo	Msata	-6.256	38.182		70			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-144	Handeni	Tanga	Handeni	Mkata	-5.759	38.605		30			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania

SF-147	Morogoro Rural	Morogoro	Morogoro Rural	Gwata	-6.733	38.074		20			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-150	Singida Urban	Singida	Singida Urban	Mtamaa	-4.904	34.59		80			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-151	Iramba	Singida	Iramba	Ndago	-4.738	34.269		60			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-152	Iramba	Singida	Mkalama	Iguguno	-4.521	34.669		20			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-154	Iramba	Singida	Mkalama	Gumanga	-4.256	34.533		12			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-155	Nzega	Tabora	Nzega	Miguwa	-4.209	33.354		20			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-156	Karatu	Arusha	Karatu	Baray	-3.855	34.967		100			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-174	Kigoma Rural	Kigoma	Uvinza	Kazuramimba	-5.217	30.225		20			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-179	Mpanda	Katavi	Mpanda	Mishamo	-5.739	30.365		60			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-188	Kongwa	Dodoma	Kongwa	Kongwa	-6.186	36.365		170			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-191	Rungwe	Songwe	Rungwe	Kisondela	-9.425	33.616		80			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-192	Rungwe	Mbeya	Rungwe	Malindo	-9.344	33.574		40			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-194	Makete	Njombe	Makete	Luwumbu	-9.436	34.166		120			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-195	Makete	Njombe	Makete	Ipepo	-9.518	34.222		400			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-197	Ludewa	Njombe	Ludewa	Ludewa	-10.167	34.771		40			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-198	Ludewa	Njombe	Ludewa	Mundindi	-9.825	34.926		40			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-199	Njombe	Njombe	Njombe Urban	Makowo	-9.577	34.417		140			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-204	Makete	Njombe	Makete	Mlondwe	-8.904	34.011		400			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-205	Makete	Njombe	Makete	Mfumbi	-9.002	34.203		140			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-209	Chunya	Songwe	Chunya	Mbangala	-8.39	32.916		120			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-215	Mbozi	Songwe	Momba	Chiwezi	-9.144	32.635		180			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-216	Mbozi	Songwe	Mbozi	Itaka	-8.944	32.716		200			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-220	Kigoma Rural	Katavi	Mpanda	Mishamo	-5.266	30.305		50			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-221	Mpanda	Katavi	Mpanda	Mpanda Ndogo	-5.98	30.826		100			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-222	Mpanda	Katavi	Mpanda	Mpanda Ndogo	-5.849	30.862		100			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-225	Kilindi	Tanga	Kilindi	Kilwa	-5.573	37.526		60			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-226	Kilindi	Morogoro	Mvomero	Kibati	-5.908	37.621		20			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-227	Muheza	Tanga	Muheza	Songa	-5.359	38.699		100			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-228	Moshi Rural	Kilimanjaro	Moshi Rural	Marangu Magharibi	-3.248	37.477		1000			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-229	Hai	Kilimanjaro	Hai	Machame Kusini	-3.352	37.231		40			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-230	Lushoto	Tanga	Lushoto	Mayo	-4.883	38.545		70			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-237	Lushoto	Tanga	Lushoto	Gare	-4.797	38.38		200			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-238	Muheza	Tanga	Muheza	Amani	-5.096	38.645		350			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-239	Mwanga	Kilimanjaro	Mwanga	Jipe	-3.678	37.682		200			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-243	Simanjiro	Manyara	Simanjiro	Endonyongijape	-4.281	37.376		200			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-244	Simanjiro	Manyara	Simanjiro	Liborsoit	-4.235	37.394		200			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-246	Simanjiro	Manyara	Simanjiro	Liborsoit	-4.443	37.469		270			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-247	Korogwe	Tanga	Korogwe	Mkomazi	-4.711	38.043		80			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-250	Same	Kilimanjaro	Same	Vumari	-4.016	37.783		120			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-253	Mpwapwa	Dodoma	Mpwapwa	Luhundwa	-6.881	36.342		100			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-254	Mpwapwa	Dodoma	Mpwapwa	Luhundwa	-6.798	36.344		400			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-256	Mvomero	Morogoro	Mvomero	Hembeti	-6.198	37.497		300			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-260	Morogoro Rural	Morogoro	Morogoro Rural	Konde	-7.07	37.705		300			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-262	Bagamoyo	Pwani	Bagamoyo	Mandera	-6.193	38.465		40			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-264	Mvomero	Morogoro	Mvomero	Mlali	-7.095	37.482		40			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania

