

**THE PROMOTION OF RAINWATER HARVESTING AS A
SUPPLEMENTARY SOURCE OF DOMESTIC WATER IN KIGALI,
RWANDA – A FEASIBILITY STUDY**

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A research report submitted to the Faculty of Engineering and the Built Environment, University of the Witwatersrand, Johannesburg, in partial fulfilment of the requirements for the degree of Master of Science in Engineering

Kigali, Rwanda 2005

DECLARATION

I declare that this research report is my own, unaided work. It is being submitted for the degree of Master of Science in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in any other University.

R P Sully

____ Day of _____ 2005

ABSTRACT

Theme and Context

Despite being the source of two of Africa's greatest rivers, the Nile and the Congo, Rwanda is a water scarce country and 50% of the citizens of the capital, Kigali, do not have access to safe drinking water. Rwanda's tragic history of violent social upheaval combined with regional macro-economic factors and the effects of globalization have made this tiny country one of the poorest on the African continent.

Aim and Objectives of this Study

The aim of this report is to establish the value that Rainwater Harvesting holds as a supplementary water source for the city of. To evaluate this potential intervention, the suitability of the climate for the harvesting of rainwater is reviewed as well as the availability of the required resources and the effect that the prevailing social environment may have on an implementation program.

The current developments in the practice of Rainwater Harvesting are researched and ways in which Rainwater Harvesting could be utilized are explored as well as the possible impediments that might be encountered.

Scope and Methodology Adopted

The scope of the report includes:

1. Providing an overview of the country both geographically as well as socially.
2. Establishing the need for alternative water sources by:
 - a. Reviewing the present water supplies for the city particularly with regard to their vulnerability to the rapid environmental degradation being experienced within the country,
 - b. Reviewing the prevailing water/health nexus.
3. Investigating metrological records, specifically rainfall patterns, and the quality of the statistics.
4. Review international trends and research in rainwater harvesting specifically in poor countries.

5. Considering obstacles to implementing a wide-ranging scheme to harvest rainwater.

The methodology adopted includes:

1. Reviewing published research on the subject of Rainwater Harvesting techniques and implementation.
2. Attending symposia on the subject.
3. Meeting with water practitioners both in the public sector as well as in NGOs to establish the current status of water availability, quality and consumption.
4. Conducting on-site research into water sourcing problems in and around Kigali.
5. Designing, sizing and costing hypothetical installations suitable for local conditions.

Summary of Main Findings, Conclusions and Recommendations

Although the climate and topography are very favorable to the use of Rainwater Harvesting, this report finds that the promotion of Rainwater harvesting is just one of a number of possible interventions which should be pursued in order to improve the availability of water to the citizens of Kigali

The cost and sophistication of Rainwater Harvesting schemes vary considerably but at the lower end of the scale the technology would be affordable to most Kigali residents and the community has the potential human resource to be trained to execute the work. Obstacles to this approach include ignorance about the safety of storing water, the comparative low cost of municipal water the perception that water collection is the responsibility of a family's women and children. This report also found that a household using a Rainwater Harvesting scheme is likely to require some supplementary water on occasions. Furthermore, as the potential to catch *sufficient* water is a function of the ratio of a dwelling's roof area to the number of inhabitants, its efficacy is limited in densely inhabited poor communities.

Strong leadership and coordination would be necessary for a successful wide-ranging Rainwater Harvesting implementation project. In addition a coordinated educational programme will have to be conducted to dispel myths about stored water

and to create the required skills base. The statutes and bylaws regarding water would also have to be reviewed to avoid legal impediments.

This report concludes that rainwater harvesting cannot be relied upon to fulfill all the communities' water needs but it can go a long way to improving the general access to safe water and in so doing reduce the time and labour presently demanded, mainly of women and children, in the carrying of heavy loads of water.

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LIST OF ABBREVIATIONS

Abbreviation

ADB	African Development Bank
AGOA	African Growth and Opportunity Act
CIDA	Canadian International Development Agency
DFID	Department for International Development, UK Government
DRWH	Domestic Rainwater Harvesting
DTU	Development Technology Unit - Warwick University
FAO	Food and Agriculture Organization of the United Nations
GIS	Ground Information System
GOR	Government of Rwanda
GRP	Glass Reinforced Plastic
GTZ	German Technical Cooperation
HDPE	High Density Polyurethane
ICCON	International Consortium for Cooperation of the Nile
IWRM	Integrated Water Resources Management
KIST	Kigali Institute for Science and Technology
KSH	Kenyan Shillings
MINAGRI	Ministry Of Agriculture And Animal Resources
MINECOFIN	Ministry of Finance and Economic Planning
MINICOM	Ministry Of Commerce, Industry, Investment Promotion, Tourism And Cooperatives
MININFRA	Ministry Of Infrastructure
MINITERE	Ministry Of Lands, Environment, Forestry, Water And Mines
NBI	Nile Basin Initiative
Nile-COM	Council of Ministers of Water Affairs of the Nile Basin
Nile-TAC	Nile Technical Advisory Committee
NRBAP	Nile River Basin Action Plan
RMS	Rwanda Meteorological Service
RWH	Rainwater Harvesting
SAP	Subsidiary Action Programs
SAP	Subsidiary Action Programs (NBI)
SEARNET	Southern & Eastern Africa Rainwater Network
SINELAC	Societe Internationale des Pays des Grand Lacs
SVP	Shared Vision Programs
SVP	Shared Vision Programs (NBI)
SWSI	Social Water Stress Index
TDS	Total Dissolved Solids
TZS	Tanzanian Shillings
UNCHS (Habitat)	United Nations Human Settlements Programme
UNDP	United Nations Development Project
UNECA	United Nations Economic Commission for Africa
UNEP	United Nations Environmental Projects
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNHCR	United Nations high commission for Refugees
UNICEF	United Nations Children's fund
USS	Ugandan Shillings
WB	World Bank
WEDC	Water, Engineering and Development Centre
WES	Water and Environmental Sanitation
WHO	World Health Organization
WMO	World Meteorological Organization
WSS	Water and Sanitation Schemes

*Here there is no water but only rock
Rock and no water and the sandy road
The road winding above amongst the mountains*

*.....
If there were rock
And also water
And water
A spring
A pool amongst the rock....*

TS Eliot 1922 The Waste Land.

1. INTRODUCTION

The motivation for this research came from living in Kigali, Rwanda, and contending with the daily frustration of an erratic water supply while at the same time experiencing regular torrential down pours. Realizing that I was still vastly better off than a large section of the city's population, who have no piped water, few water "kiosks" and are reduced to collecting surface water in densely inhabited areas, I felt it essential to investigate the possibility of harvesting the bountiful free rain water.

1.1 Aim Of Research

This report sets out to investigate the appropriateness of introducing a broad based application of the techniques of Rainwater Harvesting (RWH) in Kigali, the capital city of Rwanda, as a supplementary source of water.

The validity of this research can be supported by the following fact:

- The current piped water supply to the city is 15,000 m³/day and the present estimated demand is 40,000 m³/day with the balance being made up from unsafe surface water and springs
- The country is one of Africa's poorest and lacking in significant natural resources, therefore any alternative to conventional high capital intensive and power consuming water supply schemes should be investigated.
- The low technological basis of Rainwater Harvesting holds the potential for skills transfer and job creation.

In order to address these problems it will be necessary to:

- A. review the water demand and existing water supply within the city of Kigali as well as issues of health, sanitation and the environment and their nexus with the surface water resources,
- B. review the developments in the technology of rainwater harvesting internationally,
- C. investigate the social, administrative, financial and political issues affecting the introduction of Rainwater Harvesting ,
- D. address any major impediments to the introduction of this technology on the scale required.

1.2 Limits of Research

This research does not aim to arrive at a categorical statement supporting or rejecting the approach under investigation. The aim is rather to review the status of the water supply to the city as well as social, climatic and other factors that might have an affect on the success introducing Rainwater Harvesting

The report does not present a comprehensive financial feasibility analysis but instead reviews some of the costs involved in implementation and the complexities of the economics of water supply to an undeveloped country.

1.3 Abbreviations

Abbreviations where used in the report will be explained in the text and listed in the List of Symbols. The most commonly used abbreviation is RWH which is used to replace the term *Rainwater Harvesting* as the generic term for the technology of collecting and storing rainwater for human use at some future time.

1.4 Methodology Adopted

The approach adopted was first to establish the facts regarding access to water in Kigali as well as water usage patterns and associated health issues. To do this, I met with management officials of Electrogaz, the state owned water and electricity utility company who are the sole suppliers of piped water to the city.

I contacted public health officials at the Kigali office of the World Health Organization (WHO) to establish the prevalence of water born diseases and particularly the incidence of diarrhea and blood diarrhea, which might indicate limited access to safe water. I met Mr. Jean Pierre Ruhira who is in charge of Protection de l'Environnement Humain and Dr Bosco who supplied the diarrhea survey data.

I conducted my own field research into the water collecting habits of the Kigali citizens in some of the poorer areas of the city. I investigated prices and spoke to local water vendors and bailiffs.

With regard to climatic information, I visited the Rwanda Meteorological Service to gather data on weather and rainfall patterns and got significant assistance from Mr. Alphonse Mutabazi, the Principal Investigator.

To establish what had been done in the line of rainwater collection and utilization in and around Kigali, I made contact with the Kigali Institute of Technology (KIST) where I met Mr. Ainea Kimaro who is the lead researcher in appropriate technologies including RWH. Ainea was of great assistance and showed me a scheme he had designed and implemented at a local school. (Ainea recently received the Special African Award in the Annual Global Environmental Awards for work done by KIST on small-scale energy projects.)

To establish what progress has been made internationally on the use and implementation of RWH, I read extensively on the subject and attended a

course on RWH in New Delhi. The course presented an opportunity to gain practical knowledge on the design of RWH schemes and to hear of the successes and the difficulties India is experiencing with implementing RWH on the subcontinent on a large scale. The course, which lasted 4 days (13-16 June 2005), was conducted by the Center for Science and Environment, CSE.

To test the political thinking on water issues in Rwanda, I met with Mr. Bruno Mwanafunzi, Director of water resources in the Ministry of Land, Environment, Water and Mines (MINITERE). The aim of the meeting included finding out about developments in the National Water Policy, the legal status of water and current water management strategies in Rwanda.

Finally, I conducted a survey of material and labour costs to establish parameters for implementation costs for an average domestic RWH installation in Kigali.

1.5 Kigali Contextualized.

1.5.1 Topography and demography

Lying southwest of Lake Victoria in Central Africa, Rwanda is situated between Longitude: 29°35 East and 29°50 East and Latitude: 1°44 South and 1°23 South in the Great East African Plateau which rises from swamps and lakes in the East to the highlands in the Northwest and Southwest. Rwanda is a very small mountainous country and is



**Fig. 1.1 Rwanda and its Neighbours
(Modified from Stevenson and Fanshore)**

bordered in the North by Uganda, to the West by the DRC, to the South by Burundi and by Tanzania in the East. A little larger than South Africa's Kruger National Park at 26,340 km², Rwanda is inhabited by 8.1 million people (3rd Rwandan General Census November 2003), which gives the country one of the highest population densities on the continent (308 people per km²). The reason for the high population density is the suitability of the environmental conditions to human habitation including a temperate climate and well watered fertile soils. With a population growth rate of 2.9-2.8 % (CIA Fact File/World Bank), the country's 2003 population is expected to double by around the year 2028.

1.5.2 History

The burgeoning population associated environmental degradation and competition for arable land lead inevitably to social tensions that have erupted sporadically over the last century and catastrophically in 1994 when genocide was perpetrated by extremist ethnic Hutus on the minority Tutsi and moderate Hutu citizens. Rwanda's social instability forms part of a greater socio-political turmoil that has plagued the Great Lakes Region for decades. Because of the complexity of the regional and domestic conflicts, the details and manifestation of the resulting social problems will not be explored here further than is necessary in order to indicate their relevance to civil structures, service delivery and water security.

Kigali became the capital of Rwanda in 1962 when the Belgian colonial control over the Ruanda-Urundi territory ended and the territory was divided to form the independent nations of

Rwanda and Burundi.



Fig. 1.2 Typical Kigali Topography (Author's Photograph)

After the former village was chosen as the seat of government, it grew rapidly and now sprawls over the steep hills and valleys, which are typical of the region's topography.

The genocide, which started on 6 April 1994 when president Habyarimana's plane exploded in the skies above Kigali, ended in the early days of July 1994 leaving Kigali and Rwanda shattered – physically, socially and administratively. In the order of 200,000 of Kigali's citizens lay dead* and the majority of survivors had fled the city and even the country. The city slowly rebuilt itself as foreign assistance (belatedly) flowed in and people returned to the city, many from the Tutsi diaspora in Uganda, Kenya and Burundi who had fled Rwanda in the late 1950's. These returnees, enthusiastic but often inexperienced, slowly filled the many vacancies in the management of the city and the country.

* (It is estimated that in excess of 800,000 people in total throughout Rwanda lost their lives in the 100 days of killing after 6 April 1994.)

1.5.3 Present

Kigali today is the capital of one of the poorest countries in the world with an economy predominantly based on agriculture and foreign aid. 90% of the Rwandan population lives in the rural areas and owes its livelihood to subsistence farming. There are almost no economically exploitable minerals besides some tin deposits. According to Prof. Silas Lwakabamba, the Founding Rector of the Kigali Institute of Science, Technology and Management (KIST), the country lacks skilled personnel and there is a low level of technical training with little innovation in the fields of technology, communication, environment and economic development.

On the whole, however, the traumatized nation has made admirable progress in the last 11 years under the wise, if at times severe, leadership of a new government presently led by Mr. Paul Kagame. Rwanda's first post-genocide local elections took place in March 1999 and its first presidential and legislative elections in August and September 2003. President Kagame

won 95% of the vote but the European Union observers claimed that the presidential election was "not entirely" free and fair. However, as observed by the EU, it was "an important step in the democratic process".

With regard to fiscal affairs, Rwanda, as one of the world's Heavily Indebted Poor Countries (HIPC), has acted with commendable discipline. Rwanda's public debt at the end of 2003 was estimated as \$1572,5 million in face value according to the IMF. The Rwandan authorities have been wise to act in a responsible manner with foreign funds as more than 50% of the GDP comes in the form of foreign aid and conforming to the IMF's economic prescriptions and the rules of the World Bank are a prerequisite for future assistance and debt relief. The country's disciplined fiscal approach is bearing dividends. The debt owed to Paris Club, an informal group of creditor governments from major industrialized countries, was estimated to be \$90.4 million including EU loans as of end March 2005. This debt was totally cancelled under a debt relief programme on May 17 2005. In July 2005 the African Development Bank recognized that Rwanda had satisfactorily implemented reforms agreed to and provided debt relief of a further \$244 million.

The visit of the new World Bank (WB) President, Paul Wolfowitz, to Rwanda in June 2005 was another good sign that the country will continue to enjoy access to foreign capital and benefit from programmes such as the WB's Integrated Management of Critical Ecosystems (IMCE) project.

What is noticeable in Rwanda is the disturbing disparity between the affluent and the poor. There is also little evidence that issues such as poverty alleviation, environmental degradation and the preservation of the diminishing natural resources are receiving meaningful attention. While it is understandable that the turmoil of recent years has created priorities other than sound environmental management, it is essential that the country's leadership now lifts the populace out of poverty and steers them towards the sustainable use of the remaining resources.

1.5.4 Towards The Future

In time of mass urbanization, failing service delivery, obsolete colonial era water schemes, structural adjustment linked loans, calls for fiscal maturity and 100% cost recovery, water goes to *all who can pay* and further disillusionment and misery goes to those who cannot. Leaders of developing countries must accept that the replication of western practices is often unrealizable and sustainable homegrown solutions should be encouraged. My hope is that this thesis will be of some help in steering Rwanda towards seeking and adopting sustainable practices and technologies thus ensuring that, at least with regard to water, there is at least "*a little for all*".

2. FORMULATION OF THE PROBLEM

2.1 An Overview Of Kigali's Water Needs And Water Supply

2.1.1 Population and water demand

In 2002 Rwanda carried out a General Census of Population and Housing. This was commissioned by the Ministry Of Finance And Economic Planning and first published in August 2002, some of the statistics will be discussed later.

With regard to the population of Kigali, the following is an extract from the final version of the census dated November 2003.

Table 2.1 Rwanda Population Figures (Rwanda Census 2002)

<i>Place of residence</i>	<i>Male</i>	<i>Female</i>	<i>Total</i>
<i>Rwanda Total</i>	3,879,448	4,249,105	8,128,553
<i>Kigali City</i>	325,778	277,271	603,049
<i>Kigali Ngali</i>	370,910	418,420	789,330

The distinction between Kigali City and Kigali Ngali (Kigali region) is intended to make the distinction between the city dwellers and the peri-urban residents living in close proximity to the city. From a services point of view, this division is not very clear as many peri-urban and urban dwellers commute to the city daily. With regard to water, it is a certainty that a significant portion of the water intended for the 600,000 city dwellers ends up with the 800,000 in the environs. It is difficult therefore to define the target population other than to say it is between 600,000 and 1,400,000.

The age of the water consumers has a bearing on future demand and as can be seen from figure 2.1, an estimated 43.7% of the population is under 15 years of age. As this sector ages a significant increase in water demand can be expected.

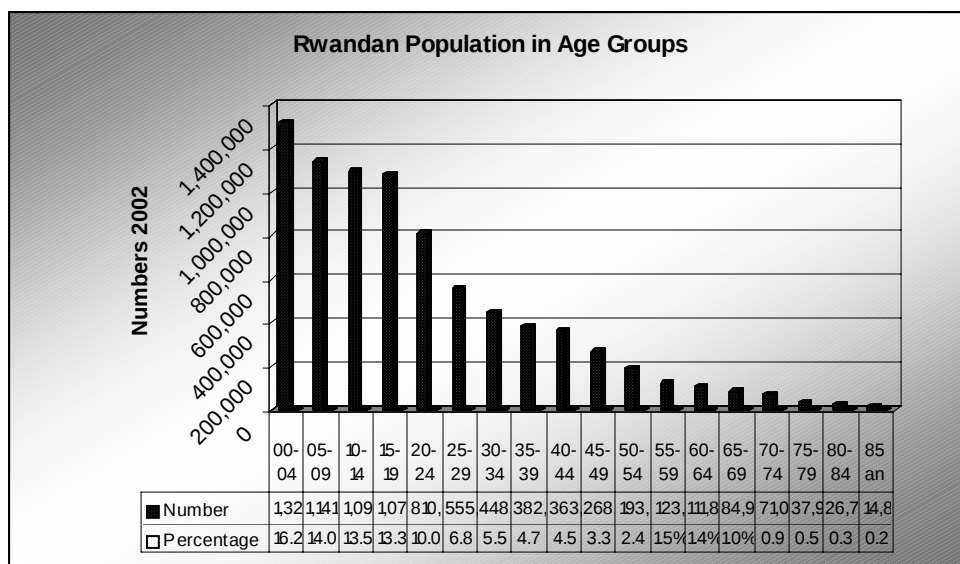


Figure 2.1 Age Categories of Rwandan Population (Rwanda Census 2002)

The population figures in the census are in line with what might have been predicted. The water supply statistic, however, need to be reviewed with some caution as according to the census, 51.2% of the urban dwellers have access to piped water in the compound as shown in table 2.2.

Table 2.2 Urban Household Water Sources (Rwanda Census 2002)

Major Urban Water Source excluding peri-urban population	Number of homesteads	Population	Percentage
Rwanda Total	272,981	1,249,444	
Pipe borne water in the dwelling	7,119	41,797	3.30%
Pipe borne water in the Compound	30,510	164,081	13.10%
Pipe borne water out of Compound	97,502	435,257	34.80%
Protected Spring/Well	81,316	361,637	28.90%
Unprotected Spring/Well	29,200	127,847	10.20%
Rain Water	92	423	0.00%
River	11,556	50,993	4.10%
Lake/Stream/pond/ surface water	10,972	47,407	3.80%
Other.	1,217	5,205	0.40%
NS.	3,497	14,797	1.20%
Total Treated water		641,135	51.30%
Total Untreated water		608,309	48.70%

At face value these statistics imply that 50% of the city's population has access to piped water either in the house, in the yard or from a community tap. What they don't show is how often there is water in the taps. This underlies the danger of such statistics, which make the situation seem better than it is. They are particularly dangerous when used by administrators who, by adding taps, just stretch the water resource thinner and further.

Field results are the only reliable platform for reality-based policy and planning but at this point, there are no meaningful field survey results for Kigali. It is thus necessary to estimate what the cities water demand would be in a situation in which everybody had easy and equal access to treated water at a reasonable price. To do this it is necessary to make some assumptions starting with average water consumption per capita.

To arrive at a reasonable estimate, water consumption figures and trends researched for Africa will be compared with those of other developing countries.

Africa. Various individuals and bodies have researched figures of water consumption in Africa and a few of the results are shown below:

Table 2.3 Water Consumption Patterns in Africa (Sources various 1972-2003)

The Mean Daily Per Capita Water Used on Piped Sites l/p/d - litres per person per day	Mean Daily Per Capita Water Used In Un-piped Households l/p/d	Source
47.4 (down from 121 - 1972)	22.3 (up from 8.3 – 1972)	Drawers of Water II (Katui-Katua et al 2001)
	25	Minister Ronnie Kasrils South Africa October 2000 Water Lifeline
In Africa, household water use averages 47 litres per person per day. (UNFPA 2000)		Food And Agriculture Organization (Rathgeber 2003)

It is significant that in my meeting with the International Committee of the Red Cross (ICRC), (see Appendix A), Mr. Luc Soenen said that from his observations in Rwanda over many years, the daily consumption of water never rises much above 20l/p/d even when water is plentiful. He was referring to un-piped water and his observations come from the many and varied water projects run by the Red Cross in Rwanda.

The Red Cross has provided food and assisted with water and sanitation facilities to prisons across Rwanda since 1994 when suspected genocidaires were first imprisoned. The numbers peaked at 143,021 in 1998 (Human Rights Watch) in the prisons collectively designed to hold 46,700. The prisons are still massively overcrowded after 11 years (87,000 in 2004) and few of the detainees have enjoyed an opportunity to plead their case or have access to legal representation.

Today the water supply to most of the prisons is much improved but, Mr. Luc Soenen says, the inmates get between 10-15 litres of water per day for *all* their needs in their cramped confinements. As shocking as this situation is, it clearly tests the low end of man's water requirements. The Red Cross says that from their observations serious health consequences can be expected as soon as the supply drops below 10 l/p/d.

For comparison some water consumption figures are presented here from other countries and regions:

India. A.Vaidyanathan and J Saravanan conducted a large-scale survey of the water consumption in Chennai Corporation in 2003/4 (Vaidyanathan 2004). This showed that the total volume consumed per capita was considerably less than that assumed as a national norm i.e. 120 l/p/d (litres per person per day).

Table 2.4 Indian Water Consumption (After A Vaidyanathan and J Saravanan)

Income (Per month)	Drinking	Cooking	Washing	Bathing	Toilet	Other	Total l/p/d
< \$115	4.6 (9%)	5.0 (10%)	18.0 (36%)	13.4 (26%)	8.1 (16%)	0.8 (2%)	49.9
\$115 - \$230	4.2 (7%)	5.2 (9%)	22.7 (37%)	16.6 (27%)	11.6 (19%)	1.3 (2%)	61.6
\$230 - \$345	3.4 (5%)	4.6 (6%)	33.5 (46%)	16.8 (23%)	13.4 (18%)	1.2 (2%)	72.9
\$345 - \$460	2.9 (4%)	4.4 (5%)	39.7 (49%)	17.1 (21%)	13.2 (16%)	3.4 (4%)	80.7

Other Countries. Table 2.5 below shows some general published figures of national water consumptions from other countries for comparison.

Table 2.5 Water Consumption - Other (FAO)

Country	Consumption l/p/d
American (USA)	500 - 578
United Kingdom (UK)	334
Singapore	170

From the above it would be fair to say that if the population of Kigali was divided into three groups of upper, middle and lower income then one might expect consumptions in the region of 140, 47 and 25 l/p/d in the three groups respectively.

This assumption was validated during my meeting with Electrogaz (See Appendix A) when Mr. Laenge said that 7% of their Kigali clients consume for 50% of the water produced. As they are selling 17,000 m³/day, allowing 30% losses, and assuming a client base of 800,000, this would imply a top end consumption of 140 l/p/d.

Thus assuming an adequate supply and access to purified water the demand can be calculated as follows:

Table 2.6 Kigali's Theoretical Water Consumption

Group	Population		Consumption m ³ /day	Consumption l/p/d
Upper	56,000	7%	7,840	140
Middle	344,000	43%	16,168	47
Lower	400,000	50%	10,000	25
Total	800,000	100%	34,008	20

So far this analysis has neglected the industrial and commercial water demand. Although this sector is relatively small, their water use must be allowed for. The total demand is thus probably in the region of **40,000 m³/day**.

So the theoretical shortfall is in the order of 22,000 m³/day (40,000-17,000 m³/day) and city residents make up the shortfall by collecting water from springs and unsafe surface water sources.



**Figure 2.2 Unsafe Water collection
Kigali (Author's Photograph)**

2.1.2 Cost Of Water

Treated water is supplied and sold exclusively by the public utility company Electrogaz as detailed below. Electrogaz sells water by means of:

- metered house connections
- water kiosks
- road tankers delivering water in bulk.

Kigali's citizens can also purchase water from other sources including:

- municipally controlled springs
- private water vendors who store and re-sell Electrogaz's water.

Electrogaz's tariff for piped domestic water is currently based on a *rising block tariff* in which the unit cost of water increases as consumption increases. This is intended as a form of cross subsidy to assist the poor. Unfortunately the really poor and the rest of the un-serviced 50% of the citizens of Kigali do not realize this benefit, which goes instead to those lucky enough to get their water in pipes – and this is normally the middle and upper income groups. The structure is illustrated in table 2.7 below.