SF-267	Tandahimba	Mtwara	Tandahimba	Michenjele	-10.809	39.844		120			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-279	Singida Rural	Singida	Ikungi	Iyumbu	-5.214	34.174		10			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-280	Iramba	Singida	Iramba	Ulemo	-4.361	34.28		180			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-281	Iramba	Singida	Iramba	Kiomboi	-4.264	34.291		180			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-283	Singida Rural	Singida	Singida Rural	Makuro	-4.521	34.92		10			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-287	Iringa Rural	Iringa	Iringa Rural	Mlowa	-7.701	35.412		100			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-288	Iringa Rural	Iringa	Iringa Rural	Mahuninga	-7.896	35.131		120			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-290	Mufindi	Iringa	Mufindi	Ihanu	-8.641	35.589		400			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-291	Mufindi	Iringa	Mufindi	Mpanga	-8.653	35.678		45			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-292	Kilombero	Morogoro	Kilombero	Masagati	-8.989	35.56		80			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-293	Kilombero	Iringa	Mufindi	Kiyowela	-8.949	35.385		60			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-297	Babati	Manyara	Hanang	Simbay	-4.484	35.652		20			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-298	Babati	Manyara	Babati Urban	Maisaka	-4.11	35.767		10			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-299	Babati	Manyara	Babati	Kiru	-4.084	35.595		200			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-300	Babati	Manyara	Babati	Kiru	-4.081	35.571		300			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-301	Kondoa	Dodoma	Kondoa	Kalamba	-4.919	35.989		200			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-302	Kondoa	Dodoma	Kondoa	Changaa	-4.847	35.624		60			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-303	Singida Rural	Singida	Singida Rural	Itaja	-4.711	35.12		80			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-304	Hanang	Manyara	Hanang	Balagidalalu	-4.571	35.304		40			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-306	Dodoma Rural	Dodoma	Chamwino	Chiboli	-6.875	35.785		50			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-307	Manyoni	Singida	Manyoni	Manyoni	-5.741	34.909		100			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-308	Manyoni	Singida	Manyoni	Sasajila	-5.928	34.921		170			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-314	Karatu	Arusha	Karatu	Daa	-3.471	35.564		80			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-315	Monduli	Arusha	Monduli	Selela	-3.233	35.909		300			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-316	Karatu	Arusha	Monduli	Majengo	-3.337	35.835		160			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-318	Mbulu	Manyara	Babati	Magara	-3.799	35.683		150			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-320	Kilolo	Iringa	Kilolo	Mahenge	-7.378	36.263		140			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-321	Mpwapwa	Dodoma	Mpwapwa	Ipera	-7.172	36.372		350			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-333	Ulanga	Morogoro	Ulanga	Kilosa kwa Mpepo	-9.312	36.154		80			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-339	Ulanga	Morogoro	Ulanga	Itete	-8.708	36.482		120			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-340	Ulanga	Morogoro	Ulanga	Ilonga	-9.053	36.457		60			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-341	Uyui	Tabora	Uyui	Miswaki	-4.993	33.767		40			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-342	Meatu	Simiyu	Meatu	Mwanjolo	-3.615	34.782		200			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-344	Nkasi	Rukwa	Nkasi	Wampembe	-7.887	30.851		280			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-346	Mpanda	Katavi	Mpanda	Mwese	-6.077	30.44		80			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-347	Mpanda	Katavi	Mpanda	Katuma	-6.158	30.69		100			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania
SF-350	Kigoma Rural	Kigoma	Uvinza	Kalya	-6.564	30.253		150			SiteFinder	SHER	Renewable Energy Mapping : Small Hydro Tanzania

- 82 promising sites

Hydro-Atlas code	Site name	Region	District	Ward	Latitude [Decimal degrees]	Longitude [Decimal degrees]	River	Basin	Site catchment area [km²]	95% guaranteed flow [m³/s]	90% guaranteed flow [m³/s]	50% guaranteed flow [m³/s]	30% guaranteed flow [m³/s]	100 year flood flow [m³/s]	Confidence in hydrological data	Type of hydropower scheme	Gross head [m]	90% guaranteed power [MW]	90% guaranteed annual energy [GWh]	50% guaranteed power [MW]	50% guaranteed annual energy [GWh]	Author of the site reference	Reference	Study level of the site
SF-153	Ndurumo	Singida	Mkalama	Msingi	-4.383	34.633	NDURUMO	Internal Drainage	2524.3	0.6	1.3	8.7	15.1		Low	Run-of-the-river	85	0.92	7.73	6.08	47.22	SHER	Renewable Energy Mapping : Small Hydro Tanzania	Site Visit 2015 (SHER)
SF-056	Manique	Arusha	Ngorongoro	Pinyinyi	-2.535	35.819	MANIQUE	Internal Drainage	1289	0.4	0.8	5.4	9.5		Low	Run-of-the-river	350	2.34	19.7	15.57	99.23	SHER	Renewable Energy Mapping : Small Hydro Tanzania	Site Visit 2015 (SHER)
M-267B	Ngongi II	Ruvuma	Mbinga	Mpapa	-11.217	34.919	Ngongi	Lake Nyasa	84.3	0.1	0.2	0.6	0.8		Medium	Run-of-the-river	290	0.37	3.13	1.31	8.91	REA	List for Feasibility Study	Site Visit 2015 (SHER)
SF-189	Lupa	Mbeya	Chunya	Ifumbo	-8.655	33.214	Lupa	Lake Rukwa	5885.6	1.1	2.6	24.1	46.1		Medium	Run-of-the-river	82	1.78	14.92	16.36	124.98	SHER	Renewable Energy Mapping : Small Hydro Tanzania	Site Visit 2015 (SHER)
SF-278	Mfizi III	Katavi	Mlele	Kibaoni	-7.154	31.124	Mfizi	Lake Rukwa	3107.7	0	0.1	3.1	8.8		Medium	Run-of-the-river	30	0.02	0.17	0.76	4.39	SHER	Renewable Energy Mapping : Small Hydro Tanzania	Site Visit 2015 (SHER)
SF-212	Muze	Rukwa	Sumbawanga Rural	Muze	-7.723	31.515	Muze	Lake Rukwa	305.5	0	0.1	1.2	2.4		Low	Run-of-the-river	420	0.38	3.16	4.06	24.96	SHER	Renewable Energy Mapping : Small Hydro Tanzania	Site Visit 2015 (SHER)
SF-217	Samvya	Rukwa	Kalambo	Katazi	-8.434	31.82	Samvya	Lake Rukwa	565.5	0.1	0.2	2.2	4.7	114	Low	Run-of-the-river	118	0.06	0.2	1.936	11.1	SHER	Renewable Energy Mapping : Small Hydro Tanzania	Prefeasibility Study (SHER)
N-002	Kawa	Rukwa	Kalambo	Kisumba	-8.489	31.211	Kawa	Lake Tanganyika	169.8	0	0.1	0.7	1.5		Low	Run-of-the-river	260	0.13	1.05	1.56	11.76	SHER	Renewable Energy Mapping : Small Hydro Tanzania	Site Visit 2015 (SHER)
M-301	Lukarasi shp	Ruvuma	Mbinga	Kigonsera	-10.782	35.097	Mkurusi	Ruvuma & Southern Rivers	30	0	0.1		0.3		Medium	Run-of-the-river	27	0.01	0.1	0.04	0.28	IED	IREP - GIS - base list	Site Visit 2015 (SHER)
M-245	Mandera's Waterfalls	Tanga	Korogwe	Mswaha	-5.151	38.328	Pangani	Pangani	44928	10.1	12.8	22	25.7	226	High	Run-of-the-river	43	4.4	36.8	7.6	56.5	IED	IREP	Reconnaissance 2015 (SHER)
M-239	Umba	Tanga	Lushoto	Mlalo	-4.57	38.347	Umba	Pangani	127	0.1	0.1	0.3	0.5		Low	Run-of-the-river	820	0.431	3.4	2.054	14.71	IED	IREP	Site Visit 2015 (SHER)
M-228	Mgugwe	Morogoro	Kilombero	Chisano	-8.675	35.825	Mgugwe	Rufiji	200.9	0.3	0.4	1.1	1.4		Low	Run-of-the-river	7	0.016	0.12	0.059	0.42	IED	IREP	Site Visit 2015 (SHER)
M-222	Mkombola	Morogoro	Gairo	Chanjale	-6.497	36.85	Mkombola	Wami/Ruvu and Coast Rivers	229	0.2	0.4	1.2	1.8		Low	Run-of-the-river	160	0.276	2.17	1.503	10.53	IED	IREP	Site Visit 2015 (SHER)
M-211	Mfisigo	Morogoro	Morogoro Rural	Kibungo Juu	-7.088	37.685	Mfisigo	Wami/Ruvu and Coast Rivers	43	0	0.1	0.3	0.5		Low	Run-of-the-river	250	0.043	0.34	0.537	3.61	IED	IREP	Site Visit 2015 (SHER)
M-230	Mulawi	Iringa	Kilolo	Udekwa	-7.697	36.314	Mulawi	Rufiji	215	0.3	0.4	1.2	1.7		Low	Run-of-the-river	340	0.71	5.6	3.245	23.22	IED	IREP	Site Visit 2015 (SHER)
M-232	Mlowa	Iringa	Kilolo	Ilula	-7.65	36.145	Mlowa	Rufiji	696	0.7	1.1	2.9	4		Low	Run-of-the-river	270	1.5	11.83	6.323	45.27	IED	IREP	Site Visit 2015 (SHER)
SF-219	Kianda	Rukwa	Sumbawanga Rural	Miangalua	-8.526	32.136	Kianda	Lake Rukwa	59.7	0	0	0.2	0.5		Low	Run-of-the-river	700	0.1	0.82	1.27	7.71	SHER	Renewable Energy Mapping : Small Hydro Tanzania	Site Visit 2015 (SHER)
SF-213	Nyembe	Rukwa	Sumbawanga Rural	Kalambanzite	-8.326	32.014	Nyembe	Lake Rukwa	177.5	0	0.1	0.7	1.4		Low	Daily reservoir	684	1.17	2.45	14.76	27.16	SHER	Renewable Energy Mapping : Small Hydro Tanzania	Site Visit 2015 (SHER)

SF-211	Lwiche	Rukwa	Sumbawanga Rural	Muze	-7.765	31.576	Lwiche	Lake Rukwa	832.1	0.1	0.1	1.4	2.8		Medium	Daily reservoir	519	2.37	4.96	24.24	44.78	SHER	Renewable Energy Mapping : Small Hydro Tanzania	Site Visit 2015 (SHER)
SF-343	Samba	Rukwa	Nkasi	Nkomolo	-7.457	30.836	Samba	Lake Tanganyika	336.4	0	0.1	0.7	1.3		Medium	Run-of-the-river	92	0.06	0.47	0.5	3.86	SHER	Renewable Energy Mapping : Small Hydro Tanzania	Site Visit 2015 (SHER)
SF-289	Lyandembela II	Iringa	Mufindi	Igombavanu	-8.265	35.163	Lyandembela	Rufiji	1214.2	0.5	1.1	6	10		Medium	Run-of-the-river	33	0.29	2.44	1.65	12.92	SHER	Renewable Energy Mapping : Small Hydro Tanzania	Site Visit 2015 (SHER)
SF-109	Lyandembela I	Iringa	Mufindi	Igombavanu	-8.292	35.108	Lyandembela	Rufiji	1375.3	0.6	1.2	6.8	11.4		Medium	Run-of-the-river	33	0.33	2.75	1.86	14.61	SHER	Renewable Energy Mapping : Small Hydro Tanzania	Site Visit 2015 (SHER)
SF-294	Kigogo	Iringa	Mufindi	Mninga	-8.682	35.243	Kigogo	Rufiji	52	0	0.1	0.4	0.7		Low	Run-of-the-river	539	0.25	2.08	1.86	11.44	SHER	Renewable Energy Mapping : Small Hydro Tanzania	Reconnaissance 2015 (SHER)
SF-296	Vambanungwi	Iringa	Mufindi	Kiyowela	-8.763	35.054	Vambanungwi	Rufiji	160.4	0.1	0.1	1	1.7		Low	Run-of-the-river	110	0.13	1.12	0.89	6.89	SHER	Renewable Energy Mapping : Small Hydro Tanzania	Site Visit 2015 (SHER)
SF-083	Mlowa	Iringa	Kilolo	Mahenge	-7.665	36.172	Mlowa	Rufiji	694.1	0.5	0.8	2.8	4.1		Medium	Run-of-the-river	117	0.77	6.53	2.71	22	SHER	Renewable Energy Mapping : Small Hydro Tanzania	Site Visit 2015 (SHER)
SF-266	Muhuwezi	Ruvuma	Tunduru	Kalulu	-10.702	36.945	Muhuwezi	Ruvuma & Southern Rivers	640	0.2	0.4	3.1	5.7	376	Low	Run-of-the-river	81	0.14	0.3	1.824	10.9	SHER	Renewable Energy Mapping : Small Hydro Tanzania	Prefeasibility Study (SHER)
SF-277	Mbagala	Mtwara	Nanyumbu	Nandete	-11.046	38.714	Mbagala	Ruvuma & Southern Rivers	3322.7	0.1	0.5	10.7	26.8		Low	Run-of-the-river	40	0.15	1.26	3.53	20.8	SHER	Renewable Energy Mapping : Small Hydro Tanzania	Site Visit 2015 (SHER)
SF-271	Mihima	Lindi	Lindi Rural	Namupa	-10.278	39.157	Mihima/Namangale	Ruvuma & Southern Rivers	128.9	0.1	0.2	0.7	1		Low	Run-of-the-river	104	0.17	1.41	0.59	3.99	SHER	Renewable Energy Mapping : Small Hydro Tanzania	Site Visit 2015 (SHER)
M-221	Mambi	Lindi	Lindi Rural	Mandwanga	-10.409	39.573	Mambi	Ruvuma & Southern Rivers	1480.7	1.9	2.9	8.5	11.7		Low	Run-of-the-river	152	3.56	30.39	10.62	87.61	IED	IREP	Site Visit 2015 (SHER)
SF-172	Ruchugi	Kigoma	Uvinza	Uvinza	-5.022	30.421	Ruchugi	Lake Tanganyika	2816.3	2.8	4.5	15.6	22.6		Low	Run-of-the-river	13	0.48	4.06	1.68	11.4	SHER	Renewable Energy Mapping : Small Hydro Tanzania	Site Visit 2015 (SHER)
SF-017	Momba I	Rukwa	Kalambo	Legeza Mwendo	-8.76	31.954	Momba	Lake Rukwa	1849	0.4	0.9	11.1	23.2		Low	Run-of-the-river	4	0.02	0.18	0.29	1.79	SHER	Renewable Energy Mapping : Small Hydro Tanzania	Reconnaissance 2015 (SHER)
M-070	Momba II	Songwe	Momba	Ndalembo	-8.792	32.376	Momba	Lake Rukwa	6418	0.2	0.4	7.4	17		Medium	Run-of-the-river	358	1.28	10.4	21.67	125.2	Dar Es Salaam Institute of Technology	The report on pre-feasibility study of small hydropower potential schemes in Morogoro, Iringa, Ruvuma and Mbeya regions - Tanzania	Reconnaissance 2015 (SHER)
M-355B	Mgaka II	Ruvuma	Mbinga	Kitumbalomo	-10.652	35.02	Mgaka	Lake Nyasa	650.6	1.5	2.3	6.6	9		Medium	Run-of-the-river	35	0.65	5.58	1.9	13.28	IED	IREP - GIS - base list	Site Visit 2015 (SHER)
SF-187	Muyovozi	Kigoma	Kakonko	Kakonko	-3.196	30.993	Muyovozi	Lake Tanganyika	2719.7	2.1	3.4	12	17.4	624	Low	Run-of-the-river	27	0.7	0.97	2.2	15	SHER	Renewable Energy Mapping : Small Hydro Tanzania	Prefeasibility Study (SHER)
M-119	Lubare	Kagera	Karagwe	Ihembe	-1.737	31.168	Lubare	Lake Victoria	17.9	0	0	0.1	0.1		Low	Run-of-the-river	125	0.02	0.17	0.09	0.71	Tanesco	Reconnaissance Study Mini Hydropower Potential in Kagera Region Draft Report	Site Visit 2015 (SHER)