Table 2.7 Eletrogaz's Water Tariff (Source: Eletrogaz)
(\$1= 570RWF = 1710 USS = 75 KSH [2005])

<i>Type of supply</i>	<i>Cost</i>	<i>Volume L</i>	<i>Cost per Litre</i>	<i>Cost per M3</i>
KIGALI				
<i>Tanker delivery</i>	RWF 35,000.0	17,000	RWF 2.1	\$3.68
<i>Kiosk</i>	RWF 30.0	20	RWF 1.5	\$2.68
<i>Controlled Spring</i>	RWF 100.0			
<i>Controlled Spring collect with wheelbarrow</i>	RWF 300.0			
<i>Piped <25m3</i>	RWF 200.0	1,000	RWF 0.2	\$0.36
<i>25-35</i>	RWF 300.0	1,000	RWF 0.3	\$0.54
<i>34-40</i>	RWF 350.0	1,000	RWF 0.4	\$0.63
<i>>40</i>	RWF 375.0	1,000	RWF 0.4	\$0.67

Table 2.8 Water Tariff in Neighbouring Countries
(Source: direct enquiry) (\$1= 1020TZS = 75 KSH [2005])

<i>Type of supply</i>	<i>Cost</i>	<i>Volume L</i>	<i>Cost per Litre</i>	<i>Cost per m³</i>
<i>Kampala Kiosk 1</i>	USS 50.00	20	USS 2.50	\$1.46
<i>Kampala Kiosk 2</i>	USS 200.00	20	USS 10.00	\$5.85
<i>NWSC Piped</i>	USS 1,000.00	1000	USS 1.00	\$0.58
<i>Kenya (0-10m³)</i>	KSH 12	1000	KSH 0.012	\$0.16
<i>Kenya (10-30m³)</i>	KSH 18	1000	KSH 0.018	\$0.24
<i>Arusha Tanzania Kiosk</i>	TZS 10.00	20	TZS 0.50	\$0.48

As can be seen by comparing the above tables, the present piped water pricing in Rwanda is very favourable when compared to neighbouring countries. If one takes a middle class home of 5 using 120l/p/d on a piped water supply (i.e. consuming 18 m³/month), the relative monthly water bills in the three centres would be:

- Kigali \$6.43
- Kampala \$10.44
- Nairobi \$ 4.32

But as stated above the wrong people are being subsidized and the really poor must buy water from vendors at a price that is up to seven and a half

times (x 7.5) that of a piped connection. This is a worldwide trend as can be seen in Table 2.9 prepared by UNCHS. It is thus hard to believe that privatization will help this large section of the population.

Table 2.9 Poor Pay More (Source Various)

City	Those connected to municipal supplies (\$ /m3)	Urban poor pay to private vendors (\$/ m3)
Nairobi, Kenya	0.30	1.50-2.00
Port au Prince, Haiti	1.00	5.50-16.50
Jakarta, Indonesia	0.09-0.50	1.50-2.50
Lima, Peru	0.15	3.00

What happens in reality regarding the poor is that they limit the quantity of purified water they purchase to essential drinking and cooking water and substitute with less safe water from springs and rivers for the balance of their water requirements. The undesirability of this arrangement is the obvious inequality of the pricing structure and the health risks. Collecting water from any source has been shown to have inherent health risks by contamination during the handling and from the containers themselves. This risk is compounded when the same containers are used for “safe” and “unsafe” water.

As an associated environmental factor, it is interesting to note the observation by Dr Czekalla (Lahmeyer International) (See appendix A) that it is customary in Kigali to boil **all** water intended for consumption. His contention is that as Electrogaz’s water is treated and sterilized. This is not necessary and by discouraging the practice, which invariably requires the use of charcoal, a significant environmental impact could be mitigated.

Due to GOR’s expressed intention to unbundled Electrogaz and to lease out the service provision to a private contractor, the national policy of providing water to all at a price which they can afford will have to be reconciled with the need for the private company to recover costs and record a profit.

The collective experience world wide, and particularly that in developing countries, on the question of privatizing water (Hall, et al, 2002 and Budds, et al, 2003) would indicate that privatization would not produce any turn around in the present level of water supply. On the contrary this approach has been shown to impact negatively on the provision of water to the poor.

South African Mail & Guardian 10 November 2004

A parliamentary committee has recommended South Africa's free basic water (FBW) policy be "re-determined" to exclude those who can afford to pay for their water supply.

The FBW policy currently provides, free of charge, 6 000 litres of water per household per month to more than two-thirds of South Africa's population.

Although the primary intention of the scheme is to ensure no one is denied access to a water supply simply because they are unable to pay for it, many urban service providers have included all their area's consumers within the scheme through a system of "rising block tariffs".

2.1.3 Water resources

Water availability and distribution. Rwanda's renewable water resource is estimated by the Food and Agriculture Organization of the United Nations (FAO) to be 5.2 km³/year as shown by AQUASTAT, a global database of water statistics maintained by FAO.

By contrast Gleick has estimated the source to be 6.3 km³/year, as can be seen in table 3.9 below. (Gleick, 1998).

Table 2.10 Rwanda's Renewable Water Resource (P.H. Gleick)

Region and Country	Year	Renewable Water Resources	Total Freshwater Withdrawal	Estimated Year 2000 per capita Withdrawal	Domestic Use	Industrial Use	Agricultural Use	Domestic Use	Industrial Use	Agricultural Use
		Km ³ /yr	Km ³ /yr	(m ³ /p/yr)	(%)	(%)	(%)	m ³ /p/yr	m ³ /p/yr	m ³ /p/yr
Rwanda	1993	6.3	0.77	100	5	2	94	5	2	94

Whichever figure is correct, only 12-15% of the renewable water is currently extracted. There is clearly then not a *Water Shortage* defined as an absolute shortage where there is not enough water to meet the needs of the country, but instead there is a shortage of supply of water at a reasonable quality in certain areas.

The term *Waters Scarcity* has been defined to cover this situation, which is partly a social construct as it is determined by the availability of water as well as by consumption patterns. This *Water Scarcity* is a relative concept describing the relationship between the demand for water and its availability. It varies largely between counties depending on their water use patterns and their sectoral usage.

Causes of water scarcity may include:

- Population growth
- Food production
- Climatic change and variability
- Land use
- Water quality
- Water demand
- Sectoral resources and institutional capacity
- Poverty and economic policy
- Legislation and water resource management
- Topography
- Sectoral professional capacity
- Political realities
- Sociological issues

The United Nations and others acknowledge that a shortage of water is a severe constraint on socio-economic development and environmental protection. They set as a threshold an internal renewable water availability of less than 1 000 m³/capita below which a country is regarded as having water scarcity. In Rwanda with its present population of 8.1 million, the present ratio is thus 640-775 m³/capita/year

As Len Abrams states (Abrams L.) however, adopting a global figure to indicate water scarcity must be done with caution. Whilst a threshold such as $1000\text{m}^3/\text{capita}$ may be useful for purposes of comparison, it should be carefully used because it may understate situations of potentially serious water shortages.

Rwanda's problem is not as much one of water resource scarcity as a problem of quality and scarcity of supply.

If *Water Stress* is defined as the symptomatic consequence of *Water Scarcity* exhibited as increasing conflict over sectoral usage, a decline in service levels, crop failure, food insecurity, and then Rwanda can definitely be said to experience sporadic Water Stress. UNECSA and UNEP predict that Rwanda will be one of Africa's *Water Stressed* countries by 2025. The reasons for this are due to the environmental degradation (chiefly soil erosion) and the increasingly poor quality of the water due to pollution and sediment, population growth and the topography.

Rwanda is at the head of, and forms the watershed for, two major rivers - the Nile and the Congo. The main rivers in the Nile Basin are Mwogo, Rukarara, Mukungwa, Base, Nyabarongo and the Akanyaru, which are drained by the Nyabarongo that in turn becomes Akagera at the outlet of Rweru Lac. The waters of the Nile River Basin thus flow out of the country through the Akagera River, which is also the main feeder of Lake Victoria. The Akagera River contributes 9 to 10% of the total Nile Water and has an average discharge of $256\text{ m}^3/\text{s}$ (Kabalisa 2004)

The average discharge for some rivers is:

- Nyabarongo at Kigali: $78\text{m}^3/\text{s}$
- Nyabarongo at Kanzenze : $100\text{ m}^3/\text{s}$
- Akagera at Rusumo: $232\text{ m}^3/\text{s}$
- Akagera at Kagitumba: $256\text{ m}^3/\text{s}$

The main rivers for Congo Basin are the Sebeya, Koko, Ruhwa, Rubyiro and Rusizi rivers. The average discharge is estimated to be 48 m³/s with a low flow of 7 m³/s.

Rainfall will be further discussed more fully in section 2.7 so it suffices to say here that Kigali is situated in the central region of the country that experiences a rainfall of 1000-1100 mm/year. It is also located within 50 km of Lakes Muhazi, Mugesera, Rweru and Cyohoha Sud as well as the Akagera and Nyabarongo Rivers (Lake Ruhondo is less than 60km).



Figure 2.3 Rwanda's Rivers and Lakes
(Source: UN Peace Keeping cartographic section 2004)

The present water sources being used to supply Kigali in the order of importance are shown in Table 2.11 below.

Table 2.11 Kigali's Present Water Sources (Source: Electrogaz 2005)

Pump Station	Rated Capacity m3/day
<i>Kimisingara / Nyabarongo</i>	22000
<i>Karenge</i>	6000
<i>Rwampara</i>	1290
<i>Mburabuturo</i>	850
<i>Kizanye</i>	360
<i>Kinyinya</i>	288
<i>Jali</i>	240
Nominal Daily Capacity	31028

One of the problems of the present system as reported by Mr. Laenge of Electrogaz (Appendix A) is the siltation of the river intakes due to the heavy silt load in the rivers, especially after heavy rains.

Four new projects are currently envisaged to increase Kigali's water supply. These are intended to draw water from the:

- Nyabarongo river
- Yanze River dam
- Lake Muhazi
- Lake Mugesera

The cost of developing the Nyabarongo river source which is located to the west of the city is estimated at \$26- \$34 million and should add 1.15-1.5 m3/sec. (i.e. 1, 500- 2,000 m3/day). Like most rivers, the Nyabarongo carries a heavy sediment load as the river valley is intensely farmed.

Another alternative being considered is to pipe water 100 km from the Rubindi-Mutobo-Mpenge springs in the Ruhengeri region to Kigali. The cost of developing Rubindi-Mutobo water sources will require a capital investment of \$91- \$106 million. Being spring water, the quality of water is very good and it could possibly be used to bottle mineral water.

According to the International Committee of the Red Cross (ICRC), the Kimisagara source cannot cope with an increased water demand (Nembrini, et al 1997). The ICRC has done a lot of work in water supply to

the city and especially to the refugee camps and detention facilities since the early 1990s.

In a paper at the 23rd Water, Engineering and Development Centre (WEDC) Conference in Durban in 1997 the ICRC said that there was a need to increase the yield at the Mburabuturo pumping station, which then delivered 35 m³/h. They advocated a second pump with a pumping head of 196 m and the construction of a new drainage system together with a new collection well to increase the yield to about 60 m³/h. It can be seen from Electrogaz's figures that they are still only getting 850m³/day so it appears that the additional pump has not yet been installed.

It seems that while there are short-term solutions to Kigali's water supply they will come at a considerable expense and the long-term prospects are not positive. If the country is to advance without large and burdensome capital expenditure, creative solutions for water provision will have to be found. Kigali in particular will have to find ways to cope with the available water resources. The solutions will have to come from an integrated approach to water management whereby cognizance will have to be taken of such factors as:

- loss or misuse of water
- effect on the national water resource by erosion and environmental degradation.
- the effect on the water quality of urban pollution and lack of sanitation.

In seeking a solution to the problems of water supply the people of Rwanda will have to be resourceful and learn to adapt. As Leif Ohlsson and B. Appelgren of FAO have said: *Water scarcity is commonly perceived as an often absolute shortage of a natural resource, although, when regarded from a management point of view, it may be better described as a lack of adaptive capacity, and thus as a social resource scarcity.* (Ohlsson and Appelgren 1998)

The ability to adapt requires a broad and multi dimensioned approach including all elements of society sensitive to socio-economic development, human rights (including and stressing women's rights) and strengthening education and general institutional capacity.

2.1.4 Health and sanitation

In order to get an overview of Rwanda's state of public health, some of country's health indicators are presented below next to those of South Africa, Burundi, Kenya and Tanzania (TZN) for comparison.

Table 2.12 Comparative Health Indicators (Modified from : *World Development Indicators database*, 2004 – note other sources put HIV in Rwanda at +11.2%)

<i>Indicators 2003</i>	Rwanda	RSA	Burundi	Kenya	TZN
Population growth (annual %)	2.8	1.1	1.9	1.7	1.9
Life expectancy (years)	39.8	45.7	41.6	45.4	42.7
Fertility rate (births per woman)	5.7	2.8	5.7	4.8	5.0
Infant mortality rate (per 1,000 live births)	118	53	114	79	104
Under 5 mortality rate (per 1,000 children)	203	66	190	123	165
Child immunization, measles (% of under 1 year)	90	83	75	72	97
Prevalence of HIV, total (% of population aged 15-49)	5.3*	15.3	6	6.7	8.8

Rwanda is classified by the CIA (Central Intelligence Agency of the USA) as having a very high health risk with food/ waterborne diseases, bacterial diarrhoea, hepatitis A, typhoid fever and vector-borne disease including malaria as being the main health risks.

I met with the head of the Environmental Health unit of the Kigali WHO office, Mr. Jean Pierre Ruhira, who said that the WHO monitors the prevalence of *diarrhoea* and *blood diarrhoea* at a number of locations within Kigali. I was provided with figures for the last three years that are shown condensed in Figure 2.4. The reporting appeared to have been somewhat

sporadic, as stations did not submit returns for some periods. As a result the results should be seen as indicative only. In addition to this WHO advise that diarrhoea is under reported as only serious cases come to the clinics and there are reports that many households do not even consider mild childhood diarrhoea to be an illness (Opio 2003).

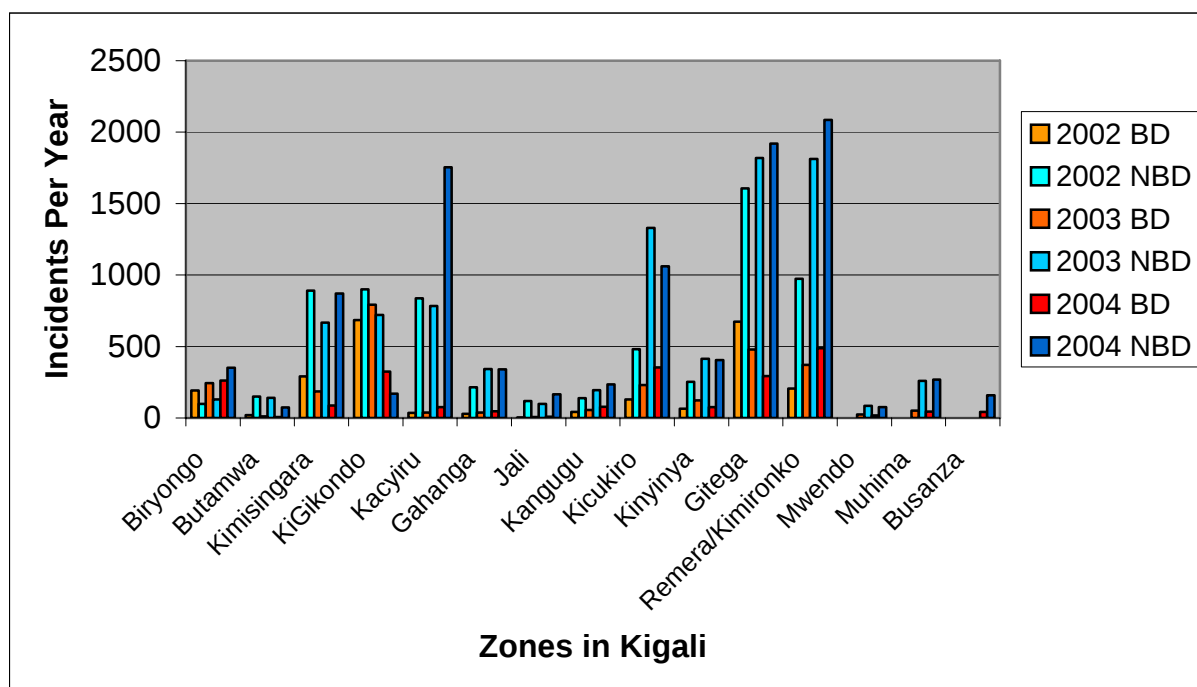


Figure 2.4 WHO Diarrhoea Records (2002-2004)
(BD/NBD – Blood Diarrhoea/Non Blood Diarrhoea)

Never the less the results can be said to indicate that:

- there are trends (2004 was a bad year and also a dry year)
- some neighbourhoods are worse affected than others.

The WHO estimates that 80% of all deaths in developing countries are related to water- and excreta-related diseases. The *Global Water Supply and Sanitation Assessment 2000 Report* approximates there to be 4 billion cases of diarrhoea each year causing 2.2 million deaths, mostly among children under the age of five. In addition it is estimated that water- and excreta-related diseases are responsible for the loss of around 400 million working days in Africa (UNDP). When translated into lost value this is a high price and investing in clean water and sanitation must be beneficial to

any national economy. Conversely, if a country does not invest in health their economy will not develop and their people will continue to die from their own wastes.

When viewing Rwanda's health indicators, one has to allow for the effect of the genocide in 1994. As quoted in the *National Poverty Reduction Programme June 2002*- the prevalence of HIV has increased dramatically partly as a consequence of large-scale population movements and the use of rape as a weapon. The prevalence is 11.2% nationally and 10.8% in rural areas, compared to a rate of 1.3% in rural areas in 1986.

The National Poverty Reduction Programme (GOR 2002) goes on to say that child mortality fell from 233 :1000 in 1980 to 140 :1000 in 1990, and then rose very sharply to 219:1000 during the period of the genocide. This data omits most of the mortality directly attributable to the genocide itself. The rate has since fallen back to 196:1000 implying that almost 1 of every 5 children in Rwanda dies before they reach their fifth birthday. In comparison, there has been a dramatic fall in child mortality internationally during this period. Rwanda's rate of child mortality is worse than the average for sub-Saharan Africa.

According to the WHO, dysentery and malaria are the major causes of death followed by pneumonia. Only 21% of women give birth with the assistance of health personnel while the majority relies on neighbours.

Several factors contribute to the failure to achieve optimum health standards in the population including deficiencies in:

- health facilities
- health education
- health personnel
- funds and lack of medical supplies.

Sanitation. There is effectively no municipal water-borne sewerage service in Kigali. The statistics in the census indicate a very high percentage of the population having access to latrines see Table 2.12. It has been found

however, that even in the Water and Environmental Sanitation project, 0.8 percent of these are *hygienic* and safe hygiene sanitation practices are not prevalent (GOR National Poverty Reduction Programme 2002).

It is easy to see by casual observation (and smell) that improving the levels of sanitation is not enjoying a high level of support. Even in the more affluent suburbs it is common practice for some households to discharge black water directly into the storm water system.

Table 2.13 Types of Toilet Facilities in Urban Dwellings (Rwanda Census 2002)

TYPE OF TOILET FACILITIES IN URBAN RWANDA			
	Number Of Households	Population	Households %
Flush Toilet	6,073	35,912	2.2%
Private Latrine.	176,079	871,114	64.5%
Public latrine.	82,448	311,125	30.2%
In the bush	2,217	7,910	0.8%
Other.	2,832	9,323	1.0%
NS.	3,332	14,060	1.2%
	272,981	1,249,444	

The need for properly designed sewerage facilities to interrupt the transmission of faecal–oral disease at its most important source by preventing human faecal contamination of water and soil is essential. While evidence suggests that sanitation is at least as effective in preventing disease as improved water supply, it involves major behavioural changes and significant household cost.

The need for sanitation to be addressed with equal vigour as that applied to water supply is for the protection of the environment. Sanitation systems should neither pollute ecosystems nor degrade scarce resources such as water sources.

The problems of sanitation in Kigali are beyond the scope of this report other than to recognize the inseparable link between water supply and sewerage disposal. In Kigali plans to increase quality and coverage of

sanitation facilities will have to be addressed along with those concerned with water supply.

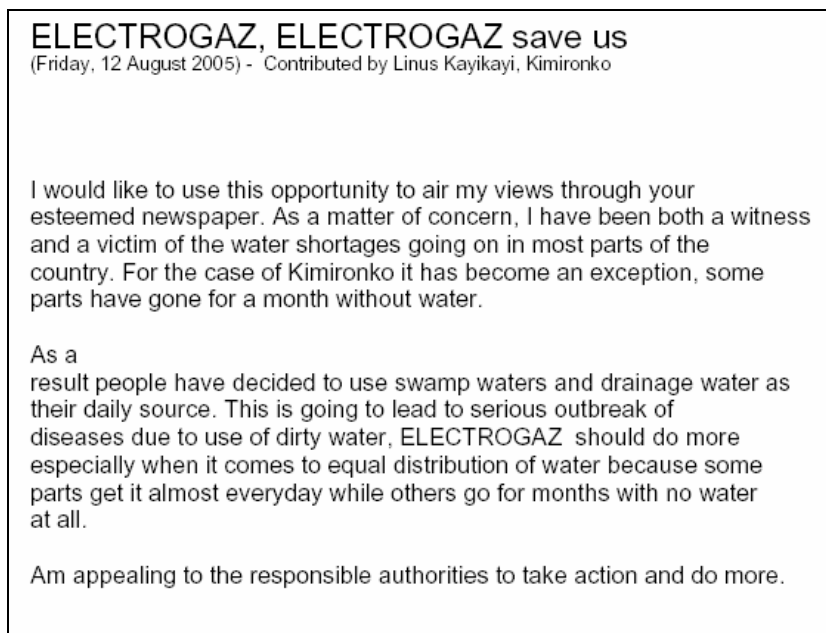


Figure 2.5 New Times Article on Electrogaz 2005

2.1.5 Governance – who controls Rwanda’s water

As clarified in my meeting with Mr. Bruno Mwanafunzi (Appendix A) the director of Department of Water and Sanitation in the Ministry of Lands, Environment, Forestry, and Water and Mines (MINITERE), the control of Electrogaz falls under MINITERE which is the main ministry in charge of water resources and supply.

Other GOR ministries that have an influence in water supply include:

- MINICOM Ministry of Commerce, Industry, Investment Promotion, Tourism and Cooperatives.
- MININFRA Ministry of Infrastructure
- MINALOC is the Ministry of Local Government, Community Development and Social Affairs
- MINAGRI Ministry of Agriculture And Animal Resources
- MINEDUC Minister of education
- Ministry of Health

As the country is heavily dependent on foreign aid, both financial and technical the donors and development partners have a large influence on issues relating to water and water resourcing. (See section 2.2.6)

2.1.6 Electrogaz : present services and privatization

The supply of water in Kigali as well as the production and distribution of electricity throughout the country are currently managed by the public company, Electrogaz. Electrogaz was originally registered



Figure 2.6 Electrogaz Purification Works

as a public enterprise for the production, transmission/transport and distribution of electricity, water and gas on 20th April 1976 by Government decree N° 18/76. Despite persistent efforts to improve its services through the late 1990s, Electrogaz's situation has deteriorated steadily in recent years.

It is estimated (Ministry Of Finance And Economic Planning) that in 2004, only 50% of the country's population had access to safe drinkable water and that a major part of that was supplied by installations constructed by international organizations and run by the communities.

The Ministry Of Finance And Economic Planning (MINECOFIN) also estimates that in Kigali, where Electrogaz has the monopoly on water provision, only 40% of the demand for water is met by reticulated water supply. This is a less generous scenario to that suggested on Table 2.2. This could be accounted for by the wide spread use of road tankers which are contracted by those who can afford them to deliver water to their homes when there is no water in the pipes.

On the 30th of August 1999, the government of Rwanda promulgated Law N° 18/99 that scrapped the monopolistic powers of ELECTROGAZ to produce and distribute water and to encourage private investors to participate in this process. This followed an earlier resolution in 1998 at a comprehensive sector reform programme to improve the cost and efficiency of the water service.

Envisaged in this was:

- abolition of the monopoly of Electrogaz
- restructuring Electrogaz
- encouraging private investment
- creating a multi-sector regulatory body (initially for the sectors of water, energy, gas and telecommunications)

Due to the poor financial and operational conditions of ELECTROGAZ, the Government decided on a phased privatization strategy. Within this context, Lahmeyer International was awarded a contract to manage ELECTROGAZ for five years, with the aim to restructure and expand the Rwandan electricity and water system so as to create a corporate enterprise suitable for private investment. This latter aim is seen as a key factor for Rwanda's economic growth and social stability.

From report in Energy Management News March 2004

Lahmeyer International takes over the management of Rwanda's electricity and water supply

Lahmeyer International (LI) GmbH, Germany's largest engineering consultant in energy has taken over the Management of the electricity and water company Electrogaz in Rwanda. The Management Contract forms part of a comprehensive reform



 **Lahmeyer International (LI)** bietet als unabhängiges Ingenieur- und Consultingunternehmen ein umfassendes Spektrum von Planungs- und Beratungsleistungen für technische und wirtschaftliche Projekte in den Bereichen Energie, Wasser, Transport, Infrastruktur, Umwelt und Technologie - weltweit.

 **Lahmeyer International (LI)**, is an independent consulting engineering company offering consultancy services for all stages of projects world-wide in the fields of Energy, Water, Transportation, Infrastructure Development, Environment and Technology.

program aiming at the privatization of the public sectors Energy and Water, Telecommunication and the Tea Sectors.

Only few weeks after handing over the management of Electrogaz to the private operator, the World Bank and other development banks are now willing to provide large scale financing for new infrastructure in the energy and water sector in Rwanda.

Lahmeyer International GmbH in cooperation with Hamburg Waterworks has been assigned by the Rwandan Government to manage Electrogaz during the period of 2003-2008. The reason for this was their experience in energy and water supply, the long standing experience of LI in Rwanda and the concept that envisages the restructuring of the company's processes in cooperation with the employees of the utility.

For satisfying the electricity demand, Electrogaz has at present only an installed capacity of 28 MW, largely based on hydropower. The water supply system shows technical and non-technical losses of more than 50% of m³ 15 million produced. Consequently the costs of power and water production were higher than the revenues during the last years.

The work program for LI comprises first an in depth analysis of the situation of all departments of Electrogaz and then a reliable demand forecast for energy and water. A loss reduction programs will be implemented as well as the rehabilitation of power and water production and distribution and a general system expansion.

Finally, the new management will advise the Government of Rwanda on setting up privately financed power projects.

LI will improve the commercial areas of the company by improving the accounting, controlling and planning systems. The program for the reduction of non-technical losses will reduce the consumption of energy and water by non-registered clients as well as detect deficient invoicing and collection procedures.

In the Human Resources area LI will implement specific training packages for capable young professionals within Electrogaz.

For the Management and the connected work program, LI has assigned the General Manager, the Chief Financial Officer, the Director Power Operations and temporarily the Head of the Commercial Department. The Management will be supported by short term experts covering the areas of demand forecast, financial analysis, system planning, transmission and distribution, hydro power and diesel power generation, water supply, IT and training.

The objective of the Management Project is to improve significantly the technical, commercial and consequently financial situation of the company. This will, apart from the necessary commitment of the donor community, pave the way also for private investors. The public and private financing of investments in long-term rehabilitation and expansion measures of the electricity and water supply will contribute to the future economic growth and social stability in Rwanda.

Figure 2.7 Lahmeyer - Managers of Electrogaz

The existing developed water sources for Kigali are shown in Appendix F with the month's production in May 2005. The bulk of the supply (70%)

comes from one source, the Kimisagara & Nyabarongo intake. Electrogaz personnel explained to me that their losses are 30% (water loss and non metered).

It can be seen that the stated production of 17,000 m³/day is feasible assuming the loss rate is correct. Electrogaz claim that the piping network is generally in a fair condition but breakages do occur due to the erosion of pipe bedding.