M-118	Achesherero	Kagera	Karagwe	Nyakahanga	-1.663	31.159	Achesherero	Lake Victoria	54.9	0	0.1	0.3	0.4		Low	Run-of-the-river	90	0.05	0.4	0.2	1.34	Tanesco	Reconnaissance Study Mini Hydropower Potential in Kagera Region Draft Report	Site Visit 2015 (SHER)
M-113	Kyamato	Kagera	Bukoba Rural	Buhendangabo	-1.221	31.808	Kyamato	Lake Victoria	11.3	0	0	0.1	0.1		Low	Run-of-the-river	50	0.006	0.05	0.03	0.19	Tanesco	Reconnaissance Study Mini Hydropower Potential in Kagera Region Draft Report	Site Visit 2015 (SHER)
M-121B	Kitogota Falls	Kagera	Muleba	Ibuga	-1.67	31.621	Kitogota	Lake Victoria	121	0.3	0.4	0.8	1.3	18	Medium	Run-of-the-river	30	0.09	0.73	0.18	1.31	Tanesco	Reconnaissance Study Mini Hydropower Potential in Kagera Region Draft Report	Reconnaissance 2015 (SHER)
M-121A	Kitogota I	Kagera	Muleba	Buganguzi	-1.693	31.602	Kitogota	Lake Victoria	104.1	0.1	0.2	0.7	1		Low	Daily reservoir	100	0.54	1.57	2.18	4.28	Tanesco	Reconnaissance Study Mini Hydropower Potential in Kagera Region Draft Report	Site Visit 2015 (SHER)
SF-082	Lukosi	Iringa	Kilolo	Udekwa	-7.728	36.192	Lukosi	Rufiji	1535	5.2	5.8	9.1	11.9	113	Medium	Run-of-the-river	103	4.76	40.3	7.59	57.33	SHER	Renewable Energy Mapping : Small Hydro Tanzania	Reconnaissance 2015 (SHER)
SF-092	Bubu I	Dodoma	Chemba	Farkwa	-5.372	35.497	BUBU	Internal Drainage	7565.5	1.7	3.6	23.4	40.6		Low	Daily reservoir	35	3.34	7.03	21.97	35.01	SHER	Renewable Energy Mapping : Small Hydro Tanzania	Site Visit 2015 (SHER)
SF-091	Bubu II	Dodoma	Chemba	Farkwa	-5.387	35.49	BUBU	Internal Drainage	7600.9	1.7	3.6	23.5	40.8		Low	Run-of-the-river	90	2.64	22.27	17.43	135.47	SHER	Renewable Energy Mapping : Small Hydro Tanzania	Site Visit 2015 (SHER)
SF-305	Mponde I	Dodoma	Chemba	Sanzawa	-5.404	35.137	MPONDE	Internal Drainage	1546.6	0.3	0.6	4.2	7.4		Low	Daily reservoir	16	0.27	0.57	1.78	2.83	SHER	Renewable Energy Mapping : Small Hydro Tanzania	Site Visit 2015 (SHER)
SF-067	Mponde II	Dodoma	Chemba	Mpendo	-5.535	35.23	MPONDE	Internal Drainage	1913.5	0.4	0.8	5.2	9		Low	Run-of-the-river	95	0.61	5.16	4.06	31.55	SHER	Renewable Energy Mapping : Small Hydro Tanzania	Site Visit 2015 (SHER)
SF-068	Luwila	Singida	Manyoni	Makuru	-5.616	35.023	LUWILA	Internal Drainage	2176.3	0.4	0.9	6	10.4		Medium	Daily reservoir	120	3.3	6.94	21.75	34.66	SHER	Renewable Energy Mapping : Small Hydro Tanzania	Site Visit 2015 (SHER)
SF-069	Maparengi	Singida	Manyoni	Saranda	-5.743	35.038	MAPARENGI	Internal Drainage	3110.7	0.6	1.3	8.5	14.8		Medium	Run-of-the-river	150	1.59	13.43	10.56	82.07	SHER	Renewable Energy Mapping : Small Hydro Tanzania	Site Visit 2015 (SHER)
SF-107	Ndembela I	Iringa	Mufindi	Sadani	-8.232	34.98	NDEMBELA	Rufiji	1641.1	0.7	1.4	8.2	13.6		Medium	Run-of-the-river	100	1.18	9.95	6.74	52.84	SHER	Renewable Energy Mapping : Small Hydro Tanzania	Site Visit 2015 (SHER)
SF-108	Ndembela II	Iringa	Mufindi	Sadani	-8.245	34.913	NDEMBELA	Rufiji	1794.2	0.8	1.6	8.9	14.8		Medium	Run-of-the-river	105	1.35	11.38	7.72	60.52	SHER	Renewable Energy Mapping : Small Hydro Tanzania	Site Visit 2015 (SHER)
SF-143	Wami	Pwani	Bagamoyo	Msata	-6.241	38.377	Wami	Wami/Ruvu and Coast Rivers	39981	12.5	25.7	168.8	293.1		Low	Run-of-the-river	8	1.7	14.35	11.21	87.1	SHER	Renewable Energy Mapping : Small Hydro Tanzania	Site Visit 2015 (SHER)
SF-145	Mkalamo	Tanga	Handeni	Kwamsisi	-5.79	38.642	MSANGAZI	Pangani	3827.1	1.2	2.5	16.6	28.9		Medium	Run-of-the-river	20	0.42	3.52	2.76	17.58	SHER	Renewable Energy Mapping : Small Hydro Tanzania	Site Visit 2015 (SHER)
SF-052A	Mara I	Mara	Tarime	Nyarokoba	-1.56	34.659	MARA	Lake Victoria	10076	3.5	7.1	46.6	81		Low	Run-of-the-river	25	1.46	12.32	9.63	61.36	SHER	Renewable Energy Mapping : Small Hydro Tanzania	Site Visit 2015 (SHER)
SF-052B	Mara II	Mara	Serengeti	Nyansurura	-1.588	34.642	MARA	Lake Victoria	10076	3.5	7.1	46.6	81		Low	Run-of-the-river	45	2.63	22.19	17.34	110.52	SHER	Renewable Energy Mapping : Small Hydro Tanzania	Site Visit 2015 (SHER)

SF-080B	Sasimo II	Dodoma	Mpwapwa	Ipera	-7.23	36.508	SASIMO	Rufiji	513.8	0.2	0.5	2.2	3.4		Low	Run-of-the-river	110	0.41	3.45	1.97	15.59	SHER	Renewable Energy Mapping : Small Hydro Tanzania	Site Visit 2015 (SHER)
SF-080A	Sasimo I	Dodoma	Mpwapwa	Ipera	-7.218	36.505	SASIMO	Rufiji	513.8	0.2	0.5	2.2	3.4		Low	Run-of-the-river	60	0.22	1.89	1.07	8.52	SHER	Renewable Energy Mapping : Small Hydro Tanzania	Site Visit 2015 (SHER)
SF-022	Luegere	Kigoma	Uvinza	Igalula	-5.895	30.029	LUEGERE	Lake Tanganyika	1317	1.4	1.6	4.6	7.8	213	High	Run-of-the-river	157	1.69	2.7	5.355	34.4	SHER	Renewable Energy Mapping : Small Hydro Tanzania	Prefeasibility Study (SHER)
SF-178	Mgambazi	Kigoma	Uvinza	Igalula	-5.828	29.994	MGAMBAZI	Lake Tanganyika	592	0.7	0.8	2.1	3.5	34	Medium	Run-of-the-river	57	0.34	2.9	0.92	6.19	SHER	Renewable Energy Mapping : Small Hydro Tanzania	Reconnaissance 2015 (SHER)
SF-041	Kivumilo	Tanga	Mkinga	Mwakijembe	-4.512	38.869	UMBA	Pangani	5489.9	3.9	6.3	22.1	31.9		Medium	Run-of-the-river	9	0.47	3.98	1.64	13.34	SHER	Renewable Energy Mapping : Small Hydro Tanzania	Site Visit 2015 (SHER)
SF-123	Mchakama	Lindi	Kilwa	Mandawa	-9.106	39.265	Mavuji	Ruvuma & Southern Rivers	3002	2.9	4.6	16.2	23.4		Low	Run-of-the-river	5	0.19	1.63	0.67	5.47	SHER	Renewable Energy Mapping : Small Hydro Tanzania	Site Visit 2015 (SHER)
M-127	Ruhuhu	Ruvuma	Nyasa	Lituhi	-10.448	34.805	Ruhuhu	Lake Nyasa	14581	15.3	26.1	105.2	158.4		Medium	Run-of-the-river	15	3.25	27.56	13.12	87.73	Tanesco	Reconnaissance Study for Minihydropower Potential Sites Iringa Region Phase II	Site Visit 2015 (SHER)
SF-029	Lupapilo	Njombe	Ludewa	Masasi	-10.489	34.76	Ruhuhu	Lake Nyasa	14618	15.3	26.1	105.5	158.8		Medium	Run-of-the-river	30	6.49	55.13	26.23	175.49	SHER	Renewable Energy Mapping : Small Hydro Tanzania	Site Visit 2015 (SHER)
M-295	Myombezi	Ruvuma	Songea Rural	Wino	-9.806	35.383	Myombezi	Lake Nyasa	35	0.1	0.1	0.3	0.4		Low	Run-of-the-river	94	0.09	0.76	0.23	1.58	IED	IREP - GIS - base list	Reconnaissance 2015 (SHER)
M-298B	Litembo Extension	Ruvuma	Mbinga	Litembo	-10.974	34.829	Ndumbi	Lake Nyasa	33.8	0	0.1	0.2	0.3		Medium	Daily reservoir	25	0.05	0.11	0.18	0.31	IED	IREP - GIS - base list	Site Visit 2015 (SHER)
M-299	Luaita	Ruvuma	Mbinga	Kilimani	-10.963	34.979	Luaita	Lake Nyasa	55	0.1	0.1	0.4	0.5		Low	Run-of-the-river	30	0.02	0.2	0.09	0.57	IED	IREP - GIS - base list	Reconnaissance 2015 (SHER)
M-355A	Mgaka I	Ruvuma	Mbinga	Kitumbalomo	-10.712	35.032	Mgaka	Lake Nyasa	519.8	1.2	1.8	5.3	7.2		Medium	Run-of-the-river	30	0.45	3.82	1.3	9.09	IED	IREP - GIS - base list	Site Visit 2015 (SHER)
M-268A	Luwika I	Ruvuma	Mbinga	Kambarage	-11.095	34.821	Luwika/Lualala	Lake Nyasa	72.3	0.1	0.1	0.5	0.7		Medium	Run-of-the-river	75	0.08	0.69	0.29	1.96	REA	List for Feasibility Study	Site Visit 2015 (SHER)
M-268B	Luwika II	Ruvuma	Mbinga	Kambarage	-11.104	34.81	Luwika/Lualala	Lake Nyasa	77.7	0.1	0.1	0.5	0.7		Medium	Run-of-the-river	750	0.85	7.21	3.03	20.58	REA	List for Feasibility Study	Site Visit 2015 (SHER)
M-297	Lipumba	Ruvuma	Mbinga	Kihangi Mahuka	-10.825	35.012	Mngaka	Lake Nyasa	349.8	0.4	0.6	2.2	3.2		Medium	Run-of-the-river	4	0.02	0.18	0.07	0.49	IED	IREP - GIS - base list	Site Visit 2015 (SHER)
SF-UN	Mbawa	Ruvuma	Mbinga	Maguu	-11.024	34.758	Mbawa	Lake Nyasa	89.5	0.1	0.2	0.6	0.8		Low	Run-of-the-river	350	0.45	3.87	1.61	13.11	SHER	Renewable Energy Mapping : Small Hydro Tanzania	Site Visit 2015 (SHER)
N-010	Kitandazi II	Ruvuma	Mbinga	Mbangamao	-11.019	35.079	Mbinga	Ruvuma & Southern Rivers	183	0.1	0.2	0.6	0.9	11	Medium	Run-of-the-river	26	0.04	0.31	0.13	0.85	SHER	Renewable Energy Mapping : Small Hydro Tanzania	Reconnaissance 2015 (SHER)
N-011	Kingilikiti	Ruvuma	Nyasa	Kingerikiti	-11.179	34.971	Lumeme	Ruvuma & Southern Rivers	114.5	0.1	0.2	0.7	1.1		Medium	Run-of-the-river	28	0.05	0.41	0.17	1.16	SHER	Renewable Energy Mapping : Small Hydro Tanzania	Site Visit 2015 (SHER)
M-267A	Ngongi I	Ruvuma	Mbinga	Mpapa	-11.191	34.932	Ngongi	Lake Nyasa	52.2	0.1	0.1	0.3	0.5		Medium	Run-of-the-river	110	0.09	0.75	0.31	2.12	REA	List for Feasibility Study	Site Visit 2015 (SHER)
M-277	Luika	Njombe	Ludewa	Lupingu	-10.066	34.552	Luika	Lake Nyasa	63.5	0.1	0.2	0.4	0.5		Medium	Run-of-the-river	58	0.08	0.65	0.2	1.4	REA	List for Feasibility Study	Site Visit 2015 (SHER)