Table 2.14 Water Production Statistics
For May 2005 (Electrogaz)

May-05	m³/day
Daily Average Production	24645
30% losses	-7393
Average dispensed	17251
Maximum daily production	29151
Minimum daily production	11746

Rwanda appears to have negotiated a way through the donors' preconditions for privatizing water supply in order to qualify for loans. This contentious issue has been exhaustively researched and commented on by many such (see Budds 2003 and Hall 2002) and it is generally agreed that privatization is seldom the answer to water supply in developing countries and that certainly the poor are left worse off after privatization. In Rwanda's case the process does not appear to have gone past the stage of privatizing the management that appears to have been the IMF's structural benchmark.

Table 2.15 IMF's Structural Adjustment Benchmark

RWANDA	Poverty Reduction and Growth Facility (PRGF)	<u>Structural benchmark:</u> Put the water and electricity company (Electrogaz) under private management by June 2001.	Arrange private management of the water and electricity company (Electrogaz) as a prelude to its privatization
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Whether Rwanda will follow through and fully privatize Electrogaz is still to be seen. But the government will know from failed privatization programmes elsewhere on the continent and in the developing world that the lower-income groups, which comprise a large percentage of Kigali's urban dwellers, will benefit the least from privatization as private companies are notoriously ill equipped to administer the water supply to this sector with all its inherent problems.

2.1.7 Topography, climate, hydrology and erosion

The central portion of Rwanda, which includes Kigali, consists of a hilly plateau with an average elevation of 1,700m. On the eastern side the plateau slopes down to a series of marshy lakes along the Akagera River and in the west the plateau rises to mountains averaging 2,700m, which form the watershed between the Nile and the Congo River catchments. This chain of mountains includes the Virunga volcanoes the highest of which is Karisimbi, reaching 4,507m

A network of lakes, rivers and wetlands characterizes the hilly central plateau. The wetlands, which are scattered among the hills, range from large permanent swamps to seasonal grass swamps (*marais*) and occupy about 6 percent of the area. These wetland areas are comprised of organic soils and peat and in their natural state are papyrus marshes.

According to Pajunen (Pajunen1999) the larger wetlands were mainly still in their natural state in 1994 while the smaller ones were drained for agriculture. By 1998 57% of the 1,650 km² of wetlands were being used for agriculture when this was surveyed (Kanyarukiga 1998). The continuing high demographic growth rate and increasing pressure on hillside lands is forcing people to exploit marshlands to ensure food security. Although the marshlands have lower erosion risks, they have large water retention characteristics, which are largely lost when they are drained for agriculture. The Ministry of Agriculture has obtained aid from the African Development Bank (ADB) for the realization of a National Master Plan for the development of marshlands and for soil conservation.

The country experiences four “seasons” annually:

- **A short dry season** - mid-December to February: characterized by occasional light rainfall. This period can vary from dry to moderately wet with the rainfall accounting for 18% of the annual total.
- **A long rain season** - March to May: This is the wettest season of the year delivering 40% of the annual rainfall. In recent years this season has tended to end around mid-May.
- **The long dry season** - June to mid-September: This season is characterized by little to no rain particularly in highlands. The rain that is received accounts for less than 12% of annual total. In recent times this period has often begun in mid-May.
- **A short rain season** - mid-September (early October) to mid-December: This season is characterized by 30% of the annual rainfall.

The rainfall varies across the country from the dry lowlands in the east to the mountains in the north and southwest as shown in the figure below.

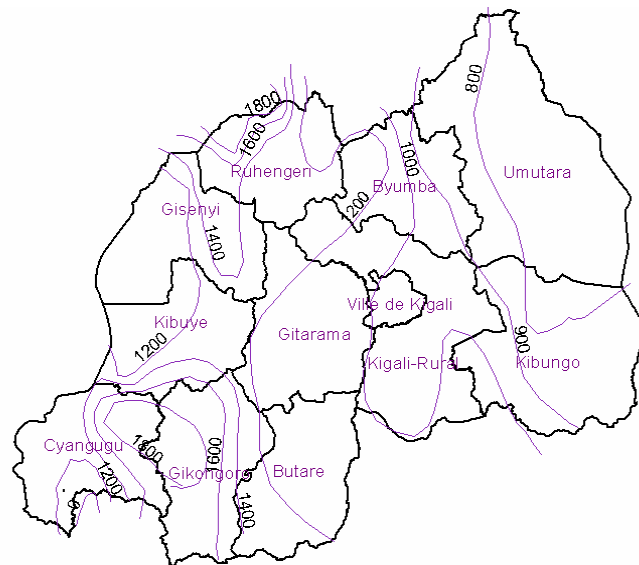


Figure 2.8 Annual rainfall distribution
(Vincent de Paul KABALISA)

From the monthly rainfall records, which have been kept by the Rwanda Meteorological Service since 1961, the average annual rainfall in Kigali is 997mm with the wettest year being 1360mm and the driest 668mm.

Mr. Alphonse Mutabazi of the Rwandan Meteorological Services (RMS) supplied the details shown here. The RMS has maintained monthly records since 1961 and daily records since 1972 with the exception of the 4 months in 1994 during the war.

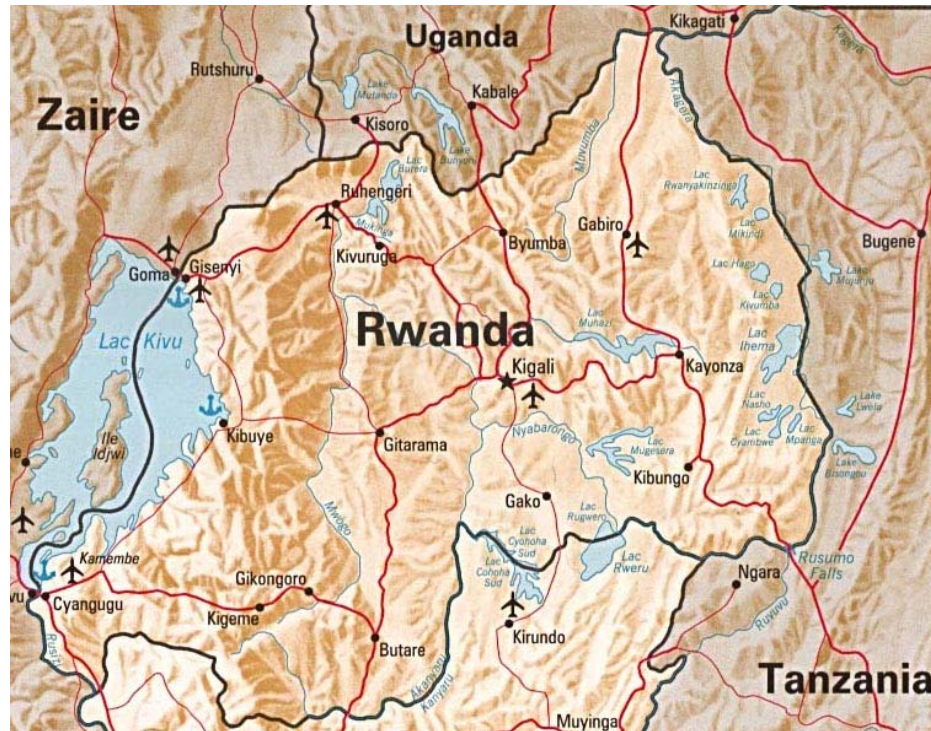


Figure 2.9 Rwandan Topography (CIA fact file)

The Meteorological Service has done a lot of work recently on disaster management specifically flooding and land slides. The figure below (reproduced from a report by the meteorological unit) shows the landslide risk zones during the rainy seasons. The high risk area

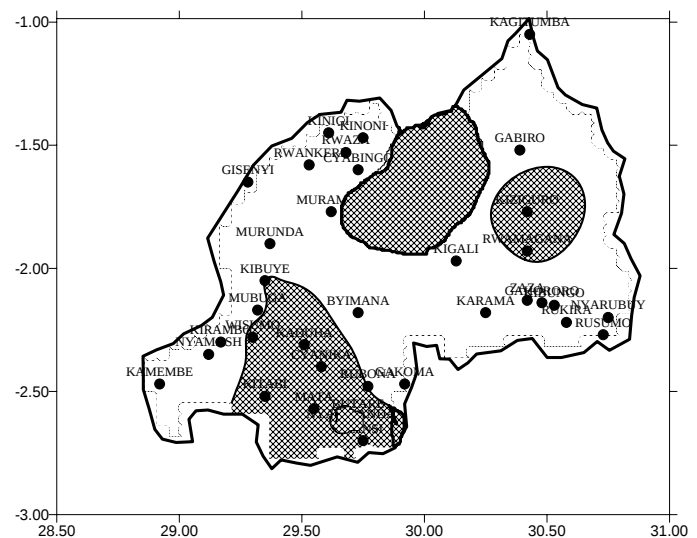


Figure 2.10 Landslide risk areas (Source : Rwandan Meteorological unit)

directly north of Kigali is the catchment of the Nyabarongo River and the area to the North East covers the catchment of Lake Muhazi. The high risk area in the southwest is the headwaters of the Akanyaru that feeds into the Akagera. It can be seen therefore that nearly all the water sources of Kigali are in areas vulnerable to erosion.

Studies indicate that environmental degradation, particularly in terms of soil erosion, is a very serious problem in Rwanda. One study suggests that nearly half the farmers are experiencing a decline in productivity and that soil erosion is moderate to severe on 50% of the land surface of Rwanda (Chris Huggins and Herman Musahara 2004). According to specialists in the field many of the traditional practices of terracing the steep slopes to prevent erosion of cultivated land are being ignored.

Population densities in Rwanda are the highest in Africa and have increased from 101 people per square km in the early 1960s, to 303 people per square km today, with some districts supporting 820 people per square km. The steep hillsides are terraced and intensively farmed with almost 60% of households living off less than 0.5 ha. This scenario, together with the clearance of fragile zones, denudation and compaction of soil through overgrazing and exhaustion of the soil through intensive cropping without compensation from applications of organic matter and nutrients, have all contributed to the erosion problem which results in the rivers carrying a very heavy silt load.

The Government of Rwanda (GOR) is fully aware of the problems of erosion and a National Soil Conservation Commission was established between 2002 and 2003 with the result that the area under terracing increased from 6,164 ha to 6,916 ha along with the rehabilitation of anti-erosion trenches. District soil conservation committees have also been trained in the different soil conservation techniques and 2,900 ha of flood prone valleys have been rehabilitated and developed.

2.1.8 Electricity

Electricity is considered here because of the high consumption of energy associated with pumping in conventional water supply, which is particularly significant in Rwanda's hilly terrain. There is also a close connection between water and power supply in Rwanda as the majority of the power is hydroelectric.

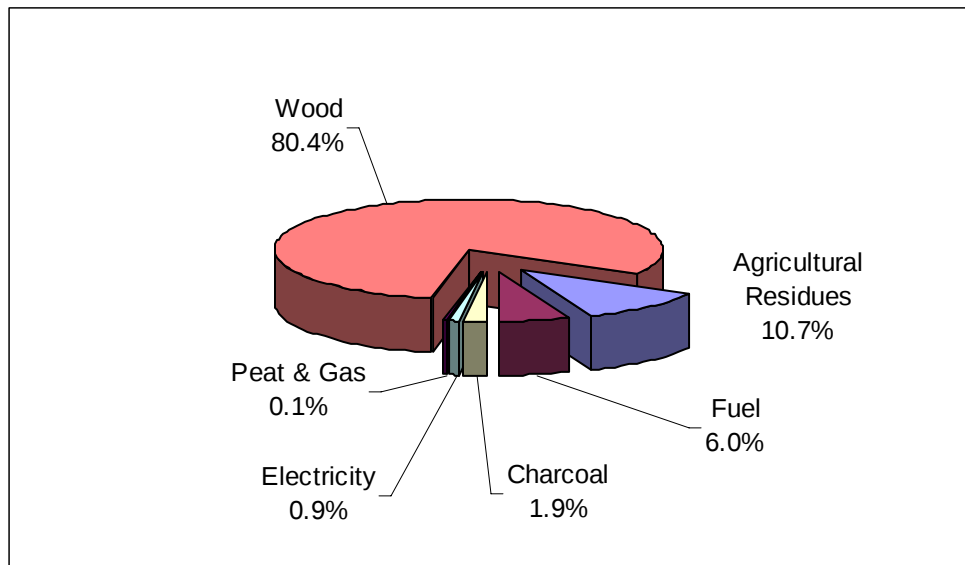


Figure 2.11 Rwanda's Power Sources
(Source: Electrogaz 2004)

In Rwanda only 2% of the population has access to electricity but still there is a gap between demand and national production of up to 65%. The total installed capacity of Electrogaz is currently 28.56MW. This comes from two hydroelectric power stations, Mukungwa and Ntaruka and a 2MW diesel powered unit in Kigali (Gatsata).

Lake Bulera, which supplies the Ntaruka plant, has fallen steadily over the last five years due in part to a reduced inflow and over production of electricity. The reduced inflow, on the other hand, is as a result of environmental degradation including siltation and the loss of wetlands. The waters of Lake Bulera pass into Lake Ruhondo, which then supplies Mukungwa. In January 2004 very low levels of Lake Bulera caused

Electrogaz to reduce the power generated from Ntaruka and to introduce comprehensive load shedding (power cuts).

The networks of Rwanda, the DRC and Burundi are interconnected and there is joint ownership of the hydropower station, Ruzizi II, that is operated by SINELAC (Societe Internationale des Pays des Grand Lacs) which is an organization established by Burundi, Rwanda and Zaire, to develop international electricity projects. By agreement Electrogaz can access 14 MW from SINELAC and a further 3.5 MW from the DRC's Ruzizi I plant. Power can also be imported from Uganda into Rwanda but this is less than 1MW.

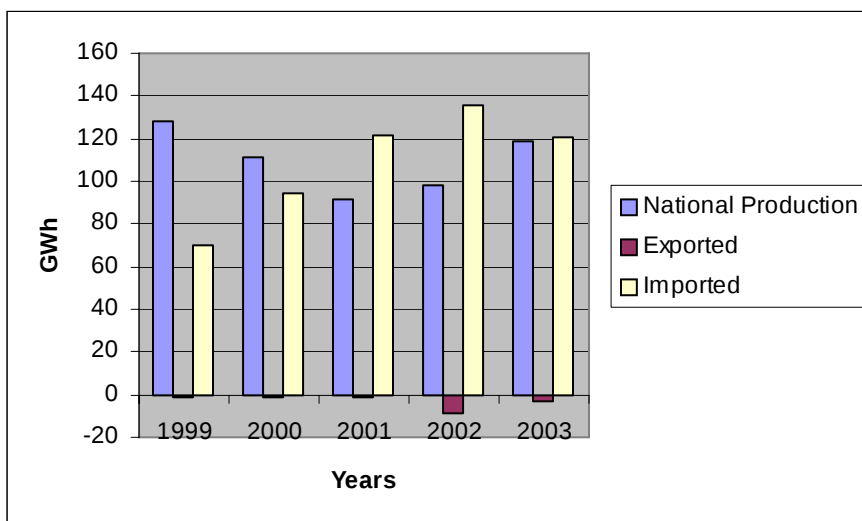


Figure 2.12 Power usage 1999 – 2003 (Source: Electrogaz 2004)

In the dry season of 2004, Rwanda's daily electricity demand was estimated at 680 MWh. Electrogaz supplied approximately 20 MWh (35%) and imported 320 MWh (47%) from SINELAC (Ruzizi II) and shed 120 MWh (17%). Electrogaz's dependency on Ruzizi II consistently exceeded their agreed contractual allowance over this dry season.

Electrogaz's short-term plan to address this situation is to purchase containerized diesel generating units and purchase more power from neighbours. The medium to long-term plan is to tap the methane gas

resource of Lake Kivu for power generation. A 27MW plant (200GWh/year) is optimistically planned to be commissioned in January 2007.

A deficit of 80-90 GWh/year is expected to continue until the gas plant is fully commissioned. (Electrogaz 2004)

Electrogaz has advised the GOR that the effects of harsh load shedding are

- loss of income for the government (taxes)
- loss off employment in Rwandan industries
- damage to tourism
- damage to investor confidence
- decreased security

In the light of the forgoing it is clear that the pumping of water up to Kigali consumes a precious national asset.

2.2 Current Water Management Initiatives

2.2.1 Water resources and the African continent.

While Africa uses only about 4 per cent of its renewable freshwater resources (WRI 1998), the sad reality of Africa's water situation is that today more people across the continent lack access to safe drinking water than in 1992, when the United Nations Conference on Environment and Development was held. Water-related diseases afflict more than half the population of the continent. While Africa has abundant freshwater resources in large rivers such as the Congo, Nile, Zambezi and lakes like Victoria and Tanganyika, there are



Figure 2.13 The Nile (Source GEF 2001)

great disparities in water availability because the water resources are so unevenly distributed.

Because the demand for water is increasing rapidly in most African countries due to population growth and economic development, there are probably few matters of common interest in Africa that have received as much attention from leaders, officials and NGO community as the issue of water. The shared problems of Africa's sporadic droughts, floods and the water demand of rocketing populations aggravated by urbanization have been discussed and debated at numerous high level fora and symposia for decades. Out of these meetings have emerged instruments intended to address these problems such as "the Abuja Ministerial Declaration on Water: A Key to Sustainable Development," adopted in April 2002 and which established the African Ministerial Conference on Water. However, legal instruments, including national and international declarations, as comprehensive as they may be, cannot by themselves resolve the issues they intend to address. As Salman of the World Bank says: *The political will of the authorities at all levels is needed for operationalizing and enforcing such laws and educating the public on the need for and virtues of compliance.* (Salman 2002)

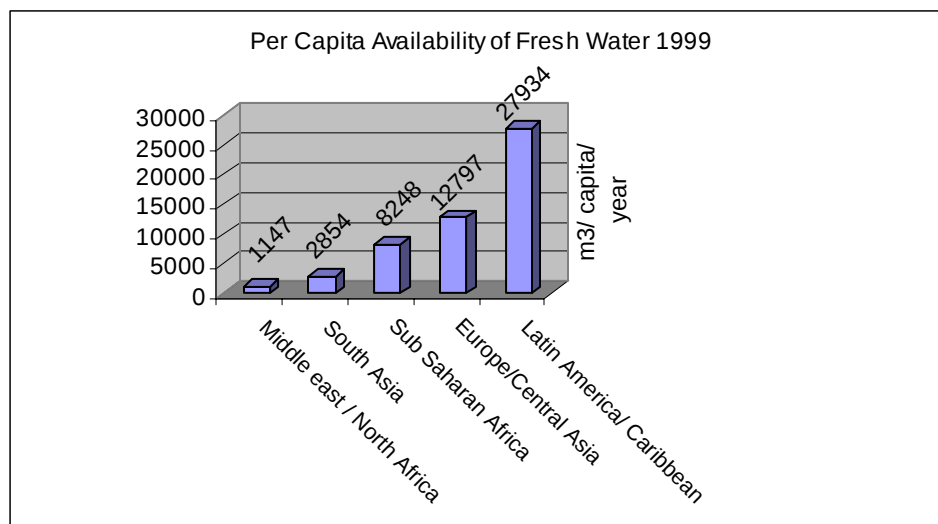


Figure 2.12 Per Capita Fresh Water Internationally 1999 (Source P H Gleick)

Sub-Saharan Africa taken as a whole is still not as badly off as the Middle East or Southern Asia as can be seen by the figure 2.12 that compares the available water per capita of different regions.

Following the argument previously raised, that the scarcity of water in a community can be a lack of *adaptive capacity* rather than simply a shortage of water, Ohlsson and Appelgren compared the water access in Nile riparian countries based first on standard hydrological indicators and then on an index which took cognizance of socioeconomic development, education, human rights (including and stressing women's rights), legislation, and water resources management capabilities (Ohlsson 1998).

Possibly predictably, Rwanda performs far better on the first rather than the second which Ohlsson and Appelgren termed *Social Water Stress Index* (SWSI). In the context of this report this lends weight to the argument that more innovation in water resourcing and management must be encouraged in Rwanda. It is also necessary to observe that any sustainable solution to Kigali's and Rwanda's water problems will have to address managerial capacity along with institutional building in equal measure with technical issues.

2.2.2 Integrated approach to efficient water use

The old school theory of water development was uni-sectoral with least respect to other water sectors. With no competition for available water resources, this approach was sustained in the past. However, with increased socio economic development, demand for fresh water has increased. To cater to the demand, most countries have adopted Integrated Water Resources Management (IWRM) strategies, which consider "water resources management" rather than "water management".

Due to single sector development approach in the past, professional outlook was limited to only surface and ground water development.

Adequate freshwater supply is the most important precondition for sustaining human life and for achieving sustainable development. Nevertheless, over a billion people around the world lack access to satisfactory supplies of freshwater. In many large cities in developing countries, population is increasing rapidly. The issue of supplying adequate water to meet societal needs and to ensure equitable water access for all urban residents is one of the most urgent and critical problems facing decision makers.

Countries tend to increase the demand on nonrenewable resources instead of using existing resources more productively. This is as true for water as it is for power. Water of potable quality is used with the same amount of consideration for the flushing of toilets and washing of cars as it is for drinking and cooking. Almost the first action considered when water shortages are mentioned is the construction of dams rather than to look at usage patterns. Although it is difficult to change wasteful water habits, there are signs of the emergence of a new thinking and a move towards closed loop water systems. *Integrated Water Resource Management* has for some time taken precedence over straight *Water Management* and an appreciation of the scarcity of water as a limited resource is evident in new approaches such as South Africa's policy that promises "Some, for all, forever." (South African National Water Act in 1998)

Integrated Water Resource Management requires attention to be paid to all issues of water resourcing. Sanitation issues, for example, are inseparably tied to those of water and must therefore be considered along with the whole question of sustainable water supply. The continued promotion of waterborne sanitation needs to be appraised to ensure that there is enough clean water for all for drinking and cooking.

This approach demands special priority in resource poor countries where scarce financial, environmental and energy resources will be squandered if inefficient practices are not avoided.

While water conservation is the cheapest and largest available source of water within a city, water resource planners should include the following for consideration in their strategies towards sustainable development.

- water re-use for non-potable applications
- augmentation of groundwater resources through aquifer recharge
- leakage control and the reduction of unaccounted for water
- harvesting and utilization of rainwater
- water demand management

In addition, it is important for administrators and decision-makers in developing countries and countries in economic transition to improve their knowledge base and skills in order to address water problems more effectively. It is also essential that educational programmes be put in place to change people's attitudes toward water and water resources.

A comprehensive national water use programme needs to be instituted to study the country's natural hydrological cycle and human impacts, plus the diverse interests of various government agencies and consumers.

2.2.3 Water management and development plans

The planning for the water supply to Kigali has not always enjoyed a high priority in the past decade. That this should have been the reality in the years since 1994 is possibly understandable as the country grappled with the enormity of the social trauma of the genocide. Prior to this however, the problem of a growing demand for urban services seems to have been addressed, if only in part, by discouraging the mass migration from the countryside. In this, Rwanda was far from unique in the world.

One of the current impediments to the water supply issue is that the control and administration of water matters falls under the control of more than one

ministry as mentioned before. These ministries include: MINITERE, MINICOM, MININFRA, MINALOC, MINAGRI, and MINECOFIN.

The National Committee on water is composed of the following members:

- Ministry of Local Government and Social Affairs
- Ministry of Land, Environment, Forestry, Water and Natural Resources
- Ministry of Defense
- Ministry of Finance and Economical Planning
- Ministry of Health
- Ministry of Agriculture, Livestock, and Forestry
- Ministry of Infrastructure
- Ministry of Interior
- Ministry of Foreign Affairs and Cooperation
- Ministry of Education, Science and Technology MINEDUC

In the Poverty Reduction Strategy Paper the GOR claimed (GOR 2002) that increasing access to and the supply of water was one of its aims. It acknowledges that the water supply system in the cities still required extensive up-grading and rehabilitation with a long-term objective of increasing the current servicing rate of 54% in drinking water and 8% in sanitation to 85% in 2015 .It claimed that the Urban Water Supply and Sanitation (UWSS) program would increase urban coverage of water from 73% to 78% and reduce leakage from 43% to 23% by 2007 along with a programme aimed at increasing sanitation and hygiene education in schools and homes.

GOR progress on water legislation. The Rwandan Water and Sanitation Policy Strategy (WSS) was launched on March 22, 2002(the first consultation on drafting a WSS policy having been held in 1997). A law on water resource protection and sanitation policy was first drafted in 2003 and according to the Director of Water and Sanitation, Mr Mwanafunzi, this should go to the senate for ratification in 2006. (See appendix A)

The GOR has embarked on a plan to decentralize governance and the management of social services, which places a lot of emphasis on community-management of WSS services through Community Development Committees. The GOR is aiming at bringing decision making power to the level where results are most felt as they see this as essential for good governance. The intention is that having administrative infrastructure in close proximity to the population will strengthen service delivery. The GOR hope for an improvement in the population's health and hygiene through a better provision of potable water and sanitation. They planned to finance the construction of 46 water supply lines, 15 of these have been completed

The NBI (Nile basin Initiative) has been assisting Rwanda in policy formation and in refocusing on *water resource management* instead of just *water supply*. The GOR has at the same time been talking of privatizing Electrogaz. These changes have many implications for the roles and responsibilities of MINERENA.

2.2.4 Nile river basin community and regional water supply initiatives.

There are 10 riparian countries in the Nile Basin: Burundi, Egypt, Eritrea, Ethiopia, Kenya, Rwanda, Sudan, Tanzania, Uganda, and the Democratic Republic of Congo. The trans-boundary nature of the river provides an unprecedented opportunity to promote regional economic development in one of the world's poorest regions. Because the Nile upstream of Aswan is one of the least developed rivers in the world, effective water and environmental management has the potential to bring benefits to all involved riparian countries.

The allocation of the waters of the Nile River Basin has increasingly been the subject of dispute as the demand for water has grown in the basin resulting in the proliferation of bodies being formed to address mutual concerns.

Regional cooperation started with a project funded by the UNDP under the name of Hydromet that was launched in 1967. The project terminated in 1982 and the participating countries continued the activities with their own funding. In 1992 the Council of Ministers of Water Affairs of the Nile Basin (Nile-COM) launched the Cooperation Committee for the Promotion of the Development and Environmental Protection of the Nile Basin. In 1993, the first in a series of ten annual Nile 2002 Conferences sponsored by the Canadian International Development Agency (CIDA) provided an informal mechanism for dialogue and exchanges of views among the riparian countries as well as with the international community.

1995 saw the creation of the Nile River Basin Action Plan (NRBAP) with the support of CIDA. Out of this action plan came the Nile River Basin Cooperative Framework in 1996 that was funded by the UNDP and allowed a forum for the discussion of shared legal and institutional matters. Thus in 2000 a draft cooperative frame work was produced which took the riparian states a long way in addressing rights and obligations and in establishing general principles and an institutional structure.

In addition to this in 1997 the World Bank was requested by the Nile Basin States through the Nile-COM to form a Consultative Group of Potential Donors to mobilize support for the implementation of Nile River Basin Action Plan (NRBAP). The Bank agreed to do this with UNDP and CIDA, acting within the framework of the Nile Basin Initiative, held a donors meeting - International Consortium for Cooperation on the Nile (ICCON)- and have helped to create climate of confidence within which a cooperative framework can be established and sustained.

The Nile Basin Initiative (NBI) was formed in 1998 when all the riparians except Eritrea came together in the understanding that the best way to approach common problems on a wide scope of issues and bring mutual benefit was through regional cooperation. The NBI is seen as a transitional institutional mechanism to facilitate the common vision *“to achieve the sustainable socio-economic development through the equitable utilization of,*

and benefit from, the common Nile Basin water resources" The mechanism, made up of the Nile-COM, a Technical Advisory Committee (Nile-TAC), and a Secretariat (Nile-SEC), provides a framework to fight poverty and promote economic development in the region.

The Shared Vision Programmes (SVP) and Subsidiary Action Programs (SAPs) of the NBI includes a series of technical assistance and capacity building projects intended to be implemented basin-wide.

What this all means to Rwanda is that they have access, through the NBI, to a nearly endless source of technical assistance and established sources of financial assistance. It is of interest to note that the Nile-COM, which serves as the highest decision-making body of the NBI and is made up by the Ministers of water affairs of the Nile Basin Riparian Countries, was chaired by Prof. Bikoro Munyanganizi, Minister MINITERE and the technical section is currently chaired by Mr. Bruno Mwanafunzi the Director of Department of Water and Sanitation

2.2.5 Costs And Funding

The IMF have estimated that if Kigali is going to use a conventionally reticulated water supply to bridge the current water supply shortfall and meet the projected growth in demand for water, the present capacity will have to be increased by more than 400% by 2025. (IMF 2004)

Four new **expansion projects** are being considered for Kigali City, which are intended to ensure self-sufficiency in the water. These are:

1. River Yanze dam,
2. Lake Muhazi,
3. Nyabarongo river
4. Lake Mugesera.

Nyabarongo river project, which is located to the west of the city, is estimated to cost US\$ 25.7 million and produce between 1.15-1.5 m³/sec.

Another project which would involve piping water for 100 km from the Rubindi-Mutobo-Mpenge springs in the Ruhengeri region would require a capital investment of US\$ 90.7-106.2 million. (GOR 2001)

The other projects have not as yet been accurately costed.

2.2.6 International aid and assistance

As stated in the introduction (1.5), Rwanda is in good standing with the World Bank and the IMF as the GOR have made a dedicated effort to meet the IMF's economic prescriptions. As one of the world's highly indebted countries however, the GOR know only too well the dangers of borrowing excessively. As Mr. Mwanafunzi (Appendix A) explained they are hoping to explore the possibility of using PPP (Public Private Partnerships) as an alternative to conventional loans.

Rwanda's main development partners to date include:

- ❑ The World Bank
- ❑ French Cooperation
- ❑ DFID (UK Department for International Development)
- ❑ FAO (United Nations Food and Agriculture Organization)
- ❑ GTZ (German Technical Cooperation)
- ❑ UNHCR (United Nations High Commission for Refugees)
- ❑ UNEP (United Nations Environmental Projects)
- ❑ SHELTER AFRICA
- ❑ UNICEF (United Nations Children's Fund)

In the past Electrogaz has received grants from a divers range of organizations including The African Development Bank Group (ADB), OPEC, the Swiss Government, GTZ and the European Union amongst others. (GOR 2000)

3. RAINWATER HARVESTING – THE TECHNOLOGY

“Where is the wisdom we have lost with knowledge? Where is the knowledge we have lost in information?” TS Elliot

3.1 History Of Rainwater Harvesting

The history of rainwater harvesting in **Asia** can be traced back to about the 9th or 10th century in the form of small-scale collection of rainwater from roofs and simple brush dam constructions in the rural areas of South and South-east Asia. Rainwater collection from the eaves of roofs or via simple gutters into traditional jars and pots has been traced back almost 2 000 years in Thailand (Prempridi and Chatuthasry, 1982) and rainwater harvesting has long been used in the Loess Plateau regions of China.

The traditional custom of rainwater harvesting in **Africa** appears to be limited. It is reported that in **Uganda** rainwater was collected from trees, using banana leaves or stems as a conduit during rainstorms. This system was also practiced in **Sri Lanka** but now with the growth in corrugated iron roofing, people often place a small container under their eaves to collect falling water during a storm - one 20 litre container of clean water captured from the roof can save a walk of many kilometers to the nearest clean water source. But the custom of collecting and storing rainwater does not seem to have been widely practiced by Sub Saharan African tribes possibly as a result of reasonable alternative water sources both on the surface and in the ground.

In more recent times nets have been used on the dunes of **Namibia** to trap mist and fog and an innovative project was initiated to collect early morning dew off granite domes in the dry thorn-veld of western **Tanzania**.

In southern Africa rooftop water collection is widely used by farmers in dry areas and rainwater tanks are now included in the specifications for most rural schools built in **South Africa**.

In **Egypt** there is evidence that fog and dew were collected by allowing condensation to form on stones and the water was stored in underground aqueducts. In a similar way, in the area that is now **Israel**, people have been tapping fog to use as agricultural water since ancient times. The inhabitants of the area build small, low, circular honeycombed walls around their vines, so that mist and dew can precipitate in the immediate vicinity of the plants.

The same technique was employed in the **Atacama Desert** in western **Chile**, where both dew and fog were collected by means of a pile of stones, arranged so that the condensation would drip to the inside of the base of the pile, where it was shielded from the day's sunshine.

On the **Indian subcontinent** practices involving the collection and storage of rainwater has been followed for centuries and in many different forms. Many of the applications were orientated toward agricultural needs but many were for human and stock consumption.

The following are three interesting examples.

Rajasthan. The semi-arid region of eastern **Rajasthan** in India's Central Highlands experiences an annual rainfall of 300-600mm. In the Aravalli hills of this region can be found ancient fortified cities and palaces with forts built on the summits of hills suitably situated to withstand sieges. These forts could be inhabited for months by the communities they protected only because elaborate rainwater harvesting structures known as *kunds* were built within their walls. Stone quarrying was also done in such a way as to create drinking water reservoirs. **Chittor Fort** was such a fort and the stronghold of the Rajputana state. Built on an oval shaped hill 152m above the surrounding plane, the Fort had 84 individual water structures to supply the inhabitants at its prime in the 16th century.

Churu District. This is the gateway to the **Thar Desert** in North Western India. It is an area of desolate landscapes of shifting dunes and acacia shrubs. The region experiences the highest summer temperatures in India well over 40° C and an annual rainfall of 350mm and an evaporation rate

of 250-350mm. The rainfall is received in two or three 3 short intense storms during the Monsoons. Since the 17th century the inhabitants have been constructing *kunds* or *kundi* of a different nature. An area of 400-500m² is cleared of vegetation and a circular catchment area with a radius of 11-12 m is set out. The catchment area is graded to fall to the center with a slope of 3° to 4° where storage well is dug. The tank is typically brick lined and the catchment is compacted and treated with available local materials such as clay lime, ash or gravel. A low bund wall around the



Figure 3.1 Kundi In Churu District Of India
(Source SCE)

perimeter and a raised access pathway completes the structure. Typically 10000l of water can be stored in a kundi, which is roofed. The water quality from the kundi is generally good if the structure is properly maintained and livestock are prevented from walking in the catchment. New technologies are being applied to these old techniques such as the use of polymer sprays on the catchment areas to reduce seepage and cost.

Stepwells. As early as 3000 BC, sophisticated systems of drains, wells and tanks were created in the towns of Gujarat. Known as *vavs* or *baolis* (step-wells) they consisted of a vertical shaft from which water is drawn and the surrounding structure that included elaborate steps and often subterranean passageways and chambers provide access to the well.

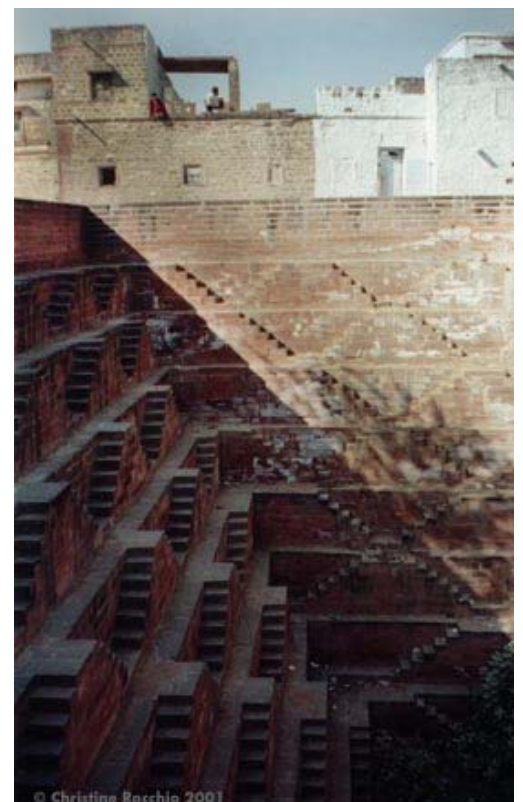


Figure 3.2 Indian Stepwell (Source Racchio 2001)

These structures, created at suitable low lying locations, were filled by the monsoon rains. They were invariably built by rulers or wealth overlords and intended to provide water for the populace during the dry months. The galleries and chambers surrounding these wells were often profusely carved with elaborate detail and were cool, quiet retreats during the hot summers. Multi-storied colonnades top some of these step wells and all are an important part of the architectural heritage of western India

3.2 Different Techniques

Rainwater harvesting is a loose term encompassing all intervention intended to collect and utilize rainwater. There are two main types of RWH; firstly to collect and save water for direct use and secondly to use collected rainwater to recharge aquifers for future extraction.

The choice of technique is often dictated by local factors such as rainfall patterns,

geohydrology, space etc. In some areas the potential to exploit ground water is so

poor that recharging aquifers is pointless. In other areas rainfall patterns deliver large quantities of rain in a few short intense storms annually. To store a meaningful amount of this type of monsoon rain would require a large storage volume that may be uneconomic or impractical due to the available space.

This research focuses primarily on **storage** techniques as opposed to **recharge** techniques as ground water is not a viable option in Kigali. It is of interest however to review the experiences which Indian cities such as

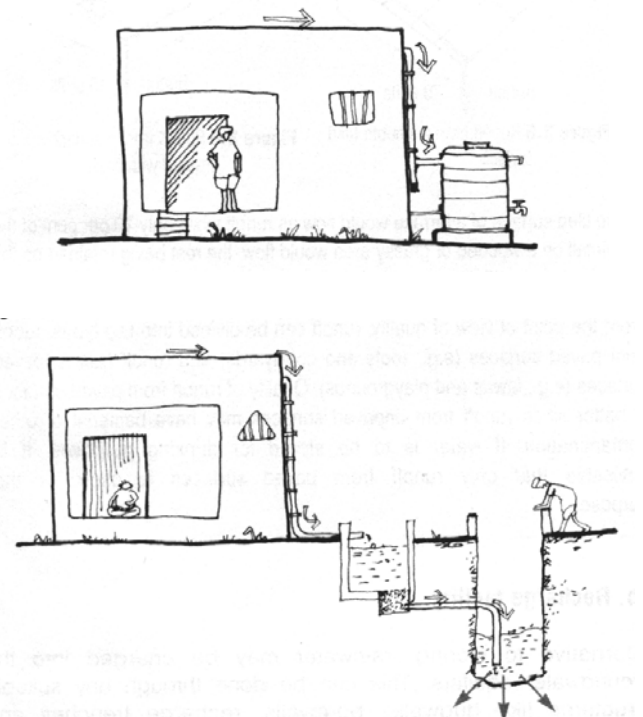


Figure 3.3 Direct Storage And Aquifer Recharge With Water Collected On Roof (Source CSE Handbook)

New Delhi have had with the wide ranging initiatives to encourage the utilization of recharge structures. This will be done further on in the report.

3.3 Where RWH is Successfully Being Employed Today

3.3.1 Singapore

The Republic of Singapore has a land area of 61000 ha so fresh water for its 2.8 million people is scarce. Luckily the rainfall is in the region of 2400mm/year and all possible measures have been taken to maximize on this by collecting rainwater although 40-50% of the water needs still have to be imported.

Schemes that have been implemented include rooftop harvesting on high-rise buildings, collecting the runoff from airport runways (for non potable uses) and integrated systems using a combination of runoffs from industrial areas and educational institutions to assist in improving the water quality in intensive aquaculture farming operations.

During storms, storm water run off is also collected in retention ponds and pumped or diverted to the main supply reservoir. Particular attention has been paid to minimizing the degree of pollution to ensure a reasonable water quality and for this reason the first rainfall after a dry period is discarded. (Appan 1997)

3.3.2 Tokyo

The average annual rainfall in Tokyo is 1400mm, which until recently all went downstream. As the city has been alternately inflicted with water shortages and floods every few years, it has been decided to better the 2 billion cubic meters of rain that fall over Tokyo each year. In 1982 a new Sumo wrestling area in Sumida City, Kokugikan, was designed and built to utilize rainwater. 70% of the facilities at Kokugikan use rainwater collected on the 8400 m² rooftop and stored in a 1000 m³ tank. Water from this tank is used for flushing and air-conditioning systems amongst other things.

Since the construction of Kokugikan, nearly 500 similar systems have been introduced into buildings in Tokyo.

Sumida City closely examined the potential of RWH between 1992 and 1994 and the achievements of projects such as Kokugikan built over the previous ten years. Their conclusion was that this approach held valuable potential to reduce the threat of flooding and to significantly augment the existing water supply. Thus in 1996 the city produced a guideline that features three principles:

- The city will install RWH systems in all its new buildings.
- The city will guide or advise its citizens and businesses to install RWH systems in all building developments on land of 1000m² or more.
- The city will subsidize residents and companies planning to install RWH systems.

The city now offers subsidies up to \$7500 and the government is considering water conservation measures including the promotion of RWH and the restriction on ground water extraction. (After Makato Murase EPD, Sumida Ward, Tokyo)

3.3.3 New Delhi

In New Delhi, the growing demand for water and the failure of the municipal structure to deliver water in sufficient quantities has led to the proliferation of private and institutional boreholes. Now nearly 25% of the city's water for a population of 13.8 million comes from boreholes. This has had a disastrous impact on the aquifers under the city and water tables have been falling steadily; – some as much as 10m and at rates from 2-5 m per year. The ground water quality has also been deteriorating with increased salinity and dissolved solids (TDS).

The city receives on average 611mm of rain a year over 2-3 months making the storage option expensive and bulky; a middle-income

household of 4 would require a storage tank in the region of 110m³ (assuming 100l/d/p).

Significant research has gone into the design of recharge structures. This includes structures to store water temporarily and others to filter it and the size and depth of the recharge bores to get the water down to the aquifers.



Figure 3.4 Recharge Structure New Delhi (Photo Author)

In the Figure 3.4 the components of a recharge structure can be seen in the foreground: The storage tank is covered with slabs and the recharge well/filter covered with mesh; the system in this case being fed from the storm water drain behind the tank. This arrangement is in the grounds of the Jamia Hamdard University, Delhi and has a storage tank of 90m³ and a typical average rate of infiltration would be 50 l/m according to Mr. Salahuddin Saiphy, Centre for Science and Environment. If one intended to recharge 50% of the rain falling in an event of 50 – 100mm/24hrs one needs to have one such structure every 1750-3500m².

This is a high density of expensive structures but with Delhi's 611 mm of rainfall and a total land area of 1,486 sq km, the annual water harvesting potential is 450 billion liters. Assuming 50 % efficiency, this is almost 35 % of the total annual water demand of the city and it is thus an option well worth pursuing.

In control tests at another recharge structure close to the above site, it has been demonstrated that the water table is raised locally at the time of recharge. (No change was detected 100m away however.) This project

has been monitored since May 2002 and although success is difficult to quantify because of the size of the aquifer, there is evidence that the fall in the water table has been arrested locally and the water quality has improved marginally.

3.4 Design Details Associated With Rainwater Harvesting.

The variables involved in designing a rainwater collection and storage system include:

- the volume, distribution and predictability of rain throughout the year
- the intensity of the rain
- the volume of rain from rain events greater than some minimum precipitation
- the area that can be utilized for catchment
- the runoff coefficient of the surface(s) (percentage of water lost due to penetration leakages etc)
- the intended water usage
- the monthly demand for water

The design must determine:

- the rainwater available for harvesting
- the sustainable supply level
- the optimal storage volume to meet the predicted demand
- the volume of top-up water - if necessary
- the layout of the scheme including collection gutters and pipes.
- filtration type and placing.
- the type of storage unit(s)
- the cost of the scheme and alternatives
- method of retrieving water for usage.

Because of the sensitivity of the design to variables such as the water demand, the coefficient of runoff and the pattern of rain events, it is generally agreed that a rigorous statistical approach is seldom appropriate in RWH design. The design choices hinge strongly on cost and the cost of the storage element as the primary cost of the scheme. The cost of supplementary water (water which may need to be purchased when the

RWH tank runs dry) is also of consideration. With surplus funds available, it is advisable to increase the storage to some degree beyond the volume calculated, as this will allow the system to benefit from atypical wet spells and better survive atypical dry spells (In this context it appears as if the degree of variance from the mean annual rainfall appears to be increasing worldwide and central Africa is no exception).

The rainfall pattern, both in quantity and distribution, of the area being considered for RWH implementation is obviously central to the design. Some form of rainfall history is essential and the longer the time frame and the better the quality of the records the greater the confidence the designer can have in the plan. Most suitable records are those for daily rainfall as it is necessary to eliminate those minor rain events that, although measurable, will not result in a significant run off. This “minimum rain” will depend on the roof type, temperature and size but is usually assumed to be 1mm.

There are a number of approaches one can take to arrive at the storage capacity required for a particular set of parameters. The rainfall pattern is a strong determinant in the approach adopted. If the rain comes in a few hard showers in one or two short “wet” periods, a simplified calculation of the amount of water needed to be stored to last the “dry” period will suffice. This must naturally be compared with the available runoff in order to optimize the tank size.

In a more varied rainfall climate, the seasonal variation needs to be considered.

For the calculation of the rainwater available for utilization the simple formula below is sufficient:

$$V = A_c \times C_r$$

Where: V = volume of run off

A_c = catchment area measured in plan

C_r = coefficient of runoff

The surface material of the catchments area as well as the quality of the gutters and down-pipes will also affect the percentage of the rainwater

being collected. This is handled by an empirical coefficient such as the published figures below.

Table 3.1 Runoff Coefficients

(Modified after Pacey, Arnold, Cullis 1989 and VLC-DRWH 2002)

RUNOFF COEFFICIENT	
Runoff coefficients for various surfaces	
Type Of Catchments	Coefficient
Roof Catchments	
- GI Sheets	> 0.9
- Tiles	0.6 – 0.9
- Organic materials e.g. thatch	0.2
- Asbestos Sheets	0.8 – 0.9
Ground Surface Covering	
- Concrete Paving	0.6 – 0.8
- Brick Paving	0.5 – 0.6
Untreated Ground Catchments	
- Soil On Slopes <10%	<0.3
- Rocky Natural	0.2 – 0.5
- Catchments	

Although many writers on this subject recommend a simple approach as suggested above, there are programmes available to do the calculations based on the specific variables and presenting statistics relating to the certainty. It would seem to me that as human behavior and weather are involved the results are still hypothetical and may lead to a sense of false security. Examples of these are the programme prepared by Ken Clive in 2003 (New Zealand) and the SimTanka, which models the performance of a rainwater harvesting system with covered storage tank.

The approach taken by the writer was to prepare a simple month on month balance sheet of predicted inflows and consumptions. The inflows are based on a modified monthly average rainfall in which the minor rain events are omitted. By first assuming a storage volume, the water volume in the tank is established for each month in the cycle by a process of iteration. The result will indicate how low the tank level falls in the dry months and the quantity of water that is lost at those times when the tank overflows. Thus by varying the assumed storage the optimal size tank can be found.

The choice of tank can be refined by comparing the combined cost of the various storage units and, where applicable, the associated cost of purchasing (commercial) water when the tank fails. The weakness of this latter refinement is that purchasing water in a drought may not be possible.

This iterative approach can also be applied to a recorded dry event such as an El Nino type drought lasting a number of years. Doing this one can see how a system would have coped over the drought. The worked example in Appendix D demonstrates this approach.

3.5 Elements Of A Rainwater Harvesting System

The elements necessary to collect and store rain are simply:

- a rain collection surfaces
- a conduit(s) to channel/direct the water
- filtration arrangement
- a storage unit

3.5.1 Rain collection surfaces

The surfaces used to collect rain are typically roofs or paved areas. As seen by the coefficients above, sheeted roofs and hard surfaces gives far better run-offs than organic coverings and surfaces. Although pavements can have good run-off coefficients, the water can be more contaminated than roofs depending on the traffic that the pavement experiences.

It has been found that the quality of the water collected off steel roof sheets is generally of the best quality. This is due to the smooth surface retaining less dust and fecal matter and the high temperatures that have a sterilizing effect and aids the breakdown of organic deposits (Vasudevan et al, 2001). Some experiments have been made with temporary or artificial catchments such as polyurethane sheets (Ariyabandu 2001) but this approach has problems including durability. The most suitable surface is the roof of the dwelling where the water will be used or some other nearby roof.

3.5.2 Conduits

Conduits include gutters, down-pipes, drains and subsurface piping. These components of the system need special attention. Firstly, malfunctioning gutters can jeopardize the success of a scheme and secondly, in many houses in poor tropical countries, gutters are not installed as a matter of course. The reason for omitting gutters is obviously cost but also the danger of providing a breeding environment for mosquitoes. In addition, the design of the roof often makes it difficult to fit a gutter, especially if there are no eave beams.

Gutters come in a variety of materials that vary in price and availability. In the study area the most readily available material is GI. Plastic gutters are also coming onto the market slowly. Considerable research has been done on the various gutter profiles and their cost versus carrying capacity, their fixing requirements and the advantages of splash guards by the Development Technology Unit of School of Engineering, University of Warwick (DTU 2002) as well as Nissen-Petersen and Lee (Nissen 1990).

Overcoming the problem of not having an eave beam on which to fix the gutter at a fall has been resolved by Nissen-Petersen (1992) by hanging a suspended gutter from a purpose made flashing which also acts as a splashguard. This is shown in figure 3.5 below.

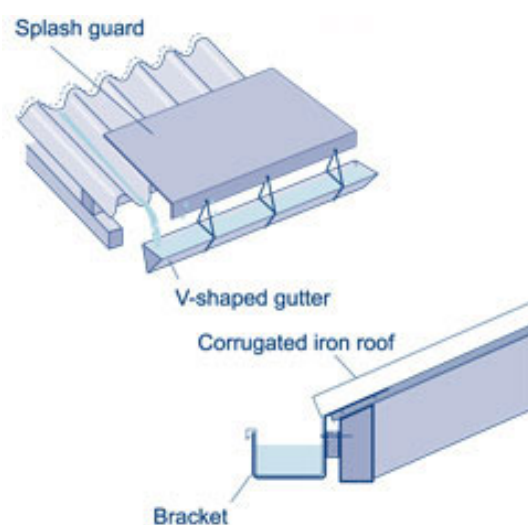


Figure 3.5 Suspended Gutters (Source Nissen-Petersen)

DTU have worked on optimizing gutter size as the cost of the gutter in a low cost RWH system can be a significant portion of the overall cost (DTU 2002). They found that a “v” shaped gutter of only 75mm wide is appropriate for most small dwellings and sufficient for all but the most severe downpours delivering more than 90% of the water it catches. Such a small gutter should cost less than \$5.25 for a 10m run.

3.5.3 Filters

It is necessary to have one or more filters to prevent foreign matter from being washed into the storage tank and thereby degrading the water quality.

Filters can be placed in various places in the system such as:

- in the gutter
- at the inlet to the down pipe
- in the down pipe
- at the end of the pipe
- just before entering the tank.

The simplest types of filter are **leaf filters**. These are effectively coarse screens, which must be easily cleanable, and should not themselves contaminate the water or reduce the flow (i.e. block pipes or gutters). Ideally, these filters should not be expensive but durable

Many practitioners in RWH support the approach of using the **first flush** approach in which a predetermined quantity of first rain water is discarded or diverted in order for it to carry away the accumulation of the dry season's leaves, bird droppings, chimney soot, dirt and salt (i.e. If near the ocean). Some researchers such as Yaziz (Yaziz et al 1989) suggest that the first 0.5mm is sufficient to achieve this while others such as DTU have observed that discarding the first 2mm reduces the turbidity and reduces the fecal coliforms count significantly.

Although opinions differ on the quantity to be discharged, there is common agreement that this approach is an effective way in which to improve the quality of the water to be stored. There are, however, practical difficulties

in achieving this **first flush** consistently. Some clever automatic systems have been designed¹ but there are also manual apparatuses that are simpler and cheaper.

Some examples of both annual and automatic **first flush** systems are shown in Figure 3.6 below.

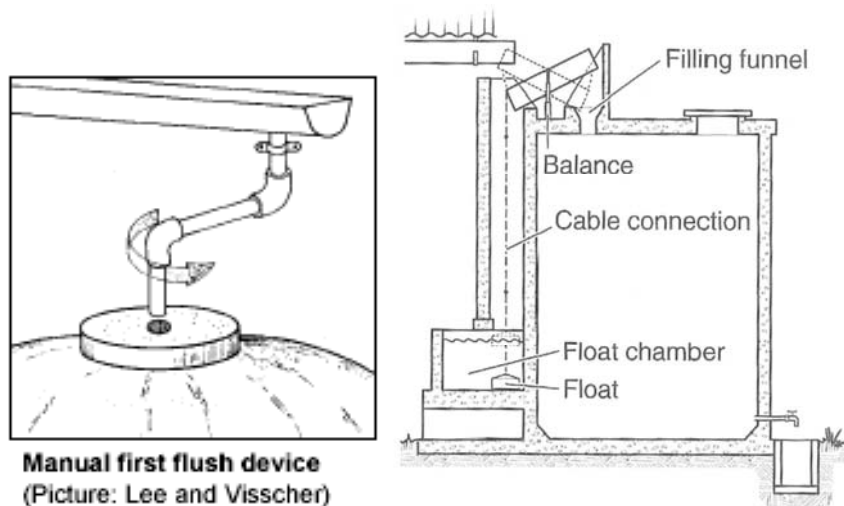
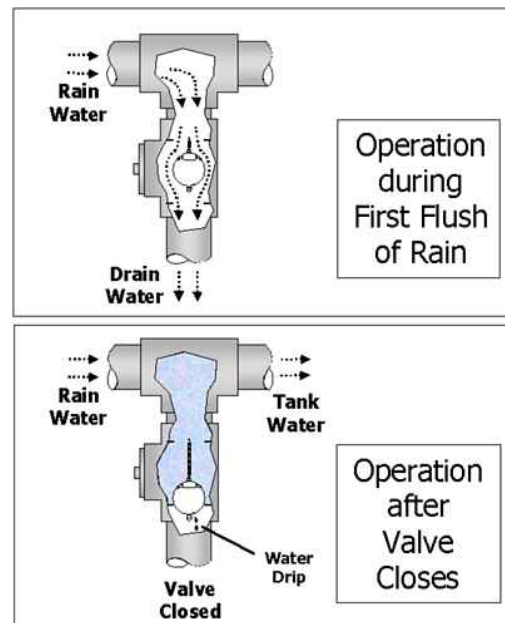


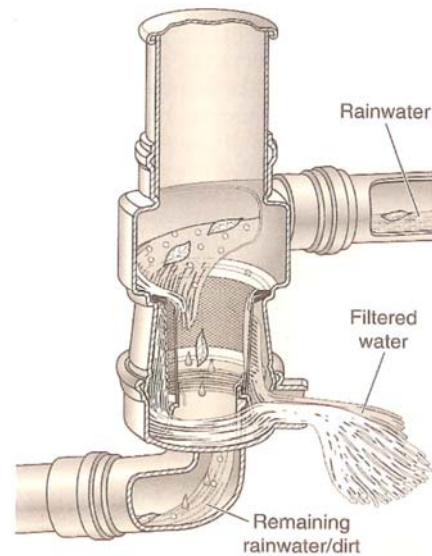
Figure 3.6 Manual And Automatic “First Flush” Systems. (Source Lee and Visscher)

Automatic systems have the obvious advantage of working without a human presence but may malfunction and hard to come by in some locations. They may also add unwanted expense.