M-288	Kelolilo	Njombe	Ludewa	Ludewa	-10.102	34.708	Kelolilo	Lake Nyasa	105	0.4	0.5	1.1	1.8	11	Medium	Run-of-the-river	79	0.29	2.43	0.68	4.71	IED	IREP - GIS - base list	Reconnaissance 2015 (SHER)
M-110	Kitewaka	Njombe	Ludewa	Luilo	-10.352	34.838	Kitewaka	Lake Nyasa	2460.6	8.9	12.8	33.5	44.4		Medium	Run-of-the-river	54	5.71	48.89	14.96	106	Unknown	Kitewaka Pre-feasibility study	Site Visit 2015 (SHER)
SF-018	Kalambo Falls	Rukwa	Kalambo	Kisumba	-8.596	31.24	Kalambo	Lake Tanganyika	3193	0.2	0.5	6.3	13.2		Medium	Run-of-the-river	200	0.82	6.85	10.36	63.06	SHER	Renewable Energy Mapping : Small Hydro Tanzania	Site Visit 2015 (SHER)
SF-019	Lwazi	Rukwa	Kalambo	Kasanga	-8.279	31.073	Lwazi	Lake Tanganyika	515	0.1	0.2	2.1	4.4		Low	Run-of-the-river	167	0.23	1.86	2.77	16.32	SHER	Renewable Energy Mapping : Small Hydro Tanzania	Reconnaissance 2015 (SHER)
SF-214A	Kalambo I	Rukwa	Kalambo	Mkowe	-8.291	31.43	Kalambo	Lake Tanganyika	1335	0.3	0.4	1.9	5	54	Medium	Run-of-the-river	17	0.05	0.42	0.25	1.53	SHER	Renewable Energy Mapping : Small Hydro Tanzania	Reconnaissance 2015 (SHER)
SF-214B	Kalambo II	Rukwa	Kalambo	Mkowe	-8.298	31.422	Kalambo	Lake Tanganyika	1348	0.3	0.4	1.9	5	54	Medium	Run-of-the-river	20	0.05	0.44	0.3	1.83	SHER	Renewable Energy Mapping : Small Hydro Tanzania	Reconnaissance 2015 (SHER)
SF-206	Chulu	Rukwa	Nkasi	Mkwamba	-7.596	31.449	Chulu	Lake Rukwa	99	0	0	0.4	0.7		Low	Run-of-the-river	829	0.2	1.64	2.39	14.14	SHER	Renewable Energy Mapping : Small Hydro Tanzania	Reconnaissance 2015 (SHER)
SF-208	Mfizi I	Rukwa	Nkasi	Mtenga	-7.235	31.075	Mfizi	Lake Rukwa	2382.5	0	0.1	2.3	6.8		Medium	Run-of-the-river	40	0.02	0.17	0.77	4.47	SHER	Renewable Energy Mapping : Small Hydro Tanzania	Site Visit 2015 (SHER)
SF-020	Mfizi II	Rukwa	Nkasi	Mtenga	-7.187	31.11	Mfizi	Lake Rukwa	2544	0	0	1.2	4	86	Medium	Run-of-the-river	153	0	0	1.49	8.28	SHER	Renewable Energy Mapping : Small Hydro Tanzania	Reconnaissance 2015 (SHER)
SF-207	Kilida	Rukwa	Nkasi	Mkwamba	-7.447	31.348	Kilida	Lake Rukwa	98.3	0	0	0.4	0.8		Low	Run-of-the-river	500	0.14	1.19	1.53	9.4	SHER	Renewable Energy Mapping : Small Hydro Tanzania	Site Visit 2015 (SHER)