¹ In Australia Trent Church has designed a self-cleaning system using ping-pong balls which, while ingenious, might not necessary have mass application.

On the other hand, manual systems require a human presence at the critical time. It is worth noting that the **first flush** approach is promoted in India where ground water recharge is generally the preferred method of RWH. After eight or more dry and dusty months prior to the monsoon rains, losing the first 2-2.5mm is an acceptable loss in order to prevent a significant deposit of fines on the recharge well's filter bed which it could block. In areas where the rainfall is more evenly spread through the year, however, the advantages of **first flush** must be weighed against the possibility of losing a lot of water.



The use of the **first flush** approach should thus be reviewed on a case-by-case basis.

Inline filters. These have been used in Sri Lanka successfully but some are not suitable for high intensity downpours because in order to cope with a volume they would require a very large filter bed. The other problem is that they need cleaning regularly or they overflow with a resulting wastage of water.

Figure 3.7 Vortex Filter

There are various inline vortex filters that can be used if available. The type in figure 3.7 is marketed in Germany.

Natural sedimentation, floatation and bacterial die-off. What are sometimes overlooked are the natural processes that take place with time to improve the water quality while water remains in the tank. These are sedimentation, floatation and bacterial die-off. Suspended matter will, with time, settle in a tank and can be drawn off by desludging the

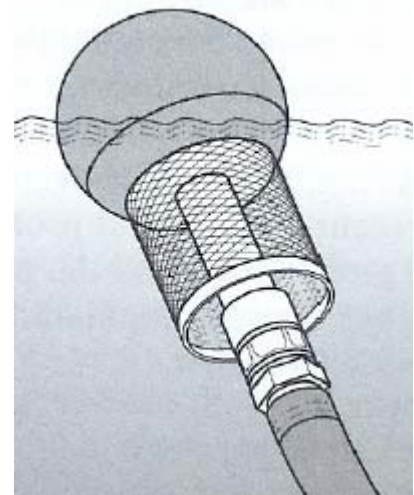


Figure 3.8 Swimming intake

tank. Floating matter can be drawn off and discharged with the overflow and can be avoided by the judicious positioning of the withdrawal system. In addition to this, bacteria in the absence of sunlight and nutrients will die off exponentially – and quite rapidly.

These processes are exploited in Germany where RWH as a technology has been actively used for the last 10 years. Their approach is to pass the water first through a **leaf filter** and then through a **finer filter** with a mesh size of 0.2-1.0mm. These filters are easily removable and can be washed before replacing.

Water is introduced to the tank through a **velocity-reducing** inlet in order to keep conditions in the tank quiescent, thus allowing the water to shed its sediment load. Water is removed using a “swimming” intake that removes water from slightly below the top surface where the water is “cleanest” and devoid of floating debris (See Figure 3.8). The overflow outlets remove floating debris, which may have escaped the filters, and the sediment at the bottom of the tank is cleaned out only when required to preserve the “microbial biofilms” that develop on the side of the tank and in the sludge which greatly enhance the die-off process of pathogens within the tank.

3.5.4 Storage Structures

As storage is the major component of the RWH system it is important to give it due consideration. The method of sizing the storage unit will be discussed later, but besides the volume there are various other aspects of the storage structure that need to be considered. Some of these are:

- the location of the storage - above or below ground level
- the structure must not create a hindrance or hazard to vehicles and people, particularly young children
- the shape of the tank and the material composition
- the tank material must not give the water an unacceptable taste
- the tank must have sufficient structural strength to withstand wear and tear and natural forces
- water loss and leaks must be kept to a minimum

- an overflow arrangement is essential to ensure excess is discharged without damage to the tank or its foundations
- the provision of vermin and mosquito netting
- the exclusion of light (so that algae does not grow and larval growth is inhibited)
- ventilation to prevent anaerobic decomposition of any washed in matter
- easy access for cleaning

With regard to above and below ground structures, both have advantages and disadvantages. In the case of above ground tanks the **advantages** include:

- ✓ easy access to inspect and repair leaks and damage
- ✓ potential for gravity extraction.

The **drawbacks** include:

- the vulnerability to damage/tampering
- failure can be dangerous
- space requirement
- UV from sun can accelerate tank deterioration
- heat gain from sun and the effect on algae growth, taste etc
- exposed piping is vulnerable and esthetically unattractive
- generally more expensive

With buried tanks the **advantages** include:

- ✓ tank is hidden
- ✓ neater in appearance
- ✓ potentially cheaper
- ✓ underground water is cooler

The **drawbacks** to buried tanks include:

- Difficulty of detecting and repairing leaks
- Need to draw or pump water out of tank
- ground water can have damaging effect on tank

- Potential for contamination from surface storm water
- Potential damage by tree roots
- Vulnerability to heavy vehicles
- Difficulty to empty and clean
- Manhole, if left open, can be a hazard to children, adults and animals.

Above-ground tanks

There is a wide selection of above ground tank and choices depend on availability, cost, dimensions and aesthetics.

Second hand containers. For a one off installation this possibility should not be overlooked. A suitable second hand container might be a used agricultural storage vessel or a boiler etc. The 44 gallon drums (210 liters) which fall into this category are often the first “large” container available to poor households in undeveloped countries. They are generally too small to be used as long term storage vessels unless interconnected with others. When second hand vessels are used however, extreme caution has to be exercised to ensure that there is no harmful residual or contaminants in the tank.

Plastic Tanks usually made from HDPE or GRP are increasing in



popularity because of their versatility and durability. The price of these tanks has come down in many semi-industrialized countries where they are mass-produced. They are light to transport and can be maneuvered in

restricted locations. Their black/dark colour tends to increase their solar gain so water drawn from them can be warm at times and this may also encourage the growth of algae. However they are versatile, easy to plumb up and they can be moved.

Fiberglass Tanks. The vulnerability of this material to UV can be partly mitigated by the inclusion of UV inhibitors but durability



is still a concern. They have the advantage of being made in two sections so that they can be nested for more efficient transport thus reducing one of the major cost elements of pre-made tanks.

Corrugated Sheeted Steel Tanks. These tanks are cheaper than the plastic equivalent but are more vulnerable to damage and tend to rust at the base unless they are well founded, drained and maintained. . An extremely firm foundation is often not required, as the steel structure will "give" a little to accommodate any settling. They are extensively used in Australia where they perform well in the dry climate and are constructed in many different sizes. See figure 3.9



Figure 3.9 Large Corrugated Steel Tank In Australia

Cast In-Situ Concrete Tanks. Great success has been recorded with 5m³ tanks in Kenya where several thousand have been built. They are simple to build with skills easily passed from neighbour to neighbour and shutters can be reused many times. (Gould ² 1999)

Pre-Cast Concrete Tanks. These come in two types, the first where the whole tank is cast off site and transported as a complete or nearly complete structure to the site and the second, where the components of a tank are pre-cast off site and the tank is assembled on the site. The availability of both of these require a sophisticated manufacturing environment and the cost would be the main determinant. Pre-cast rings have been used successfully in Bangladesh (Ferdausi & Bolkland, 2000). This ability to mass produce items gives the technique some promise in

the field of tank components such as segmented covers and filter boxes and concrete is often used for ancillary work around tanks such as foundations, drainage and soak-aways.

Commercial Fiber Cement Tanks. Complete tanks are composed of asbestos fiber reinforced cement. Although there is no evidence of carcinogenic effects by ingestion (Campbell 1993) health concerns remain about the use of asbestos in drinking water structures. To be economical, these tanks also require a local industry to be making such tanks. These have been widely used in South Africa on school projects.

Pressed metal “Breithweight tanks”. This type of tank is very flexible in design but usually only economical for large volumes.



Masonry Tanks usually have the advantage of using locally available materials and skills. The wall thickness will add considerably to the space required but they can be constructed cheaply even utilizing compressed-soil blocks. As the bricks are a standard size the walls are often much thicker than necessary in smaller tanks and consume more mortar than the equivalent Ferro-cement tank. Interlocking bricks, usually using stabilized soil, have been tried in Uganda (Rees 2000) and Thailand .

Ferrocement Tanks. Great progress has been made in this technology both for small tanks as well as large ones. The material lends itself to being formed into almost any shape and the skills required for small tanks can be easily learned and the resulting storage vessels produced very cheaply. If leaks do occur repairs can be made with the same skills.

Originally developed in France in the mid-nineteenth century, the technique was initially used for pots and tubs and even boats, (Morgan, 1994). Tank construction with Ferro cement has been ongoing since the early 1970s (Watt, 1978), was popularized by its use in Thailand (IDRC,

1986) and has spread to Africa (Nissen-Petersen & Lee, 1990) and Sri Lanka (Hapugoda, 1995) among others.

Tank construction using Ferrocement involves the plastering of a thin layer of cement mortar (typically 1 part cement to 3 parts sand mixed with about 0.4 parts water) onto a steel mesh. Despite being described as a "low skill" technique, workmanship is a strong issue with all Ferro cement constructions. The thickness of mortar is often as little as 5mm giving little room for error when covering the mesh.

The most popular design of medium size Ferrocement tanks continues to be the straight cylinder. Formers are easy to construct using sheet metal or BRC mesh. There can be some problems of cracking at the base if stress concentrations are not accounted for in the design and there have been some reports of cracking at the lid interface. To combat this, several designs have been produced with a rounded shape to reduce sudden junctions.

with regard to small tanks, ferrocement has been used with legendary success with the "Thai jar", which has been mass-produced in Thailand for the last 20 years. There are more than 14 million of these jars throughout Thailand with capacities ranging from 0.5m^3 to 3m^3 (Bradford & Gould, 1992). The jars are manufactured by plastering mortar onto a mould in the shape of the jar. The moulds are centrally produced at a low cost and the jars are made in reasonable numbers in small workshops (Ariyabadu, 2001).



An African version of this, the "Jumbo Jar" has been designed by Gould and Nissen-Petersen (see Figure 3.10). The Jumbo Jar uses a canvas former which is filled with sand or other easily removable bulk. (Gould ² 1999)

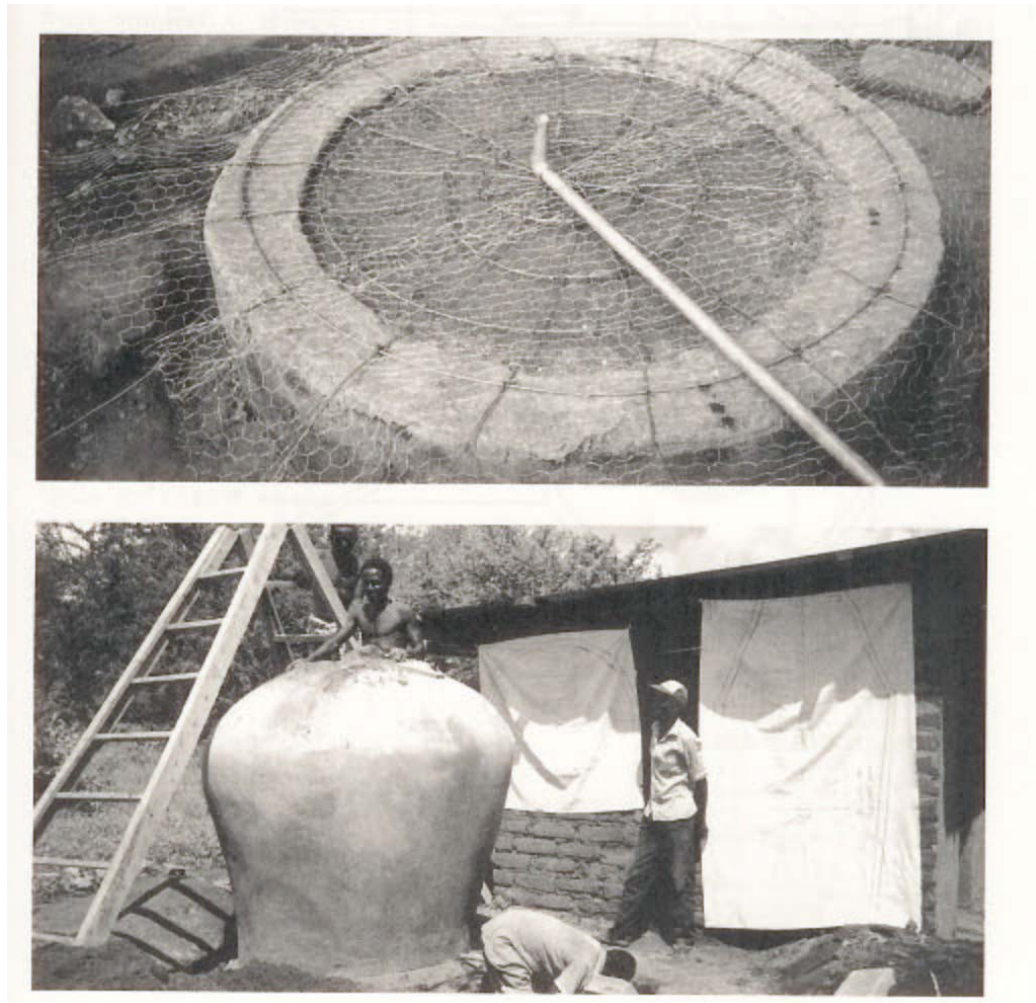


Figure 3.10 The Jumbo Jar 3m^3 (Gould and Nissen-Petersen)

Choice of below ground tanks

With underground tanks one is effectively using the insitu soil as the support structure so that the lining is primarily there as a water proofing element. The rigidity of the substrata determines to some degree the choice of lining.

Brick masonry has been used for this function for centuries as previously indicated in the construction of *kundi* in India. The size of the excavation has to be increased to accommodate the thick walls and working space.

Cement slurry lined excavations in stable soil. Neat cement mixed with water or *Nil*, is ideal for the construction of very thin shells to line pits. Neat cement is significantly stronger than mortar and more flexible. If the

substrate has sufficient residual strength, the excavation can be waterproofed by applying cement slurry to the surface. Attention needs to be given to the application as very low leak rates can be achieved but care must be taken not to damage the lining. Such a lining is however flexible and will accommodate a degree of deformation. Thomas and McGeever (Thomas and McGeever 1997) claim to have built several such tanks in western Uganda. The 25mm mortar lining they applied directly on the earth wall was still performing well after 5 years.

Ferrocement. The use of Ferro cement for underground tanks needs some consideration. As the reinforcing in the cementations layer is to provide tensile strength it may be redundant as this strength is effectively already provided by the walls of the excavation and can be the cause of air pockets behind the lining that, in turn, may be a failure point. Large semi spherical tanks have, however, been build very cost effectively for schools and similar institutions but require well trained artisans and stable soils.

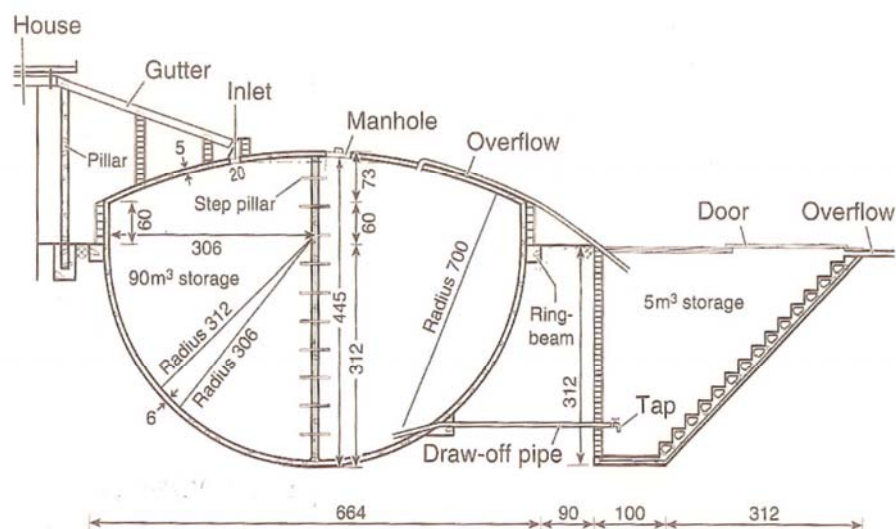


Figure 3.11 90 M3 Underground Ferrocement Tank

(Gould And Nissen-Petersen)

Sleeve Well. These are sheet plastic lined excavations. A lot of work has been done on the use of plastic “sleeves” which can be produced very cheaply as an answer to creating storage for the “Very Low Income Sector”. (The cost element of the excavation can be contributed by the poor in the form of direct labour.) (DTU January 2002)



Figure 3.12 Sleeve Wells

Source Rees And Whitehead 2001 (DTU)

DTU, who have pioneered this research, report that the original design was fairly successful and several of these tanks are in service but have exhibited problems after a year or so of use (DTU 2002).

Some of the problems with this approach were:

- The cost of the parapet wall dominates the overall tank cost and forces the design to compete directly with more robust designs such as the Ferro cement jar.
- The hole, which is only 540mm Ø, is difficult to dig.
- The sleeve is tied off at the bottom and this point can leak.
- The liner is extremely difficult to remove if it is punctured – those that do leak have not been repaired.
- The overflow can leak resulting in accumulation of water between the bag and the excavation walls.

Modified sleeve well. Modified plastic liner design have addressed the problems by including:

- A pre-cast concrete cover, which reduces the cost. The cover, which is similar to those found on some hand-pumps, uses similar casting techniques to pit latrine covers (sanplats).
- The tube is folded in two, eliminating the tied joint, making the hole 40% larger and are consequently, easier to dig
- The tube itself is easily replaceable by using a retaining ring and binding wire to hold the tube in place.

On this basis a very cheap tank can be constructed which can be increased in size (depth) at a very minor additional cost.

3.6 Cost Comparison Of Different Storage Structures

In order to assess the various options with regard to material and type of tank, Table 3.2 has been prepared. The table sets out recently published figures from researchers and practitioners in the RWH field and some commercial prices received from vendors in Rwanda. As the prices are general for East/Central Africa, they are presented here for comparison purposes only.

As can be seen the cost per cubic meter of storage capacity varies from \$11 to \$179, which is a huge variation in price. The cost of the storage element is the most expensive and for this reason institutions such as DTU and others are paying particular attention to it because cost is the greatest stumbling block to the introduction of RWH in poor communities where it is most needed. The solutions they have come up with have promise for this population segment but field-testing to prove their durability is required.

Ferrocement in its different forms appears still to be a strong contender in this field for both small and large tanks.

Plastic tanks and similar commercially available products, though versatile, are still far too expensive to be recommended generally for domestic RWH and too small to be used in large scale applications.

Table 3.2 Comparison Of Storage Structure Prices (Various Sources)

Cost comparison of different RWH storage tanks						
TYPE OF TANK	DESCRIPTION	VOLUME M3	TOTAL COST USD \$	COST \$/M3	COMMENTS	SOURCE
Above Ground	Ferrocement cylindrical	46	\$1,200	\$26	Suitable for schools	Gould and Nissen-Petersen
"	"	23	\$750	\$33	For domestic water	"
"	"	11	\$550	\$50	Small domestic	"
"	Brick cylindrical	10	\$500	\$50	Low skill	"
"	Jumbo Jar	3	\$150	\$50	Easy	"
"	In situ concrete	5	\$300	\$60	Simple but small	"
"	HDPE	10	\$1,462	\$146	Commercially available	ROTO S.A.R.L. Kigali
"	"	5	\$759	\$152	"	"
"	"	3	\$489	\$163	"	"
"	"	1	\$179	\$179	"	"
Partially below-ground	Hybrid tank with ferrocement dome	10	\$126	\$13	In experimental state	DTU School of Engineering, University of Warwick
"	"	3	\$76	\$25	"	"
Underground	Mortar tank with organic roof	8	\$90	\$11	Very low cost community built	"
"	Ferrocement semi circular	90	\$1,900	\$21	Skilled Artisans	Gould and Nissen-Petersen
"	Tube well horizontal	2	\$46	\$23	In experimental state	DTU School of Engineering, University of Warwick
"	"	1.2	\$38	\$32	"	"
"	Tube well vertical	1	\$33	\$33	"	"
"	Mortar tank with organic roof	2	\$70	\$35	Very low cost community built	"

3.7 Water Quality And Filtration

As discussed above, a lot can be done to ensure good water quality of stored rainwater by prudent design. Water stored in this way will be as good if not better than piped water in developing countries where reticulation pipes are empty or under negative pressure for some portion of most days.

There are a range of ways rainwater can be handled for domestic uses:

- I. For washing and flushing only with possibly a separate plumbing system to facilitate this.
- II. Filtering and sterilizing only the water intended for drinking/cooking water.
- III. Purification all rainwater so that it can be put to any domestic use.

Using filters and water purifiers is easier than boiling water and can be cheaper and surprisingly uncomplicated. There are many available on the market in a variety of capacities and types depending on the intended use.

For domestic use there are two basic types of water purification/filtration systems. A *point-of-entry* device, which is attached where the water enters the household distribution system, and a *point-of-use* device placed on the specific tap sites being used. The *point-of-use* would be the most appropriate if approach III above were adopted with rainwater supply. In this case it would be advisable to it in combination with an inline UV sterilizer.

For bigger installations such as those for schools and institutions, a *Slow Sand Filter* could be considered. These can remove up to 99.99 percent of turbidity, bacteria, viruses and Giardia cysts without the need for chemical flocculents or the use of electrical power. As the water is passed through a layer of sand, a naturally forming biological layer purifies the water. Recent improvements in design have solved the problem of the filter requiring a continuous flow of water to keep the top layer of sand from drying out. (David H. Manz 1988)

Other types of filter used for water treatment include:

- *Rapid sand filters* - these filter at a rate of 100 liters per minute per square meter (l/min/m^2) and physical straining and trap solids in the pores between sand particles throughout the bed.
- *Carbon Filters* - these are excellent for removing organic by-products and for improving the taste of water and decrease the odours usually caused by organic materials. Carbon filters are generally easy to install, often attaching to the kitchen taps.
- *Reverse Osmosis Filters* - these are excellent at removing most constituents from water but not as effective in removing organics as carbon filters are, so unpleasant tastes and odours may persist

3.8 Rainwater Harvesting: An Economic And Social Good?

Water is accepted as both a social as well as an economic good in that the presence of water allows economic activities and clean water is essential to sustain human life. Further than this, should a society's access to water fall below some level of quantity and/or quality the physical health of the society will be negatively impacted – costing the society in social and financial terms with regard to health care and productivity. Having said this however, the cost society places on water seldom reflects the full cost of that water because the price is discounted precisely *because* water is an economic and social good. Hidden in the real cost of water are environmental costs such as power to pump, the use of water treatment chemicals, dam construction, intake works etc.

Joel Ruet accurately encapsulates this state of affairs when he refers to the “fuzzy economic characteristic of water supply” (Joel Ruet 2004).

The problem this presents to the implementation of RWH is that set against prevailing tariffs it is often at best only marginally cost effective over a long period.

This is all the more unfortunate as RWH holds the promises of many social and economic goods as well as environmental benefits. Amongst these are:

- the freeing of children and women from the daily toil of collecting water and in the process missing the opportunity to work or study,
- having ample water in the home thus improving health prospects',
- saving on pumping, purifying and reticulating costs of conventional supply,
- delaying the need for capital expenditure on extending water extraction and storage facilities',
- reduced erosion due to reduced urban runoff,
- providing a ready water source in emergencies i.e. fire or natural disaster,
- creating opportunities for generating new low-investment livelihoods, especially amongst women.

3.9 RWH Research And Practice Internationally

Because the use of RWH has been neglected for many decades, there is a current shortage of published standards of practice to guide the would-be user of RWH in houses or on industrial and commercial premises with the design and implementation of a scheme. For instance, there are currently no standards in England and Wales relating directly to domestic rainwater recycling systems that have statutory obligations. In Sydney, Australia, where a Rainwater Tank Rebate Program is being run, participants are only required to engage a registered plumber to install a rainwater tank in order to apply for a rebate from Sydney Water. In Germany, where RWH as a technology has been actively used for the last 10 years, the methods used are based on best practice. Some such as

Rott and Meyer (Rott 2001) have looked at how RWH practices relate to existing standards.

The absence of such standards may be an impediment to its introduction in some cases as planners, architects and building managers draw confidence from work done to existing codes of practice.

As the systems are by definition *low technology*, however, success can be achieved by artisans with conventional building and plumbing skills provided they pay attention to some practical elements which have been recorded by the many who have researched this field.

Some of these practical elements are contained in published guidebooks such as:

- *A Water Harvesting Manual For Urban Areas* produced by the Center For Science and Environment which has some practical guidelines more specifically for ground water recharge (2003).
- *Rainwater catchment systems for domestic supply* by Gould, John and Nissen-Petersen, Erik (1999), IT Publications London.
- *Rain Catchment and Water Supply in Rural Africa: A Manual* by Nissen-Petersen, E. (1982).

3.9.1 Research.

With the re-emergence of RWH in the last two decades, spurred by the need for answers to the crisis facing the world with 1.2 billion people without access to safe drinking water, a significant body of research has created in the field of RWH. Individuals such as John Gould, Anil Agarwal, Gwilym Still, Terry Thomas and Erik Nissen-Peterson, to name just a few, have done a great deal to advance the application and practice of RWH internationally and in the developing world in particular.

The largest funded research programme in the field appears to be that run by the Development Technology Unit (DTU) of the School of Engineering, University of Warwick, UK, which is funded by DFID the Department for International Development in the UK Government.

RWH has been a topic on the agenda of numerous conferences and the World Summit for Sustainable Development (WSSD) in Johannesburg was no exception. During the World Summit the International Rainwater Harvesting Alliance (IRHA) was formed by the **Rainwater Harvesting Collective**.

The draft Strategic Plan for IRHA in Africa set out a three-year plan (2003-2006) which included

- setting up policy framework
- knowledge building and networking
- rainwater harvesting activities/projects
- capacity building
- documentation and public awareness.