10.4 APPENDIX 4 : LIST OF PARTICIPANTS TO THE KICK-OFF MEETING (NOVEMBER 7, 2013)

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10.5 APPENDIX 5 : LIST OF PARTICIPANTS TO PRESENTATION OF PROGRESS REPORT (NOVEMBER 20, 2014)

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PRESENTATION OF PROGRESS REPORT

ON SMALL HYDRO MAPPING IN TANZANIA

AT REA, THURSDAY, 20 NOVEMBER 2014

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10.6 APPENDIX 6 : LIST OF PARTICIPANTS TO THE WORKING SESSION ON SMALL SCALE HYDRO RESOURCE MAPPING - PHASE 1 WORKSHOP (MARCH 17, 2015)

RURAL ENERGY AGENCY

WORKING SESSION ON SMALL SCALE HYDRO RESOURCE MAPPING

REA CONFERENCE HALL – 17th MARCH, 2015

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10.7 APPENDIX 7 : LIST OF PARTICIPANTS TO THE TRAINING SESSION ON SMALL SCALE HYDRO RESOURCE MAPPING (MARCH 18-19, 2015)

RURAL ENERGY AGENCY

TRAINING SESSION ON SMALL SCALE HYDRO RESOURCE MAPPING

REA CONFERENCE HALL – 18th MARCH, 2015

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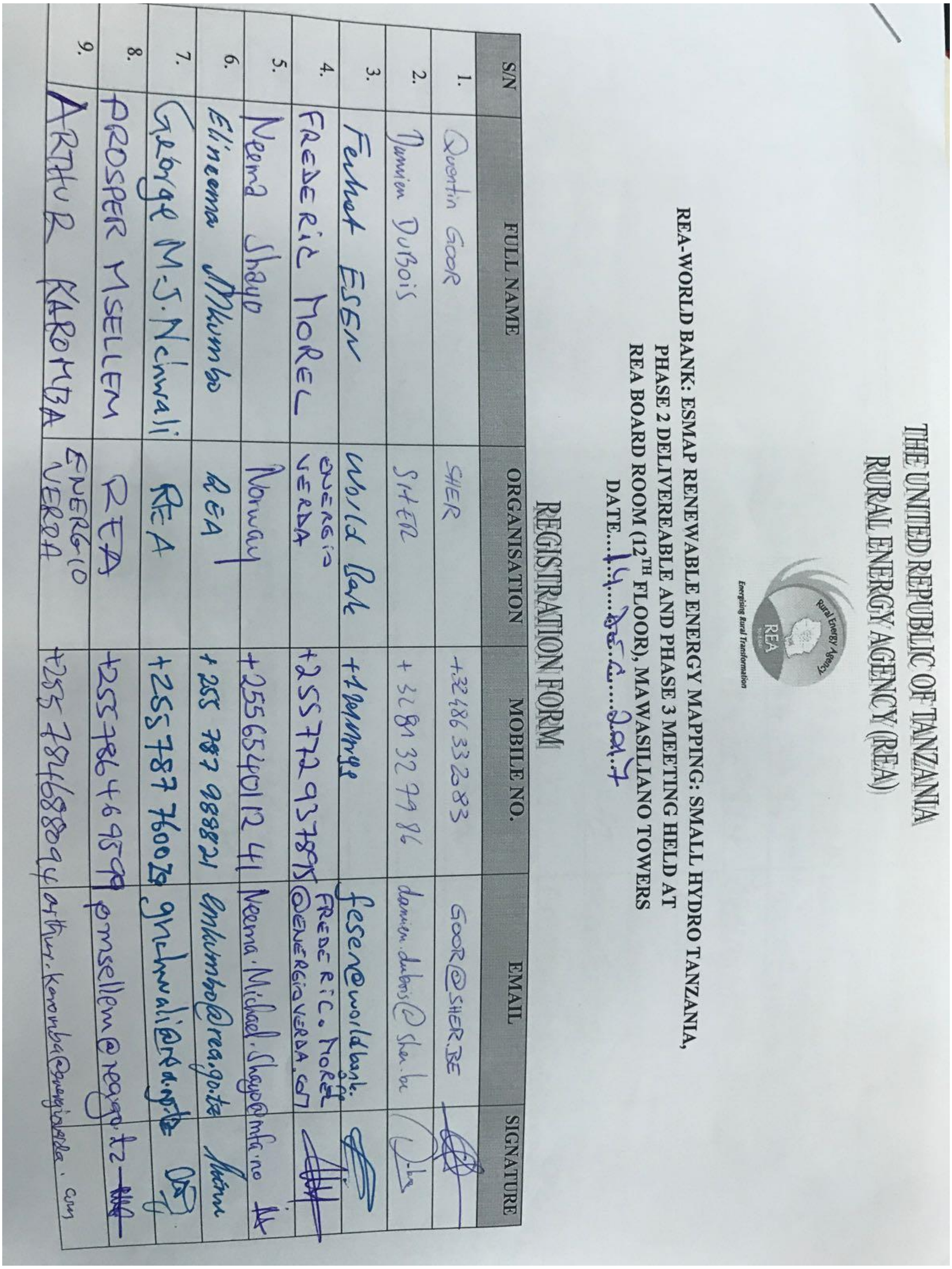
10.8 APPENDIX 8 : LIST OF PARTICIPANTS TO THE FINAL WORKSHOP (DECEMBER 14, 2017)