The South East Africa Rainwater Harvesting Network (SEARNET) an affiliate of IRHA, is due to hold their 9th conference in Kigali from 27 November – 2 December 2005.

4. WILL RWH WORK IN KIGALI?

"You don't know the worth of water, until the well runs dry" (Ben Franklin)

This chapter will test the hypothesis that *Rainwater Harvesting could be an answer to bridging the gap between the water demand in the city of Kigali and that currently supplied by the water utility.*

The best way to test this hypothesis is to answer some direct questions. The questions that need to be answered include:

- Why RWH as opposed to other water sources?
- Will RWH work technically in this area?
- What techniques could be used?
- Who will drive the implementation process?
- How would it be funded?
- What will it cost?
- Will RWH work socially?
- What implementation strategy could be adopted?
- What are the major impediments to this approach?
- Are there any additional benefits in taking this approach?

The sections of this chapter will address these and other issues.

4.1 Why RWH?

This section discusses the question of why RWH is being investigated as opposed to other interventions to supplement the water supply to Kigali.

As outlined in the introduction, the further development of the existing water infrastructure serving Kigali is problematic because of the capital investment needed, issues of privatization/cost recovery, the reliability of the sources and the poor quality of the surface water. This research accepts, as a starting point, that while solutions may be found to resolving these difficulties in the

future, there is an immediate need to ensure that the population of Kigali has access to at least a minimum quantity of water. The minimum daily water requirement has been set by the WHO at 25 l/p/day but other studies in both developed and developing countries suggest that an average of 20 liters per person per day appears to satisfy most regional standards and that 10 l/p/d will meet basic needs. (White G.F., D.J. Bradley et al 1972) (U.S.A National Research Council, *Recommended Dietary Allowances*. 1989)

Alternative water sources are not mutually exclusive and it may be possible or necessary to have more than one source depending on the circumstances. The different options will have to be evaluated on the basis of reliability, cost and quantity. In Kigali RWH must be considered along with the potential of exploiting ground water, spring development etc.

Rwanda's fairly good bimodal rainfall makes the consideration of RWH a water source worth investigating. In addition, the relatively low cost and simple technology of RWH and the fact that water is generally collected and stored where it is needed adds to its attraction as the steep topography of Kigali and its environs makes the distribution of centralized water difficult.

Although all other possibilities must be pursued it is unfortunate that the potential for ground water extraction is poor in Kigali¹ and springs are limited to low lying areas, some of which are threatened by polluted surface water. These facts also encourage the investigation into the use of RWH.

Finding: RWH is just one of a number of possible alternate water sources. However given Kigali's climate and topography it appears to be one of the most favorable.

¹ Rwanda, being situated in the East African rift valley system, underwent a lot of tectonic movement and as a result the landmass is very rugged and fractured, with steep mountain slopes and deep valleys. These compressive and shear forces disrupted the preferential pathways of the underground waters resulting in many fractures being closed and dry.

4.2 Climatic Suitability Of Kigali For RWH

This section addresses the suitability of Kigali's climate and rainfall to the utilization of RWH.

As already discussed in section 2.1.7, the rainfall in Kigali average out at 997mm per year. It can be seen from the Figure 4.1 below that the rainfall is bimodal having two rainy periods, the first from March to May and the a less intense second wet season from October through to December.

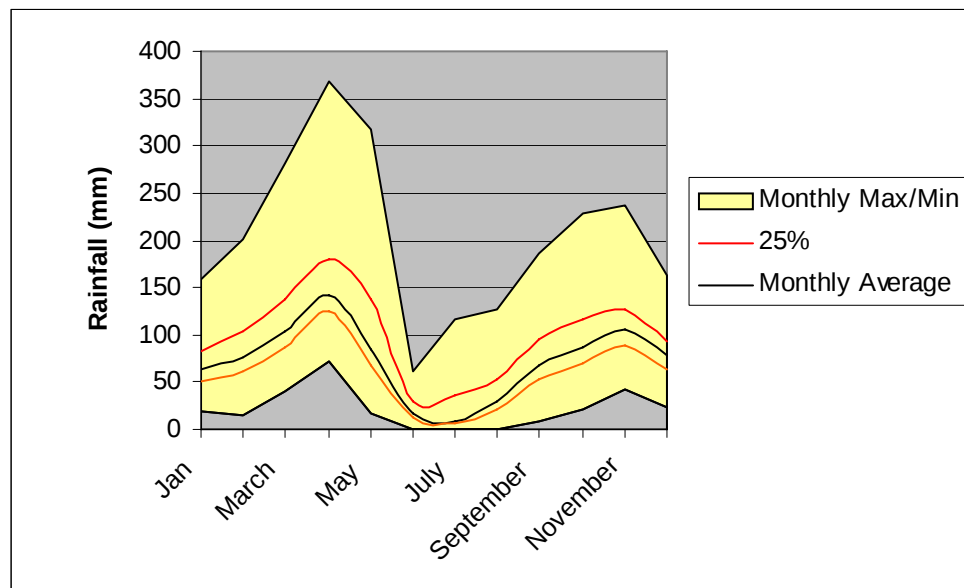


Figure 4.1 Average Monthly Rainfall For Kigali
(From data supplied by Rwanda Meteorological Service)

The rainfall pattern has two major implications on the question of the suitability of Kigali's climate for the use of RWH.

- I. As will be shown below, the 997mm of annual rain can sustain a supply of 25 liters per day off a hard roof of 12m² (9.5m² for 20 liters/day). Thus a household of 6 needs 57-72m² to be self sufficient for basic water. The fact that this amount of hard roofing will not generally be available in the poorer sectors of the community underlines the fact that RWH can only be a supplementary water for the present.
- II. The fact that the rainfall is bimodal is advantageous in that the quantity of water that must be stored to last the dry periods is less than that required with the same rainfall in a unimodal weather pattern. As will be

shown later, the storage tank is the major cost component in a RWH system so reducing the size/cost of this element makes the scheme more viable.

To design a RWH installation, detailed rainfall records are required as well as an appreciation of the reliability of the rainfall. The keeping of rainfall records in Rwanda started in 1931. However, those specific to Kigali only started after independence when the capital was moved to Kigali. The results presented here are from the Rwanda Meteorological Services (RMS) that have recorded monthly rainfall in Kigali since 1961.

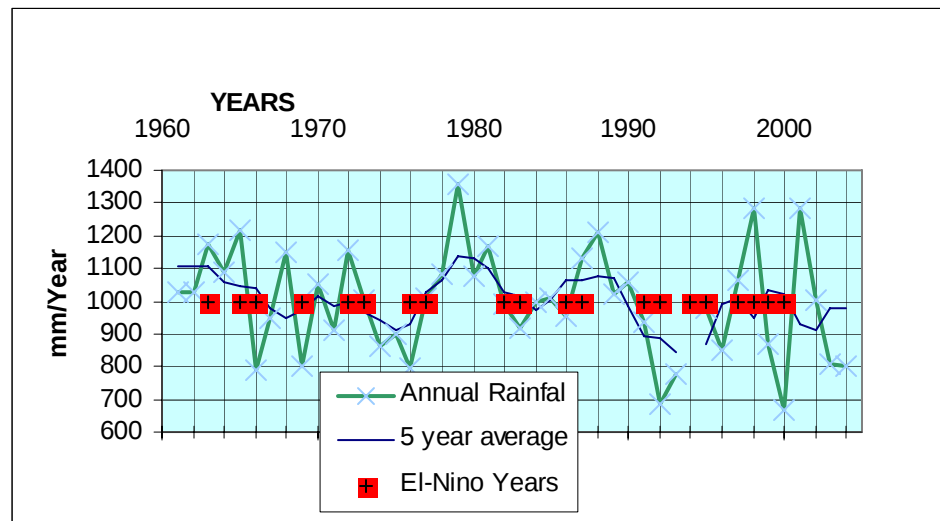


Figure 4.2 Kigali Annual Rainfall From 1961 To 2004
(From data supplied by Rwanda Meteorological Service)

From figure 4.2 the cycles of *wet* and *dry* years can be seen. The years marked in red are the *El-Niño* years which recur with a frequency of 2-7 years (Coghlan, C. 2002). The *El-Niño* phenomenon is a result of the periodic building up of a large pool of unusually warm waters in large parts of the eastern and central equatorial Pacific Ocean. This system is mirrored by an opposite cold event called *La Niña* - the two systems are often collectively referred to as the El Niño / Southern Oscillation (ENSO) (WMO 1984). Some of the *La Niña* episodes can be associated with suppressed rainfall especially in the September to December period over much of Rwanda. The latest *La Niña* was in 1999-2000 following *El Nino* of 1997-1998 and was associated

with the drought experienced in East Africa which resulted in serious crop shortfalls in Rwanda, and notably for this study, especially in eastern Kigali-Ngali.

These cycles will obviously affect any RWH system. The approach taken here to account for them in a specific design, is to run the storage model developed over a known period of a deep drought, such as 1999-2000, to see the effect on the water yield of the system.

It would appear from Figure 4.2 that the *dry* and *wet* cycles are increasing in severity. As observed by Trenberth, El Niño events have been unusually frequent since the mid-1970s and the same period has seen a dramatic rise in global temperatures, suggesting a correlation between global warming and the El Niño Southern Oscillation (Trenberth 1999).

Although such predictions are largely speculative, more severe cycles will obviously impact on the design and performance of all RWH systems. Although it is impossible to make an accurate adjustment in the design to offset the effect of a hypothetical future event, it can be recommended that, where possible, the storage unit should be oversized to benefit from any surplus rain so as to better weather more extreme dry spells.

Temperature does not directly affect RWH but it does influence consumption patterns. The statistics of monthly average and maximum temperatures from Rwanda Meteorological services (RMS) are presented in Figure 4.3. It can be seen that Kigali experiences a very temperate climate with very little variation through the year.

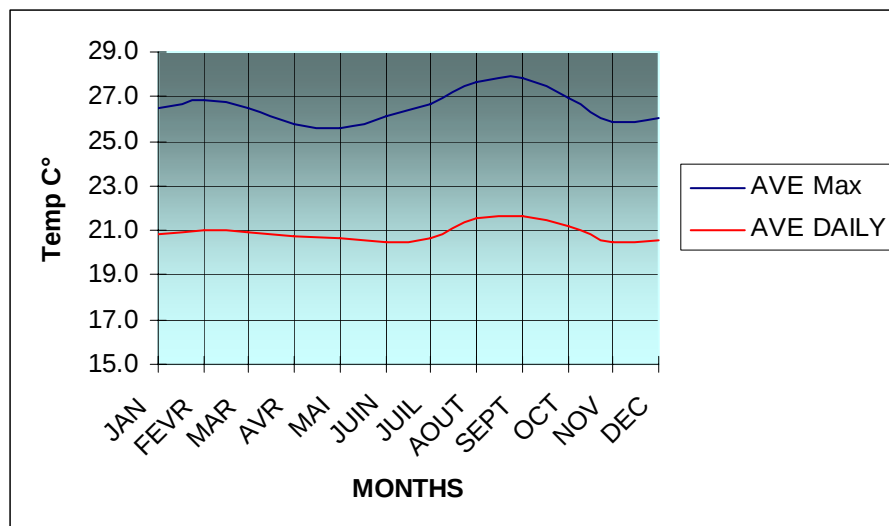


Figure 4.3 Kigali Daily Temperatures
(From data supplied by Rwanda Meteorological Service)

Finding: Kigali's climate can sustain a water supply equivalent to the basic needs of an individual off 9½ -12 m2 of sheeted roof. There is unlikely to be seasonal changes in water demand but a cycle of wet and dry years is to be anticipated.

4.3 Costs And Potential Harvests

In this section two separate domestic RWH installations are designed and the costs are estimated. Examples of typical Kigali houses are used.

As this research is not directed at any one income group or type of building, a middle-income house in the Kigali suburb of Kiyovu (referred to here as House "A") and a small house in the low-income neighbourhood of Kimihurura Pauvre (referred to here as house "B") were chosen in order to analyze the costs of installing RWH schemes.

4.3.1 House 'A'

This house, which has a floor area of 205 m² and a roof catchment area of 243 m² has 4 bedrooms, 2 ½ bathrooms and one garden tap. The municipal water supply is good in comparison to other parts of the town but water pressure varies and total water supply interruptions of up to 5 hours are not uncommon in the dry season. For these reasons a small header tank was

installed to ensure a constant water supply. Water is not used straight from the tap for drinking but is first filtered and boiled. The water exhibits varying degrees of turbidity and there is a deposit on the filter elements that needs cleaning periodically. The filter also has occasionally to be cleaned of grit.



Figure 4.4 House 'A' Kigali

RWH System Design. The first task was to determine the size of the storage required. To do this the mean monthly rainfall was calculated from the records of the last 34 years with all rain events reduced by 1mm to allow for initial absorption and evaporation. The mean annual rainfall was thus reduced to 860mm.

Certain assumptions needed to be made and as can be seen on the calculation sheet in Appendix D, the house occupancy was assumed as 4 persons with a daily consumption rate of 120 liters/person². The house is roofed with “big 6” asbestos cement sheets for which a coefficient of run off of 0.8 was assumed. With this data the annual potential harvest can be calculated as 167 m³.

The calculation was done by way of a model that computes the net monthly loss or gain from consumption and inflow figures. A tank size and an initial volume were assumed and the calculation was run through a number of iterations until it stabilized. See Appendix D.

² Section 2.1.1 has a discussion on water consumption. In this case a consumption of 120l/c/d was assumed. This is an above average African consumption rate but appropriate for the fairly affluent neighbourhood. The sensitivity analysis described below highlights the effect the consumption has on the success of a RWH system.

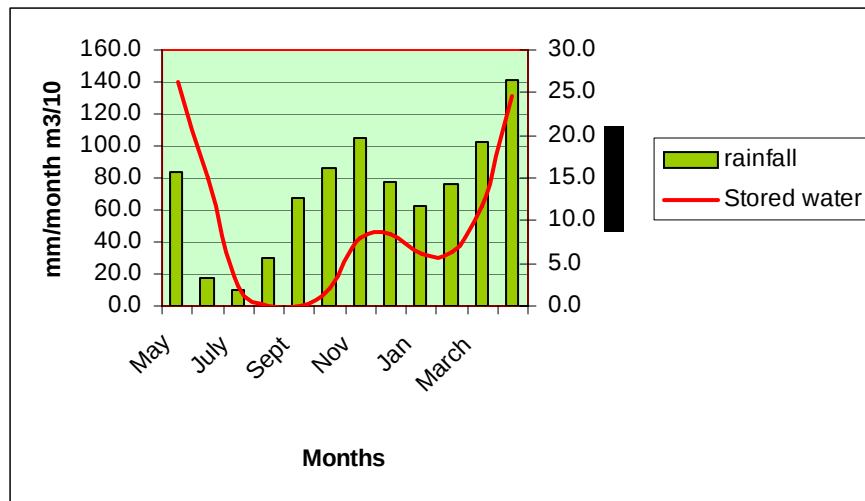


Figure 4.5 Rainfall And Storage Calculations

In this case the annual water demand is greater than the potential harvest. By using the model described, one sees that the tank will only fill to 26m^3 . An optimum size for the tank for an average year would thus be just more than 26m^3 .

If the harvest is greater than the estimated consumption then a tank size can be chosen so that no shortfall occurs in any month.

Performance over a dry period. To test the affect of tank size on performance over a prolonged dry period, the same calculations were run over the known 4-year drought 1998 – 2001, first with various size tanks and then differing consumption figures. 1998 was an above average year, 1999 was 15% below average, 2000 was the driest year on record and the drought broke in 2001. This pattern has been ascribed to the El-Nino effect as discussed in 4.2.

The results of the calculations (which are fully shown in Appendix E) are summarized in the Table 4.1 below. Note *Water bought* refers to water that needs to be purchased from another source to sustain the consumption.

Table 4.1 Effect Of Storage Volume And Consumption On Supply

Selected Storage Volume m ³ (Assuming 120 l/p/d)	Water bought (Litres)	% Water bought	Number of months in which storage may be exhausted.
20	117	17%	4
25	104	15%	4
30	94	13%	3
35	89	13%	3
40	84	12%	3
45	79	11%	3
50	74	11%	3
Water Consumption l/p/d (Assuming 26m ³ storage)			
140	182	22	5
120	104	15	4
100	49	8	2
80	9.2	2	0
60	0	0	0

It can be seen that selecting a tank larger than the originally assumed 26 m³, would only have resulted in 2-3% saving in water purchases. On the other hand a small change in water use habits (say from 120 to 100 l/p/d) would halve the additional water needed.

As a result of the above, it was decided to keep the tank size at 26m³. Although not costed here, the water harvesting potential of the property could be greatly increased by collecting surface water from the paved areas shown in Figure 4.4. If this lower grade water was collected and used for activities such as gardening and car washing, the demand on the roof water tank would be reduced and would improve the ability of the property to withstand long dry periods.

Types of storage tank. Considerations regarding the type of tank that had to be taken into account here were space and aesthetics. An underground tank was chosen and the best location was on the North side of the house as the septic tank is on the south side. The soil around the house is a firm, shaley soil visible at the back of the property where a bank was originally cut to create the building platform for the house in the steep slope. Although firm, the soil has a rough surface when excavated. The possibility of using a

slurry lining was considered but it was decided to go for a brick lining which was more durable although more costly

The house is gable ended so water from the two guttered sides will be lead to the storage tank via underground pipes. The design layout chosen is shown in the drawing *Layout of House Showing Roof Plan & Drainage* (see Appendix E).

Leaves and pine needles³ will be retained on coarse screens in the down pipes which include a first flush mechanism (see Appendix E) and a finer screen will be provided before the tank in an inspection chamber. Water will be introduced near the bottom of the tank using a bucket to dissipate the energy and reduce the velocity so as to avoid excessive turbulence.

Water will be extracted by a manually operated single-phase pump that will pump to the existing header tank. The water will be drawn in via a swimming intake, which will take the cleanest water from just below the tank surface

The total scope of work is measured and priced in the bill of quantities (BOQ) also shown in Appendix E .The house has only 30% of the required guttering and no down pipes so this additional work is included in the BOQ.

A summary of the costs can be seen in Table 4.2 below:

Table 4.2 Cost of RWH system for House 'A'

<i>Component</i>	<i>USD \$</i>
<i>Storage tank</i>	\$ 2940
<i>Piping and catchpits</i>	\$ 969
<i>Gutters and down pipes</i>	\$ 119
<i>Pumps</i>	\$ 1194
<i>Total</i>	\$ 5222

³ The Cyprus trees close to the house pose a real problem as the fine needles tend to mat and clog. Consideration would have to be given to replacing these trees with a more suitable indigenous trees.

The anticipated water consumption of 120 l/p/d or 14,400 liters/month will only cost RWF 2880 (\$5.18) if purchased from Electrogaz through the water meter. This volume of water is still in the lowest category of Electrogaz's block tariff. Some savings could be made in the cost of the scheme such as omitting the standby hand pump. However the repayment period for the RWH system with the low cost of water will still be in the region of 80 years!

4.3.2 House 'B'

In this example a typical small house is assessed for its RWH potential. The house, which is shown in Figure 4.6, has a mono pitch sheeted roof of 62m². If it is assumed that there are 5 occupants then with Kigali's annual average rainfall (modified as before) it can be shown that, a daily consumption of 25l/person can be sustained with a surplus of nearly 1000 liters.

Table 4.3 Potential Water Harvest House 'B'

	Quantity	Unit		Quantity	Unit
Roof Area	62	m ²	Number of house occupants	5	No
Modified Annual Rainfall	860	mm	Daily water usage per person	25.0	Liters
Coefficient of Runoff	0.9		Total annual water requirement	45.6	m³
Total Water Harvested	48.0	m³	Shortfall/Surplus	2.4	m³

From the figures shown in Table 4.3, it can be deduced that a roof area of 12m² is required per person to provide a basic water requirement of 25 l/d.

The optimum tank size for House "B" has been calculated in the same way as it was done for House "A". The calculations are shown in Appendix D. In this case, however, there is surplus water. The householder now has a range of choices depending on how much money he has or is willing to spend on the scheme.

- He can choose a tank that is big enough to ensure that no additional water is needed on average with "basic" consumption.

- He might choose a bigger tank to collect all the available water for increased water security or greater consumption.
- He might opt for a smaller tank that will provide water for some months of the year.
- He might start with a small tank and add a second or third with time.

From the calculations it was determined that to ensure that no additional basic water is needed, a storage of 8.2m^3 is required. If the budget did not allow this, a smaller tank of say 6m^3 might be chosen. This would require that water be carted in the old fashion for an average of

nineteen days of the year – a great improvement on 365 days.

Type of storage tank. In this example, a surface tank might be the better option as water could be drawn directly from the tank by way of a tap. The suitable tank option here might be a ferrocement jar or cylindrical brick tank costing in the order of \$300 for 6m^3 or \$400 for 8m^3 .

As the roof is a mono pitch a gutter is only required on one side of the roof. If “V” gutters are fabricated on site the price should be around \$10 and piping can be assumed to cost a further \$20. Therefore, with labour, the whole installation with an 8m^3 tank would come in at \$450. The daily water use of 125 liters, if drawn from the kiosk, would cost 188RWF and if this were drawn daily for a year it would represent \$122/year. Thus if \$450 was invested in the RWH system, the repayment period would be under 4 years even without putting a value to the water carriers’ time.



Figure 4.6 House ‘ B ‘ in Kimihurura

It is almost certain that the present water needs of this household are collected from the water kiosk (or the local perennial stream) by the mother and/or the children who will typically spend two or more hours per day hauling the five jerrycans required. (The kiosk is one kilometer away in this case).

Thus, with a relatively modest investment of \$450 and some labour the household would have their basic water needs met without the daily toil of fetching and carting it. In addition, the quality of the water will be safer than the surface water previously collected and the time saved can be put to more productive uses such as studying or tending a kitchen garden

Findings:

- 1) A RWH scheme for the typical middle to upper income house investigated with a water consumption of 120 l/p/d can be sustained for all but 17 days a year on average. The cost of installation would be in the order of \$5222. Although this would not be a major investment for middle to upper income families, it is very significant if compared with the equivalent cost of mains water. It may however be an attractive option to those with poor water supply to guarantee a constant supply of water throughout the year.**
- 2) A RWH scheme in the typical low-income house can sustain a consumption of 25 l/p/d with a repayment period of under 4 years.**

There are two main observations that may be made based on these results.

- **The pricing policy of commercial water has serious inconsistencies, it is too cheap for piped users and possibly too expensive for the poor at the kiosks. The cost of water is obviously held down because of its role as a social and economic good. But in reality the poor are forced to resort to unsafe surface water and there is no incentive for the middle and upper income groups to save water. Thus the policy will be self-defeating and the water shortage will get worse.**
- **The benefit that RWH will bring to both social strata considered in the two examples and in fact the society as a whole, cannot only be evaluated in financial terms.**

4.4 Who Will Drive The Implementation Process?

In this section consideration will be given to who has an interest in the implementation of RWH in Kigali , which groups may drive the process forward and where the problems lie in this process.

There are many sound reasons for promoting the use of RWH in Kigali but these reasons are diverse and many of them cross cut society and government structures.

In simple terms the benefits will include the following, many of which are inter-related:

- improved access to water on a domestic level for all who invest in rwh
- less pressure on the existing infrastructure therefore better reliability
- improved public health
- less storm water discharged into the city drains with less resulting erosion
- more water security for industrial and commercial needs
- less social tension
- less time spent mainly by children and women in collecting water.
- potential job creation and skills transfer

Interest in RWH can be expected from the following groups and organizations:

Upper income group. The fact that many recently constructed upper income houses in new residential areas experience a poor and highly erratic water supply service will encourage these homeowners to take an interest in the potential of RWH.

Lower income group. The poor should be easy to convince about the merits of using RWH but this will first require education, training and, above all, financial assistance. This is by far the biggest social group and the one that stands to benefit the most.

Benevolent groups. If properly informed, religious groups and other welfare organizations will appreciate the potential that RWH holds for small-scale projects using any large roof space that can be commandeered for a catchment.

Government Ministries. There is good reason for various ministries to support the promotion of RWH for different reasons.

- o The Ministry Of Lands, Environment, Forestry, Water And Mines (MINITERE) will see in RWH multiple benefits for the population and the environment.
- o The Ministry Of Infrastructure (MININFRA) will see in the implementation of RWH a part solution to the problem of urban erosion caused by the discharge of storm water from properties into the road reserve. (See Figure 4.7)
- o Ministry of Finance and Economic Planning (MINECOFIN) will appreciate that a successful RWH programme would result in the increased availability of water generally, including water for industry and other commercial uses, which will benefit that sector. In addition they will, along with those involved in the health services, see in RWH's potential to increase the access to water, a significant benefit to public health and thereby a reduction in the burden on the state as well as improved productivity.

UNEP and other UN agencies who have already conducted pilot projects and workshops in Kenya and elsewhere to promote rainwater harvesting at national and local levels.

NGOs For example, the ICRC, the International Committee of the Red Cross, who have for many years been directly involved in the provision of water to the hospitals and prisons around Kigali would support this initiative as would DFID who have sponsored wide research in this field for many years.

The interest groups are thus quite clearly the citizenry of Kigali, the government water managers and planners, public and private health officials, NGOs, welfare and human-rights groups and work seekers and entrepreneurs.

The fact that there are so many diverse groups with a common interest could impede the introduction of this technology unless there is good coordination between interest groups.

As an example, health and women's issues have no direct link with infrastructure but improving the general population's access to water would be an advantage to both groups. However neither camp may see fit to actively lobby for the promotion of RWH.

Kigali has many steep unsurfaced roads. Heavy rains and large volumes of concentrated runoff from properties overload the storm



Figure 4.7 Erosion In Kigali Street After Heavy Rain

water systems resulting in wash-a-ways, silted drainages and rocks and soil washed

onto surfaced roads. This problem could be significantly reduced if RWH was implemented on a large scale. However the roads section alone is unlikely to lobby for RWH implementation.

Because of this diversity of interest, especially amongst government ministries, it would be necessary that all stakeholders be consulted and included wherever possible but also that the programme be directed for a high level of government. Integral in this process of drawing in support and interested parties will be the important function of educating decision makers

and instructing the government functionaries in the aims and advantages of RWH.

A secondary advantage of having the programme directed at a high government level will be that NGO's and financial institutions have established channels of dialogue with government at a high level and this will make their valuable integration easier.

Findings: There is the potential for support for RWH from an array of Government ministries, welfare organizations and NGOs. It will be necessary to carefully coordinate any initiative to ensure that they are all included and united. The initiative will have to be driven from a high level in the GOR.

4.5 How Can Individuals And Business Be Motivated To Implement RWH?

This section will look at the options available to encourage the use of RWH in the different sections of society

With regard to introducing this approach to the large poor element of Kigali's society, it will be essential that the community 'buy into the idea'. As Suzanne Niedrum observes, "the opinions of the community must be treated with the utmost respect, even when they differ from those of the 'experts'" (Niedrum 1994). She goes on to say that from her experience in Rwanda, hygiene education and social marketing cannot create a need. For success in this sector, therefore, the concept and practice of RWH will have to be workshopped with the communities to ensure their understanding and willing participation. In principal, with regard to domestic schemes in poor communities, it would be best if the construction of tanks and installation of gutters and pipes etc. could stimulate neighbourly cooperation and a sense of self-reliance.

As every liter of rainwater saved and used in the city represents a saving to the country, it is possible to encourage households to install RWH schemes by offering some form of financial bonus. Incentives such as tax rebates and

discounts on materials are offered in Texas, Hawaii, Caribbean islands, Australia, Germany and other European countries (Calfoforo Salas -Internet). In Kenya tax rebates on roofing materials and guttering facilities are offered as an incentive (UNEP). As stated before, assistance with the financing of domestic installations is a prerequisite in the low-income group. An incentive scheme could be worked in with this by offering discounted materials etc. It is beyond the scope of this report, however, to look at innovative financing schemes but in the context of the general development and up-liftment of the Rwandan people, this aspect has the potential to build organizational and managerial capacity from a low level. The whole process will also empower citizens by providing them with a rudimentary knowledge of financial systems and the process of obtaining a loan and the responsibility of repaying it. As an example John Gould reports (Gould 1999) that the use of revolving funds have been widely used in the Nakuru district of Kenya where both the Anglican and Catholic Diocese water programmes have successfully used this approach for many years. Several thousand 10-15m³ roof tanks have been financed in this way mainly by women's groups. Groups comprise 10 to 30 women contribute small amounts - anything between \$2 and \$10 per month until enough is collected to building at least one tank.

With regard to providing subsidies and incentives however, FAO cautions that several points need to be taken note of. (www.fao.org/docrep/U3160E/)

- Help and assistance should only be considered as stimuli to the programme; too big a subsidy to begin with can cripple future expansion and deter participation.
- It is important that in all cases the beneficiaries should make at least some voluntary contribution towards construction. The level of contribution should rise when incentives are provided.
- A *tools-for-work* policy can be considered amongst other general incentives.

Texas Incentive Schemes

The **Texas Legislature** is currently considering a bill to promote water conservation in the State. The Bill (Senate Bill 1332 and accompanying House Bill 2402) if passed, will provide among other things, sales tax exemptions for items to be purchased and used for rainwater harvesting.

Hays County in Central Texas has become the first county in the nation to provide tax incentives for rainwater harvesting. The county, as part of the Rainwater Collection Incentive Program, provides a \$100 development fee rebate and a property tax exemption equivalent to 100 percent of the value of the rainwater collection system.

To learn from the India experience, the approach of using statutory pressure to force compliance must be treated cautiously. If forced to comply, individuals and communities who see no real benefit in a RWH programme, will find ways to circumvent the legislation or pay it lip service and the result will be a failure. (See the *Times of India* article below.)

In their concern to addressing their groundwater problems, India municipal authorities and states have vied with one another to come up with byelaws, notification and ordinances making RWH mandatory. Unfortunately enforcement and monitoring are still very weak and in practice the poor institutional mechanisms are not equipped to support and carry forward the legal requirements put in place. As a result, the number of threats to the Indian public is matched by the number of public notices extending the deadlines for implementation. It is doubtful therefore if this approach will achieve its aims. (For further discussion on India's RWH legislation see Appendix C *Rainwater Harvesting In India*.)

It is important to note that with Rwanda's highly unstable recent past there is an understandable tendency for all socially coordinated activities to be executed strictly under government decree. This autocratic approach can be at odds with an attempt to engender a culture of self-reliance and to get the individual to take ownership of his problems.

Rain harvesting deadline extended

Saurabh Sinha
New Delhi, December 15

THE CENTRAL Ground Water Board (CGWB) has extended the deadline for installing rainwater harvesting systems in certain areas to June 2004.

"The deadline for South and South West Delhi, Faridabad, Gurgaon, Bal-labgarh and Ghaziabad is June 30, 2004," CGWB chairman J.S. Burjia told the Hindustan Times.

Not harvesting rain in these place could invite the penalty of having ground-water extraction systems sealed or seized.

However, hardly any action has been taken against offenders till date as the CGWB says it is a scientific body without enough manpower for policing.

The board been extending its deadlines since the first one in May 2001. The next deadline was March 2002, then September 2002, November 2003, November 2003 and now June 2004.

By CGWB's own admission, just two per cent of Delhiites are equipped to harvest rainwater. "It is not possible to act when 98 per cent of the people are violating the law. Had there been two percent defaulters then we could have acted in tandem with local bodies," an official said.

4.5.1 Motivating Householders

To encourage the willing participation of the community a number of things should be considered:

- I. An awareness campaign aimed at all levels of society explaining:
 - a. the value and scarcity of water
 - b. the process of rainwater harvesting
 - c. water quality aspects of stored rainwater
 - d. the connection between health and water
- II. Demonstration models erected and costed out and placed in areas with easy access to the public
- III. A scheme by which bonuses can be paid to participants on completion of an installation
- IV. The free training of technicians in the skills required
- V. The participation of NGOs or foreign funders to subsidize materials
- VI. The involvement of micro financing schemes

There are two areas where legislation might be appropriate. Firstly, it should be made a requirement that all new houses incorporate a RWH design. The municipality should provide free guidance on this and a handbook on RWH installations should be made available.

Secondly, all large properties of 1000 m² and over should have to have a storage structure of say 50 m³ to catch rainwater off paved surfaces to prevent it being discharged into the road reserve. This would have the dual benefit of reducing erosion in the road reserves and thus reducing damage to buried services as well as providing a source of water for the garden and thus reducing the demand on piped water.

4.5.2 Motivating Institutions

There are many instances around the city of large institutional buildings, churches and sports

facilities where significant amounts of rainwater could be collected. This

water could be used for local domestic use at very low operating costs and because of the steep gradients in Kigali, it should nearly always be possible to gravitate water to a point close to where it is needed.



Figure 4.8 New Church Nyarutarama Kigali

The best approach to installing and managing such schemes would be to form partnerships between the owners of the building and a locally formed water committee. Such partnerships would have to be set up on a case-by-case basis and the authorities could assist in facilitating the process.

The new church shown in Figure 4.8 has a roof area in excess of 900m². This could provide basic water to 75 adults and requires a total storage volume in the order of 120 m³. This storage could be created with one large tank or by using two or more smaller interconnected tanks. For instance, a tank near the roof would be necessary to collect the rainwater but this could feed a more distant tank(s) closer to the community to be served.

4.5.3 Motivating Industry and Commerce

This is an area where legislation might be necessary along with an information campaign. It should be legislated that all large commercial

buildings and offices (particularly government offices) must have RWH schemes installed large enough to cater for all flushing and gardening requirements. In addition to this, rainwater must be used in any operation that calls for washing e.g. cleaning busses and workshop floors etc.

Most old buildings will need additional plumbing to fulfill this requirement so some period of grace will be necessary to allow the owners to make the conversion.

Findings: The process of implementing RWH must be carefully planned so as to ensure a wide range of community support. There is room to use legislation but it must be done with discretion and only when it can be effectively monitored and enforced. A system of incentives paid out or rebates offered is a common practice but must be applied cautiously and well controlled.

4.6 Effect On Access To Water And Cost Of Water

This section will look at what effect RWH can be expected to have on the overall access to water. The influence of RWH on the cost of reticulated water will also be considered.

A successful RWH programme holds the promises of making water available where it is needed in homes and schools, even in 'difficult' locations, at a fraction of the cost, both financial and environmental, of more conventional technologies. This having been said, one has to acknowledge that a large percentage of the Kigali residents live on or below the poverty line in small houses.

In Table 4.4 below, it can be seen that only nineteen percent of the urban population earn a salary. Self employed can generally be taken to mean *hawker* and wage earners are traditionally very poorly paid and can expect just over 1\$ a day.

Table 4.4 Employment In Kigali
(GENERAL CENSUS OF POPULATION AND HOUSING
AUGUST 2002)

Urban Statistics				
	Male	Female	Both	Total %
<i>Self Employed</i>	127465	131744	259209	55%
<i>Employer</i>	1998	695	2693	1%
<i>Salary Earner</i>	56971	32402	89373	19%
<i>Wage Earner</i>	43346	14625	57971	12%
<i>Apprentice</i>	783	479	1262	0%
<i>Unpaid Family Worker</i>	10988	30906	41894	9%
<i>Other</i>	1144	497	1641	0%
<i>NS</i>	8889	7774	16663	4%
Totals	251584	219122	470706	

Although no figures of house size and occupancy are available, the average hard roofed area is very likely to be less than the minimum 9.5 – 12 m² necessary to sustain a basic water need as established earlier.

Table 4.5 shows the variation in urban building materials and roofing types. It can be seen that twenty five percent of the roofs will be difficult to adapt to RWH and 47% of houses are built of low-grade materials indicative of poor (small) houses.

Table 4.5 Urban Housing - Roofing And Walling
(GENERAL CENSUS OF POPULATION AND HOUSING– AUGUST 2002)

Urban Statistics (3rd GENERAL CENSUS OF POPULATION AND HOUSING OF RWANDA – AUGUST 2002)			
Roofing material		Walling type & material	
<i>Zinc Sheetting</i>	75%	<i>Wood/Unplastered Swish/mud</i>	34%
<i>Local Tiles</i>	19%	<i>Wood/Plastered Swish/mud.</i>	10%
<i>Industrial Tiles sheets</i>	1%	<i>Sun-dried mud bricks</i>	45%
<i>Concrete</i>	0%	<i>Burnt bricks</i>	7%
<i>Cartons/plastic</i>	2%	<i>Cement blocks/Concrete</i>	1%
<i>Grass</i>	2%	<i>Stones</i>	1%
<i>Other</i>	0%	<i>Plank</i>	0%
<i>NS</i>	1%	<i>Plastic sheetting/Cartons.</i>	1%
		<i>Other/NS</i>	1%

It must be accepted, therefore, that many houses are not ideal for harvesting rainwater and that the poor will require a high level of financial assistance or subsidized materials if a wide use of RWH is to be achieved. However, RWH is intended as a supplementary water source and not to replace other sources entirely. What it can do is improve the access to water and reduce wasted time and drudgery to the benefit of the whole society.

Because RWH cannot stand entirely alone there will always be room for a conventionally reticulated water supply. The argument against the policy of full cost recovery in the pricing of water is based on the fact that it most affects those who already have the poorest access to water the.

With the implementation of RWH, once the supply of basic water can be accounted for, water can begin to be priced at its true value. This will lessen the load on the state in subsidizing water and a more realistic water price will naturally encourage the more efficient use of the resource.

Findings: RWH cannot be expected to deliver basic water to all who need it, as there are other constraints, chiefly roofing and finances. However, it can go some way to improving the general access to water and lessening the load on women and children who traditionally are the water carriers. This will impact on health, education and living conditions.

Once RWH can contribute to basic water needs in the city, the pricing of piped water can be revised towards the principle of full cost recovery, which will further encourage the efficient use of water.

4.7 Will RWH Have A Significant Impact On Health?

This section reviews the impact RWH can make on public health through improved access to water.

In the quest to improve the health of a society, access to water is but one factor. The intention of any health intervention is to break the disease vectors that threaten man. In the “F” diagram (Figure 4.9) the interventions are clear. Although as Steven Esery has argued, sanitation confers broader and larger benefits to health than water supplies (Esery 1996), an adequate availability of uncontaminated water does improve health significantly.

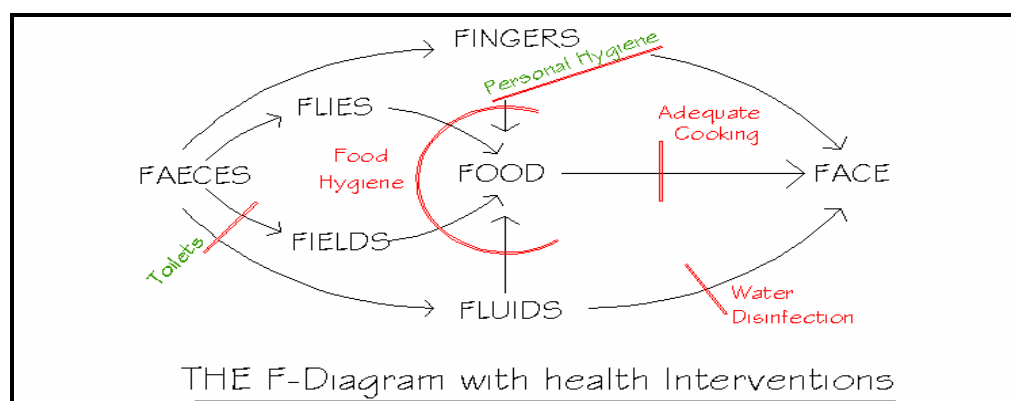


Figure 4.9 The “F” Diagram

In Table 4.6 below the relative effects on the impact on excreta-related infections by sanitation and water provision is demonstrated. In the Kigali RWH context, the collection of rainwater would improve access to water and thereby improve personal hygiene. Provided the technology is correctly applied; the quality of stored water would be acceptable for cooking and should certainly be an improvement on the unsafe surface water sources presently used in poor areas.

Table 4.6 Relative Benefits Of Sanitation And Water To Health

DISEASE CATEGORY	SANITATION ALONE	WATER PROVISION ALONE
I Non-BACTERIAL faecal-oral	Negligible	Great
II Bacterial faecal-oral	Slight to moderate	Moderate
III Soil-transmitted helminthes	Great	Negligible
IV Beef and pork tape worm	Great	Negligible
V Water-based helminthes	Moderate	Negligible

Any success of a RWH implementation initiative should immediately be extended to encompass sanitation. The same educational channels can be used to instruct the population in the necessity for proper sanitation.



Figure 4.10 Collecting ‘Spring’ Water In Central Kigali

Technicians used on RWH installations can easily be trained to convert to building VIP latrines.

As stated earlier, the installation of a RWH system of whatever size will reduce the daily burden of carrying water. Carrying heavy loads over long distances must have negative effect on health especially for small children.



Figure 4.11 Carriers Of Water

In Figure 4.11 it can be seen that this task regularly falls to the very young. (This photograph was taken on a normal school day at 11am).

Findings: improved access to water will have some impact on health. The health impact will be greatly improved if this initiative could be combined with new or existing sanitation projects. There would be ancillary health benefits if the demand for carrying water was reduced.

4.8 Societal Implication

This section attempts to gauge the receptiveness of Rwandan society to the promotion and introduction of a new technology like RWH.

On the domestic level, RWH is installed household by household, maintained by that household and mainly benefits just that household. The implementation process would however benefit greatly by a spirit of mutual cooperation and like-mindedness amongst the people of Kigali or at least within sub-communities. Rwanda's turbulent social history and social rifts might appear as a limitation in this regard but a programme such as the implementation of RWH may in fact help in the process of social repair. This is because the necessary building of managerial and technical capacity for the programme would require dialogue between many different bodies, both

private and public, regarding administrative, financial, legal and technical matters. This dialogue would have to go down to the 'nyumba kumi' or 'ten household cell', which is Rwanda's lowest local administrative unit. It is from here that planning would have to be done and water committees formed. This process would need to develop a sense of self-reliance and ownership in the population and this would be a significant achievement in itself.

Socially Rwanda has a number of positive features, including institutions of traditional social organization, which could be harnessed for such a project. These include:

- *Umuganda*, the tradition of work on public projects
- *Ubudehe*, the tradition of mutual assistance
- *Umusanzu*, the tradition of support for the needy and contribution to the achievement of a common goal.

In this sense, a RWH initiative may find resonance in the National Poverty Reduction Programme that aims to strengthen the spirit of cooperation.

Suzanne Niedrum has observed (*Niedrum 1994*) that in *the Rwandan* society, participation and sustainability should not be taken for granted, even when the need is a given priority. To ensure success, consensus must be sought in all decision making from the start. In particular, Niedrum says, it is necessary to address the problems which women face in participating in the decision-making and seek ways to overcome these.

There may be a general concern that the male element in society may resist paying for RWH, as water collection is traditionally the responsibility of the women in the household. While there is undoubtedly still an element of this thinking there are reasons for optimism. The Drawers of Water II project (Katui-Katua 2003) found that although women continue to be the main drawers of water, there has been an increase in the number of males involved in this activity. They claim that increase in male participation is due in part to changes in income generation patterns and the use of bicycles and

carts to collect and carry water – this type of conveyance frees men from the stigma of doing women's work.

Findings: Stereotypical thinking regarding water collection as a female duty is not anticipated to be a major obstacle because of social changes in society. Rwandan society does have a strong tradition of working together that can be harnessed to good effect.

4.9 Technology Transfer – Job Creation

This section looks at the need and potential for skills and technology transfer and how a RWH initiative would assist in this regard.

As stated by Professor Silas Lwakabamba of KIST, Rwanda lacks skilled personnel and there is a low level of technical training and innovation. (Lujara and Lwakabamba 2003). In the post colonial period there has been a shortage of qualified and experienced Rwandan experts in the technical, scientific, administrative and managerial domains in Rwanda. Many of the limited number of technical experts who were in the country, were either killed or simply disappeared during the war and genocide of 1994.

Through its *Appropriate Technology And Innovation Unit*, KIST tries to address this shortfall in Rwandan society. The unit offers training and a consultancy service to the community with the emphasis on easily applied technologies. One of KIST's main aims is the transfer of technology by installing units for a community and using the installation process as a training opportunity.

The technological skills shortage in Rwanda may be both an advantage as well as a disadvantage to a RWH implementation programme. The disadvantage is obviously that the lack of technical capacity may disrupt or delay the implementation but the advantage is that a RWH programme would have to offer training and with it the promises of work. The genuine desire that exists in the Rwandan society to advance, would draw individuals to such a training programme and give it additional impetus.

Romain Murenzi, Rwanda's Minister Of Education, Science, Technology And Research "If we invest heavily in education, in particular in critical thinking in science, the environment, peace education and human rights, we will have a chance to have not only citizens with knowledge that will make a difference, but citizens who also respect human life and value human life," he said. *Mail and Guardian 28 October 2005*

Applying RWH on a large scale would be directly in support of the GOR's vision and KIST's programme and give it significant legitimacy. Given training in the required plumbing and building skills, a new generation of technicians could make this a new low-investment livelihood and the whole process would be self-sustaining. There will be considerable opportunities for women in RWH implementation as little of the work is very physically demanding and the process of constructing ferrocement tanks in particular has been found well suited to women. (Gould² 1999)

The technology around RWH is on the whole very elementary and the tools and materials⁴ needed are generally readily accessible. The more serious shortfall is the planning and the managerial capacity. The sustainable way to introduce RWH is on a community basis working with community structures for the planning and implementation. The danger is that if managerial capacity is not developed early it could derail the entire programme. The role of NGOs in this whole endeavor will be very valuable but particularly in connection management and planning guidance.

Findings:

RWH hold great potential for Rwandan citizens to be trained, acquire skills and be gainfully employed. The present shortage of skills will encourage citizens to engage themselves in this activity but there is a danger that not enough skills transfer can be achieved. Of greater danger is the fact that there may not be sufficient managerial and planning capacity in the community. To counter these problems Kist and similar institutions should be asked to produce guidelines on the practical and planning aspects of RWH in easily accessible publications.

⁴ It is the writer's general experience that the quality of the plumbing fittings on the market in Rwanda is particularly poor. The fact that the county is so poor has forced down the price of such commodities until the only competitive items are the cheapest imports of the lowest quality. This has a very negative impact on the whole water provision cycle as leaking and malfunctioning fittings can add significantly on the volume of water going to waste. The GOR would be well advised to address this issue soon. In addition to this, manual wages are low which increases the feasibility of labour-intensive communal works where this is appropriate.

5. IMPEDIMENTS TO IMPLEMENTATION

5.1 The Legal Status Of Water

This section looks at the possible impediments that the law can create to the widespread use of RWH and conversely what amendments can be made to Rwandan law to encourage the practice.

Worldwide, most national water policy documents were drawn up well before widespread use of RWH techniques were envisaged. In policy documents, water source development has conventionally meant ground water or surface water and legislation has followed this trend to set user's rights and limitations. Although very few (if any) national water policies give a clear mandate for the development of RWH, the concept has been accepted and is practiced by millions around the world.

The question here is to ask whether the exclusion of RWH from Rwanda's national water policy is in fact a potential difficulty or a constraint to its general implementation.

Some researchers such as Terry Thomas (Thomas⁴ 2003), have found that the absence of RWH from the statutes has not proved to be an impediment to its implementation and several governments around the world are encouraging RWH in some way. He warns however, that at some point, it may become contentious if the practice starts to undermine water supply monopolies.

It is fair to say that while a country's water laws may not have a significant influence on the success of a RWH implementation initiative, they have the potential to be a major impediment to its wide scale implementation. The issue hinges on the legal status of water and its ownership. While no one is going to stop the odd individual from collecting and storing water on his premises, a community scale initiative will first have to ensure that there are no conflicts of interest with regard to the ownership and governance of water. This consideration has increased significance when there are commercial

interests in the water provision. In Kigali's case, the GOR has not reached the point of privatizing the water supply as yet the idea has been suggested.

At present there is no single statute covering water in Rwanda. The first consultation on drafting a WSS policy was held in 1997 and as discussed in section 2.2.3, the proposed water policy is due to go before cabinet for ratification in 2006. (See also Notes of Meeting with Director of Water Appendix A). The GOR has also embarked on a policy of decentralizing governance which includes the management of social services. This places lot of emphasis on the community-management of WSS services through Community Development Committees (CDCs). This spirit of decentralizing governance and taking management to the people will be advantageous to RWH development if it gives water users the choice to select their water source.

Older Rwandese laws regulate natural resource use, among them the Forest Code, laws on fishing and aquiculture, land tenure, pollution of water resources, conservation and land use, protected areas and public health. However, RWH is not yet mentioned.

The problem of RWH not being mentioned in national law is a problem Rwanda shares with many other countries and particularly most African countries (See Table 5.1). South Africa has a more favorable situation as South African law has established water as a *public right* whereas elsewhere in Africa all water resources, which include rainwater by default, have the status of property.

In Rwanda:

The water of every body of water or upon any land is vested in the government. The control of every body of water shall be exercised by the minister in accordance with this Act. The right to the use of every body of water is hereby declared to be vested in the Ministry.

In South Africa:

Everyone has a right to basic water supply and basic sanitation (Water Services Act 97, 3.1.) The national government, acting through the minister, has the power to regulate the use, flow and control of all water in the republic. (3.3.)The minister is ultimately responsible to ensure that water is allocated equitably and used beneficially in the public interest, while promoting environmental values (3.2. National Water Act 98).

Table 5.1 Legal Status Of Water And RWH In Other Countries

(Source Rajindra De S Ariyabandu 2003)

Country	Status	Description
Sri Lanka	Public ownership	No restriction on development of DRWH
India	Not specified	Water is a state subject. No potential threat to development of DRWH
Bangladesh	State ownership	No constraints on development of DRWH
Thailand	State ownership including atmospheric water	Storage of water requires a license as decided by the river basin committees
Kenya	State ownership	Requires a permit to construct water works. Not clear whether this includes DRWH. No restriction on water for domestic use.
Uganda	State ownership	Requires a permit for water development but not clear as to whether this includes DRWH. No restriction on water for domestic use.
Ethiopia	Public ownership	No permit is required. But large scale water development is not permitted without permission. Status of DRWH is not clear. No restriction on water for domestic use.

The type of legal impediment that could obstruct RWH is the requirement for a permit to store water on a property or the need to register a water works. Such a requirement is not clearly defined in Rwandan law.

It is significant that across the border in Uganda this is the case as one needs a permit to *construct a water works* to use non-public water:

"No person shall acquire or have a right to (a) use water, (b) construct or operate any works. (II.1.6) A person may while temporarily at any place, or being the occupier of or resident to any land, where there is a natural source of water, use that water for domestic use. (II.1.7,1) No person shall construct or operate any works unless authorized to do so under this part of the statute.

A person wishing to construct any works or to take and use water may apply to the Director in the prescribed form for a permit to so."

Another type of legal impediment that occurs in some countries emanates from laws requiring all dwellings to be connected to the water supply of the local service provider. Such a law would be impossible in Kigali at present as there is only sufficient water for half the population. However, it is necessary to avoid this type of legislation as it may be considered in the future to protect the interests of a contracted supplier.

Findings:

With the current status of Rwandan water policy it can be said that there are no immediate legal obstacles to implementing RWH. However in order to facilitate the general use of RWH the GOR should:

- consider the role of RWH and its contribution to the overall water supply
- not force water users to draw water from a designated water provider
- entrench the principle of reasonable and equitable distribution of water
- consider all water, including rainwater, not as a property, but as a basic human right - as per the legal status of water in RSA
- the harvesting of rainwater should be freely permitted without special application or approval
- permit groupings of NGOs, churches, donors and banks to form partnerships to manage local resources.
- transfer water resources development to community ownership to serve the communities in a sustainable fashion
- avoid conflicting water development policies through water sector reforms
- establish the right to develop "private water"

5.2 Funding And Implementation

As stated before it is beyond the scope of this report to plan and cost an implementation strategy. This section will therefore identify some of the major costs to the GOR and how they might best be funded.

If carefully handled, the implementation of a RWH initiative need not involve the GOR in major financial cost. If these costs to the GOR are considered as an investment in water security then, liter per dollar, this is a far cheaper venture than investing in conventional water infrastructure. This is partly due to the fact that the householders install the systems and materials are cheap and simple. For a country struggling to free itself from poverty and financial obligations this is very important.

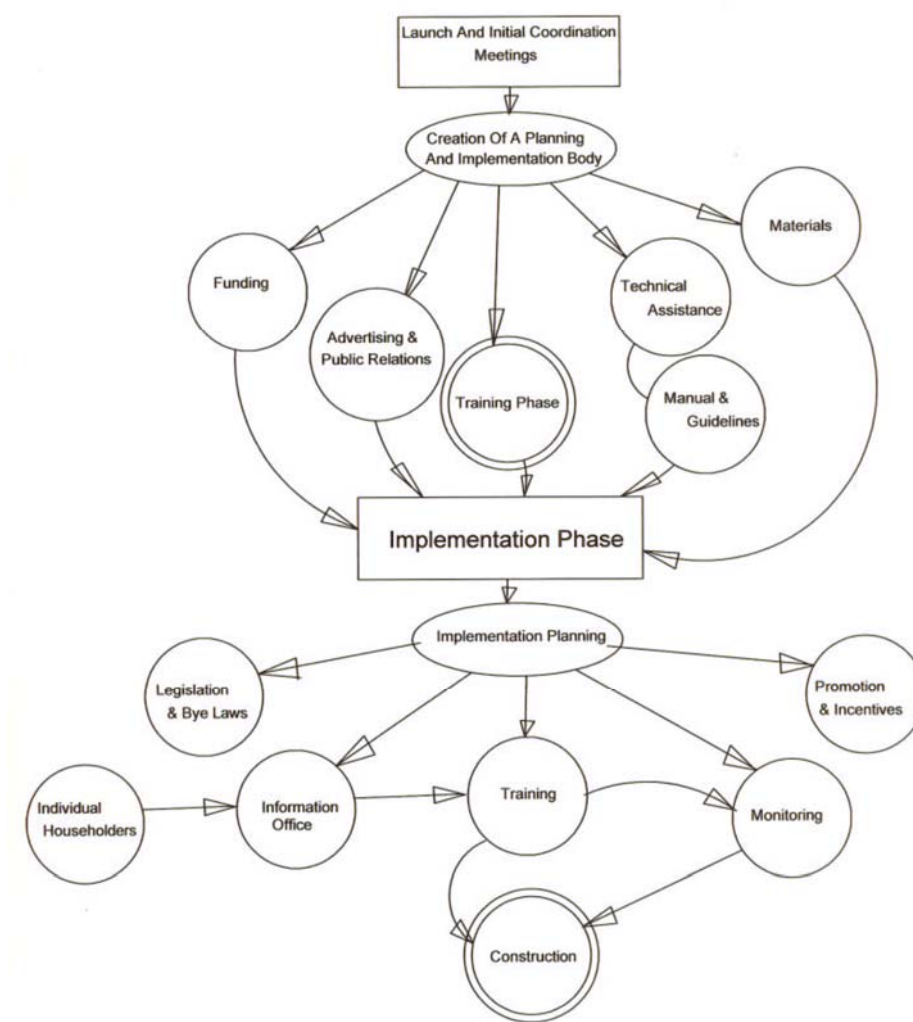


Figure 5.1 Planning And Implementation Cycle

In broad terms the implementation process would need to be planned in phases such as those shown in Fig 5.1 above.