THE UNITED REPUBLIC OF TANZANIA
RURAL ENERGY AGENCY (REA)

Energising Rural Transformation

REA-WORLD BANK: ESMAP RENEWABLE ENERGY MAPPING: SMALL HYDRO TANZANIA, PHASE 2 DELIVEREABLE AND PHASE 3 MEETING HELD AT REA BOARD ROOM (12^{TH} FLOOR), MAWASILIANO TOWERS
DATE...14...Dec...2017

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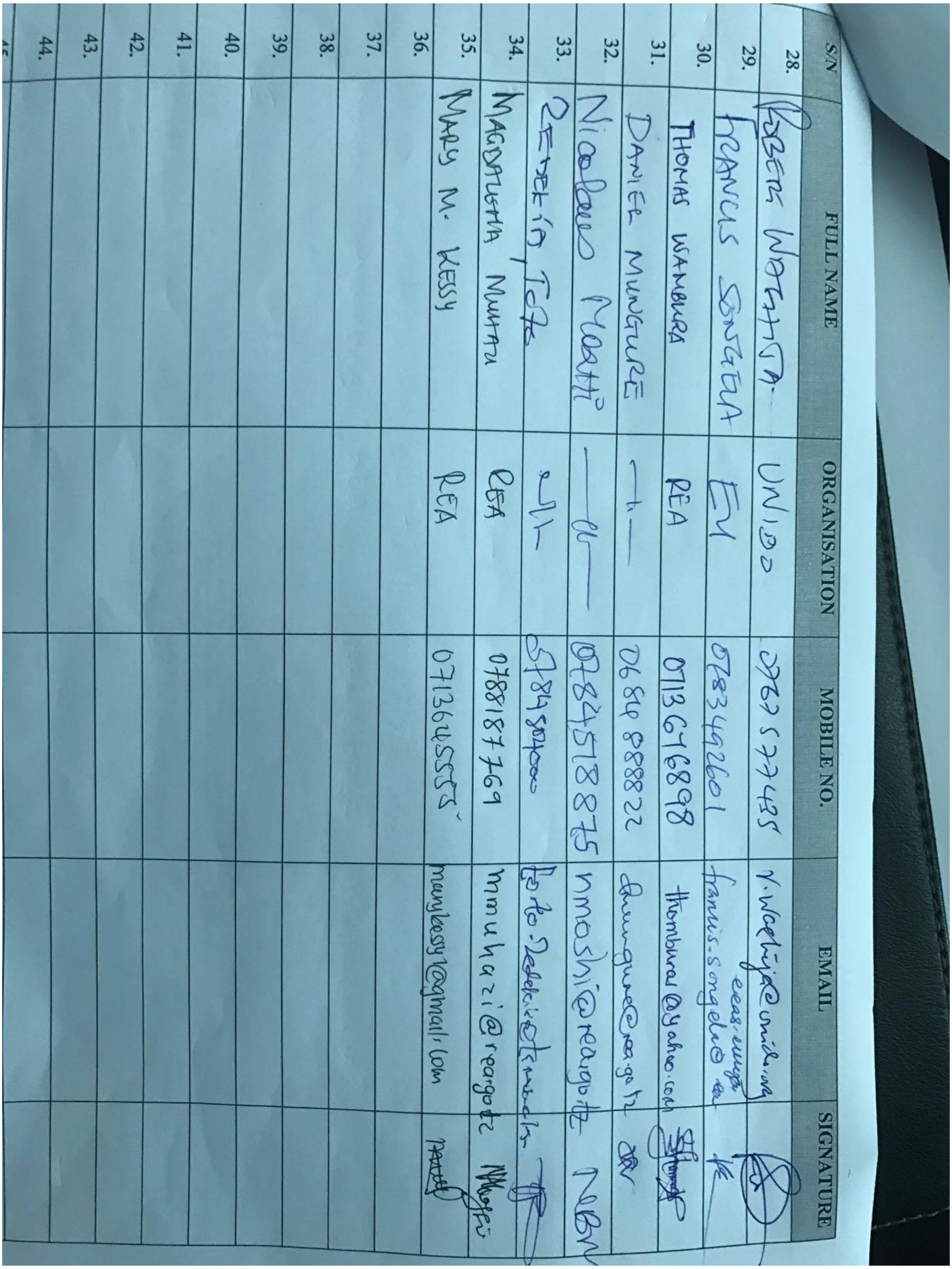

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10.9 APPENDIX 9 : SITE VISITS REPORT

10.10 APPENDIX 10 : SITE INVESTIGATIONS REPORT

10.11 APPENDIX 11 : ATLAS OF THE HYDROPOWER RESOURCE OF TANZANIA