An initial consultative forum would be needed where all interested parties, including representatives from industry, Electrogaz, academic institutions, religious leaders and NGOs, would be drawn together and included in formulating a shared vision with regard to RWH. Such a meeting(s) would establish broad principles and objectives to be translated into an action plan later. For the planning stage, it would be desirable to form a planning and implementation body consisting of government personnel, RWH specialists and NGOs experienced in project implementation.

The expenses to this point would be minor and relate to logistics and administrative costs. The larger project expenses would start with training and the construction of working demonstration models.

5.2.1 Training

There is a significant advantage in the fact that KIST has an appropriate technology training programme in place as this can be built upon (Lwakabamba 2003) The training will have to be undertaken on a number of levels as suggested in the planning cycle. Amongst other areas, there will be a need to:

- train or enlighten decision makers in the government
- run educational programmes in schools
- train technicians who will provide guidance and assistance to the public
- train trainers to work in the field giving instruction in tank building and plumbing etc.
- train supervisors to monitor the quality and progress of the implementation.

There will also have to be a significant public awareness and information programme aimed at sensitizing the people of Kigali to the need for an alternative water source(s) and what RWH can provide in this regard.

It should be possible for a lot of this training and promotion to be handled locally with assistance from specialists from organizations such as FAO and DFID. The implementation body would probably identify these activities as meriting a dedicated sub committee headed up by a strong leader such as Professor Silas Lwakabamba of KIST to coordinate the different initiatives.

These activities will undoubtedly incur costs but some assistance will be forthcoming in the form of grants.

5.2.2 Demonstration models.

In a society with a high illiteracy rate, working demonstration models cannot be overrated. If selected sites are chosen within the city and well constructed RWH systems installed, these would be a significant help in encouraging the citizens to accept the concept, dispelling fears/prejudices and setting a standard of workmanship.

Because this project will complement the mandate of most NGOs; namely poverty alleviation, upliftment, water provision, skills training, hygiene etc, it should be relatively easy to get such organizations to sponsor one or more demonstration models and to handle the very necessary public relations component of the programme.

5.2.3 Incentive Schemes.

The costs to the GOR from this point forward would relate mainly to further training, maintaining field staff and incentives schemes. This latter element would depend on the implementation strategies adopted but would typically cover rebates and discounted materials etc. If correctly structured these should not represent a net cost to the country as the investment would be

recovered in time and as such could possibly be underwritten by the ADB or IMF.

Much research has been done on innovative ways of financing small development projects and domestic installations (Miller 2001) and similar approaches will have to be considered with RWH in Kigali. Although such details are not relevant to this report, it is worth noting that within the context of the general development and upliftment of the Rwandan people, this activity in itself has potential to build organizational capacity from a low level. At the same, time the process will empower citizens by providing them with a rudimentary knowledge of financial systems and the process of obtaining and repaying loans.

Findings:

A RWH initiative will create expenses for the GOR but steps can be taken to off set them.

During the initial discussion phase, costs will be limited to administrative expenses only. The most significant costs will be incurred later and relate to training and promotion which can be largely resources locally.

Costs associated with demonstration units and advertising could be covered by donations or avoided if provided by NGOs.

Offering incentives will incur costs to the government but can be recovered if structured correctly and could be underwritten by banks.

Financing on a household level will need special consideration but has advantages to the community with regard to exposure to financial mechanisms.

Because the householder installs the systems and materials are simple, this is a far cheaper venture than investing in conventional water infrastructure for the same increase in water availability

5.3 Other Impediments

This section looks at other more general impediments and commonly recognized limitations that might impact negatively on the introduction of RWH and how these might be addressed.

Roof Area. The greatest reality opposing the success of RWH as an alternative water source is the shortage of sufficient suitable roofed area to provide basic water of 20-25 l/p/d. As has been seen earlier, a sheeted area of 12 m² per person is required to sustain a consumption of 25 l/d throughout

the year. This figure is unlikely to be achieved in many African cities and Kigali is no exception. The steady growth in sheeted roofing is being offset by urban migration and population growth. This must be recognized as a limitation and is the major reason why RWH is likely to remain a supplementary water supply only. However, rather than abandon the concept, alternative water catchments or water sources should be developed in parallel to a RWH programme.

Installation costs. The second general limitation of RWH is the installation cost to the user. This is particularly a problem in Rwanda, a very poor country where incomes are low. The cost of the storage tank is by far the most expensive element of a RWH installation. Fortunately, because of the favorable rainfall pattern, the sizes of storage tanks required in Kigali will be relatively small. As discussed before, creative financing options will have to be pursued and some aid funding will definitely be found for this project as it strikes at the grass roots sector and has many societal and environmental benefits. The calculation done earlier shows that the repayment period could be 2-3 years and attempts must be made to bridge this period with micro financing.

Misconceptions. The third limitation involves misconceptions about RWH. This includes suspicions about the bacteriological quality of harvested roof water and fears that mosquitoes will be encouraged to breed in tanks and gutters. These preconceptions can only be counteracted by an honest and energetic educational programme supported by decision makers leading by example.

Some male dominated households may query the necessity for and resist the required expenditure on a RWH system because of the low value placed on the time committed to collecting water in the “traditional” way. These attitudes can only be countered by education and sensitizing the public to gender issues.

Image of RWH. Many developing societies wish to break with old values and embrace all things “High-tech”, which are perceived as superior. In this context, RWH may be viewed negatively as a “traditional practice” and thus obsolete technology. (This is nowhere more clearly stated than in the Ethiopian water policy that refers to “... *traditional and localized water harvesting techniques which depend on local resources and indigenous skills.*”) Such terminology can be an impediment to the promotion and propagation of RWH in a developing society where piped domestic water is seen as a sign of affluence, success and progress.

Water quality. As shown before, rainwater’s chemical and physical quality is usually excellent and its taste is acceptable but it may be polluted between falling on the roof and getting to the storage. The information given to the public will have to highlight this along with the various simple measures that can be taken to improve the water quality. The message that will have to be communicated is clearly that the quality of the harvested rainwater will undoubtedly exceed that of most rival sources especially where water is transported in jerrycans.

Mosquitoes. It has been proven that mosquitoes are not a problem in RWH systems provided the systems are designed are used correctly. (Thomas³ 2003)

Findings:

The scarcity of sufficient roofing is a limitation but it does not negate the real benefits of RWH. Because of the prevailing poverty in Rwanda the costs associated with RWH schemes, although minor, are an impediment. This will have to be creatively addressed with a combination of loans, financing and grants.

There are a number of potential image related problems with RWH; its unsophisticated low-tech nature, concerns over water quality and the breeding of insects. These problems can only be addressed by education and example.

6. CONCLUSION

“Wisdom is knowing what to do next, skill is knowing how to do it and virtue is doing it.” David Starr Jordan

In its aim to investigate the feasibility of using RWH as an alternative water source for the city of Kigali, this report has established that while RWH is just one of a number of possible interventions to improve the water shortage in the city, the climate and topography are very favorable to the use of this technology. Kigali's climate can sustain a water supply equivalent to the basic needs of an individual off 9½ -12 m² of sheeted roof on an average year. The vulnerability of the system to dry cycles is dependant on the size of the catchment and storage volume.

The cost of implementing domestic RWH schemes is largely a function of the size and type of storage unit. Two studies were carried out, one on a typical middle to upper income house and the other a low-income house. The cost varied from \$5222 for the upper income to \$450 for the lower income houses respectively. This demonstrates that prices vary considerably due to the level of sophistication but a RWH system can be constructed very economically nevertheless. The studies also indicated that neither scheme could be relied upon to sustain the water demand at **all** times but that the supply **could** be sustained for all but a few days a year on average. The systems' resilience to withstanding drought periods is greatly improved with reduced consumption rates.

The prevailing low price of commercial water does not make the installation of a RWH scheme **appear** viable. The water pricing policy in Kigali has serious inconsistencies, as it is too cheap for piped users and a lot more expensive for the poor who buy water at kiosks. The result of this water pricing policy is that the poor resort to collecting unsafe surface water and there is little incentive for the piped users to conserve water.

Evaluating the viability of installing a RWH scheme at the domestic level on the basis of cost saving is very difficult in this situation and is aggravated if the societal cost of children and adults spending many hours a day carrying water is under valued. On the positive side however, traditional attitudes suggesting that water collection is the responsibility of women and children are not anticipated because of social changes in society. Another advantage is that Rwandan society has a strong tradition of community work that can be harnessed to good effect with regard to RWH. Education will have to be relied upon to off set the negative perception of RWH as a “traditional practice” and as such inferior to modern technology.

The benefits of RWH are clearer on a macro basis and there is potential for support from an array of government ministries, welfare organizations and NGOs. It will be necessary to carefully coordinate any initiative to ensure that they are all included and united. For this reason the initiative would have to be driven from a high level from within the GOR.

To get full community support an energetic education and public relations campaign will have to be run. There is some room to use legislation but it must be done with discretion and only when it can be effectively monitored and enforced. Incentive schemes in which bonuses are paid or rebates offered have been used elsewhere, however experience shows that these must be applied cautiously and requires good control.

RWH cannot be expected to deliver basic water to all who need it, as this potential is limited by the availability of roofing and finances. It can, however go a long way to improving the general access to water and to reducing the physical labour required in carrying heavy loads of water, particularly amongst children. In this regard, RWH will impact on health, education and living conditions. The health benefit would be greatly compounded if the RWH initiative was implemented in conjunction with a programme to improve sanitation standards generally.

The price of water is presently constrained because of its role as an economic and social good. However once RWH can contribute to basic water

needs in the city, the pricing of water (and especially piped water) can be revised upwards with a view to full cost recovery. This will further encourage the efficient use of water.

RWH holds great potential for Rwandan citizens to be trained, acquire skills and be gainfully employed. The present shortage of skills will encourage citizens to engage themselves in this activity but there is a danger that the rate of skills transfer will be too slow. Of greater danger is the fact that there may not be sufficient managerial and planning capacity in the community. To counter these problems KIST and similar institutions should be asked to produce guidelines on the practical and planning aspects of RWH in easily accessible publications.

There are no immediate legal obstacles to implementing RWH. However, in order to facilitate the general use of RWH the GOR should be encouraged to take the following steps:

- Avoid legislation forcing water users to draw from a designated water services provider.
- Entrench the principle of reasonable and equitable distribution of water
- Consider all water, including rainwater not as a property but as a basic human right - as per the legal status of water in SA.
- Permit the free harvesting of rainwater without the need for special application and approval.
- Permit groupings of NGOs, churches, donors and banks to form partnerships of to manage local RWH schemes.
- Transfer water resources development to community ownership to serve the communities in a sustainable fashion.
- Avoid conflicting water development policies through water sector reforms.
- Establish the right to develop “private water”.

A wide ranging initiative to harness rainwater as a supplementary water source in Kigali will undoubtedly create expenses for the GOR. The GOR will

need to acknowledge that, because the householder installs the system and the materials are simple and cheap, this is a far less expensive venture than investing in conventional water infrastructure for the same increase in water availability particularly in Kigali's hilly terrain.

In addition, there are steps that can be taken to reduce the costs to the GOR and these include:

- using local trainers and service providers
- arranging for NGOs to construct and promote demonstration units
- structure incentives so that costs will be recovered and have these costs underwritten by banks.

Although the scarcity of sufficient roofing must be recognized as a limitation, it does not invalidate the real benefits of RWH. Because of the prevailing poverty in Rwanda the costs associated with RWH schemes, although minor, are impediments so financing on a household level will need special consideration. Use will have to be made of a creative combination of loans, micro financing and grants to fund domestic installations. It must be recognized that the process of funding a domestic scheme in this way is empowers the householders as it exposes them to financial mechanisms, which can be used for other ventures.

The success of introducing RWH to Kigali will hinge on leadership. It is clear that the technology holds great promise to vastly improve the general access to water at a relatively low national investment and there are great benefits associated with the plan such as skills transfer, job creation and improved health. However, the influences are many and varied and success will require vision, commitment and determination on the part of the country's leaders.

The citizens of Kigali must be made to realize the true value of water and to respect it. Education can be relied on to instruct and correct perceptions but the failure of a RWH initiative would be a failure of leadership not of the technology.

APPENDIX A

NOTES OF MEETINGS HELD

- A.1 MEETING WITH ELECTROGAZ**
- A.2 MEETING WITH RED CROSS**
- A.3 MEETING DIRECTOR OF WATER**

A.1 MEETING WITH ELECTROGAZ

NOTES OF MEETING

Meeting with Mr. Holger Laenge, Director of du Département de l'Eau Electrogaz, and Dr Christoph Czekalla, Project Manager from CONSULAQUA Hamburg, held at Electrogaz offices on 7 June 2005.

***Both Mr. Laenge and Dr Czekalla are employed by Lahmeyer International (LI) GmbH, which was awarded the Management Contract for managing Electrogaz, Rwanda's para-statal electricity and Water Company. (LI) GmbH is Germany's largest engineering consultant specializing in energy matters.**

By way of introduction, I informed the meeting that the aim of my research was to investigate the viability of introducing/promoting Rainwater harvesting (RWH) as a supplement to conventional reticulated water supply.

In this regard the Electrogaz delegates were advised that some background on the current water supply specifically from the point of view of technical limitations and costs. I said I also wanted some insight into the structure of Electrogaz insofar as their degree of state subsidy went and what plans if any were in place to privatize the supply of water.

I began the discussion by saying that the economics of collecting of rainwater was unquestionably favorable but the motivation to introduce may be lacking. I hoped my discussions with Electrogaz would also highlight some "Drivers" for the introduction of a RWH initiative.

Mr. Laenge pointed immediately to the serious problem the Kigali municipality was having with erosion. He said any scheme that resulted in water being retained on properties and not discharged onto the road network would be welcomed by the municipality. He said this was specifically a problem on some of the newer and larger homes and developments around town. On these properties there were often large paved areas designed to discharge into the road reserve. The erosion is a serious problem not least because it exposes services and silts up drains.

On the subject of Kigali's reticulation the two Electrogaz consultants had this to say: Some of the piping dates from the 1950s but a lot is quite new. The network is generally in a good condition but there is generally a shortage of scourer points, which has lead to blockages and reduced flows.

With regard to metering, Mr. Laenge said that 30% of the water produced was not recorded through meters these losses were due to both leakages as well as illegal/non metered connections. It was agreed that this was not a bad statistic when compared to other cities.

With regard to bulk water resources, Mr. Laenge presented a table showing 7 sources with a total daily water production varying from 29,000 to 11,750 m³/day. He ascribed the daily variance to weather conditions, explaining that the river intakes, particularly Kimisangara and Nyabarongo, which were the strongest sources, had a tendency to silt up after heavy rain. It

was accepted that a sustainable supply of 20,000 – 25,000 m³/day was possible considering the moderating effect of stored water from reservoirs assisting temporarily when the need arose.

Mr. Laenge said that the population of Kigali from the last census in 2002 was in the region of 600,000 but daily migration of workers could put this up to 1,000,000. If a figure of 800,000 were assumed then the water consumption per capita would be 31l/p/d. Mr. Laenge said however that from their analysis 7% of their Kigali clients accounted for 50% of the water produced. If this is true it is clear that the balance of the population of 744000, left with 10,000m³/day or 13.4l/p/d must be finding alternative water supplies.

Dr Czekalla said that there might be a culture of conserving water, as it was a precious asset considering that Rwandans traditionally live on the hillsides high above the valleys and river courses where there was the threat of malaria and other hazards. It was agreed however that by any definition the consumption of 13.4 l/d/person was too low would translate into health problems.

Asked if he drank Electrogaz water directly from the tap, Dr Czekalla, who is a water treatment specialist, commented that he did, provided he could detect chlorine in the water. He said that Electrogaz produced water to WHO standards but that the problem was in the network. He said the fact that the mains did not remain under pressure all the time, meant that there was the danger of the ingress of untreated water and even sewer into the water pipes. Breakages in the mains caused by the exposure of pipes as a result of erosion were also a source of contamination. Mr. Laenge said that he has observed insect larvae in his tap water at home but said that this was most likely due to stagnant water from the storage tank. He noted that the use of storage tanks was a common practice in Kigali as householders installed elevated tanks for emergency use during the regular outages. He said that such systems should be designed to be in the main stream of the supply so that the water in them was constantly refreshed.

Dr Czekalla observed that everyone in Rwanda boiled their drinking water. He said while this was understandable, it should not be necessary. If this practice could be avoided it would save a lot of energy (wood, electricity, gas and charcoal) and so by reduce a significant environmental impact.

With regard to planned future extensions of the Kigali water infrastructure, the Electrogas representatives said there were no immediate plans to expand the

A.2 MEETING WITH RED CROSS

Notes of Meeting

With Mr. Luc Soenen - International Committee of the Red Cross.

22/August 2005

Mr. Soenen is the engineer in charge of the ICRC programs to assist the government in providing water and sanitation to the inmates of the prisons in Rwanda many of which are in Kigali. The ICRC's valuable involvement in area this is covered by an article entitled Rehabilitation of alternative water supply systems P.G. Nembrini, M. Serafino, P.Y. Monnard and R.G. Conti, Switzerland, which was presented at the 23rd WEDC Conference in Durban in 1997.

The prisons in the years immediately after the genocide were horrifically overcrowded and the conditions today even after many inmates have been released, is still critical. Mr. Soenen says it is reality that the detainees receive 10-15 l/p/day. This combined with the cramped and overcrowded conditions present very precarious health conditions. The ICRC is presently assisting with the sanitation in a number of prisons. Due to the concentration of the effluent, septic tank systems are inappropriate and they have piloted a biogas system that is proving very successful.

With regard to water resourcing within the city, Mr. Soenen who has been here for 2 years says he sees little inertia to resolve the supply situation in the short term. As reported by Electrogaz, he says that feasibility studies have been carried out for the further exploitation of the Nyabarongo and Kimisagara rivers and to resource water from the volcano areas. He says that there are technical difficulties with the latter due to the distance and the topography, which would result in a pipeline having to sustain pressures in excess of 40 bar in places. His reading of the situation is that a large amount of capital will be required to implement any of these schemes but the central government is not actively initiating such projects. The responsibility falls rather on Electrogaz to source funds for such work and they do not have this capacity he says.

Regarding domestic consumption Mr. Soenen says that his observations in the rural areas even where water is relatively plentiful, is that the average person uses 20 l/p/d. He claims these are figures he has measured. He says the studies, which have been done on the supply to Kigali, have used a nominal consumption of 60 l/p/d.

Regarding other initiatives he says the European Union has recently started funding a water project that will cover a large area South West of Kigali in the Kibungu Prefecture and will supply water as far as Kinombe on the outskirts of Kigali.

Regarding sanitation within Kigali he said that although the government knows about the problems, it has received a low priority in the recent years. He says it is clear that the city has grown much faster than the supply of services such as water, sewerage and power.

150 cubic meters fixed dome digester in Cyangugu prison. The digester is fed human waste generated by 1500 prisoners and it produces 50% of the energy needed to cook for the 6000 to 10,000 inmates (the number vary depending on the source), cutting in half the £25,000 (\$44,000) yearly firewood bill - a lot of money in Rwanda. I'm not sure why the digester doesn't get the waste from all prisoners, but the simple answer probably is that it's simply too small for that, which would mean that with expansion the firewood bill could be eliminated.

The Kigali Institute of Science and Technology has also built a smaller digester (25 cubic meters) for the Lycée de Kigali, solving its sewerage and hygiene problem. "The methane gas produced is used to cook for 400 students and for operating Bunsen burners in the school science laboratories..."

Five of the country's largest prisons - two at Gitarama, and one each at Butare, Kigali and Cyangugu - now boast biogas plants, either in operation or under construction, and their effect has been dramatic.
[...]

A.3 MEETING DIRECTOR OF WATER

NOTES OF MEETING with Mr. **Bruno Mwanafunzi** Director of Department of Water and Sanitation under MINITERE Ministry of Lands, Environment, Forestry, and Water And Mines. Telephone: +250 72016/93 E-mail: DEA@rwandatel1.rwanda1.com, and **Mr. Vincent De Paul Kabalisa** of Department of Water and Sanitation who is the Chairman of Rwanda's Rainwater Harvesting Association +250 08432042 nilerwa@yahoo.com The meeting was the held at Department of labour offices on 10 November 2005.

-
1. I informed the meeting of the aim of my research i.e. the introduction of Rainwater harvesting (RWH) as a supplementary water supply.
 2. I asked Mr. Mwanafunzi which government ministry was directly responsible for water and which others were indirectly involved. He said
 - MINITERE - Ministry of Lands, Environment, Forestry, and Water And Mines and under them the Directorate Of Water And Sanitation were the main water authority.
 - Also involved were:
 - a. MINICOM Ministry of Commerce, Industry, Investment Promotion, Tourism and Cooperatives.
 - b. MININFRA Ministry of Infrastructure
 - c. MINALOC is the Ministry of Local Government, Community Development and Social Affairs
 - d. MINAGRI Ministry of Agriculture And Animal Resources
 - e. MINEDUC Minister of education
 - f. Ministry of Health
 3. Asked about water supply and sanitation policy, Mr. Mwanafunzi said the legislation was in draft form and had been submitted to the Ministry of Justice for final vetting before being presented to the senate in 2006.
 4. He said that the water policy would recognize the right of a property holder to harvest any rainwater falling on his land.
 5. On the question of how the principles of "Accessibility to water supply for every Rwandese at the price he can pay" would be balanced with the principles of privatizing water, Mr. Mwanafunzi replied that to date they had awarded the management contract of Electrogaz to a private firm. The intention was to give this arrangement 5 years trial (2 years already having lapsed). At that time they would reassess the issue of privatization.
 6. Asked about the responsibility for future planning for water supply, Mr. Mwanafunzi said this was the joint responsibility of Electrogaz and MINITERE. He acknowledged that the current supply of water was 50% of demand. He said that various options had been looked at with regard to the upgrading the existing infrastructure and that the most promising was to opt for a Public Private Partnership as opposed to conventional loans

through institutions such as the IMF or EU. He said the hope was to get proposals submitted early in 2006.

7. With regard to sanitation in Kigali, Mr. Mwanafunzi said a comprehensive study was planned and bids were expected in soon. He said the African Development Bank ADB was funding the study.
8. Mr. Kabalisa said he was working on various schemes with FAO both in the rural areas as well as urban schemes.
9. Mr. Kabalisa said there was a good east African network of parties interested in RWH.
10. Mr. Kabalisa said the 9th SEARNET (Southern & Eastern Africa Rainwater Network) on "Rainwater Harvesting in Eastern and Southern Africa" - Kigali, Rwanda ... conference was planned for the 27th to 2 December 2005 in Kigali and asked if I would like to present my findings on Kigali

APPENDIX B

PHOTOGRAPHS



Picture 1 Traditional Brick-making in the flood plain - an erosion hazard.



Picture 2. Early morning water collections from an Electrogaz Kiosk in Kimihurura Kigali



Picture 3. Blue jerrycan being filled from a “spring”. Washing and other activities are conducted in the same area.



Picture 4. "Spring Water" being collected in a typical urban setting with limited sanitation



Picture 5 Children collecting surface water



Picture 6 Water vendors in the suburb of Remera, Kigali - note lack of gutters on house behind.



Picture 7 The endless task of collecting and hauling water - in this case from a developed spring.



Picture 8 Steep gradients up which water must be carried - note new church, erosion and rain clouds.



Picture 9 Typical polluted nature of urban surface water Kigali



Picture 10 Men and bicycles – new comers to water distribution.



Picture 11. Landsat image of Kigali looking north. Note volcanoes top left behind lakes Ruhondo and Burera. On the left is the start of the serpentine lake Muhazi and the foreground shows the Nyabarongo River and wetlands.



Picture 12 Looking down on the Nyabarongo river North West of Kigali

GREENHILLS SCHOOL KIGALI



Picture 13 Mr. Ainea Kimaro and the school technician inspect the underground storage tank



Picture 14. The collection sump leading to the underground tank and the overflow tank and flap to prevent the ingress of insets



Picture 15. The pumping sump adjacent to the storage tank



Picture 16. The main school building with auxiliary tank in the left.



Picture 17. Neat piping from gutters to underground tank.



Figure 6. The boarding facility - this large roof area is still unutilized for rain water collection.

APPENDIX C

RAINWATER HARVESTING IN INDIA

Rainwater Harvesting In India

RWH is implemented in two forms in India mainly:

Groundwater recharge

Direct storage

Groundwater levels in low lying cities have been falling rapidly to the alarm of local and regional municipalities. Because of the monsoon weather pattern, rainfall is generally received in intense downpours during one or two short rainy seasons. This rainfall pattern is not suitable for the use of the direct storage method of RWH as the storage unit becomes excessively large and expensive. In some cities like Bangalore however, the rainfall is more evenly distributed and the direct storage option can be used.

Many Indian cities and states have rainwater harvesting legislation including:

- Chennai
- New Delhi
- Kanpur
- Indore
- Bangalore
- Hyderabad
- Rajasthan
- Haryana

Bangalore in Southern India does appear to have been more successful with the introduction of RWH than other cities and this is partly due to their high water tariff. Water is pumped from the source at 400m to the city at 900m above MSL. Thus the pumping costs are high and the water tariff is the highest in the country at \$1.4/m³. Many houses have RWH systems and the number is growing.

By contrast New Delhi has a low tariff and ground water. The CGWB central Ground Water Board has attempted to force the use of RWH by the use of legislation. This approach has been ineffectual as there is sufficient capacity to enforce the legislation and the deadline has been repeatedly extended. Where there has been compliance it has generally been half hearted poorly implemented.

The new clip below from December 2004 indicates the farcical nature of this approach.

Rain harvesting deadline extended

Saurabh Sinha 7/13/15
New Delhi, December 15

THE CENTRAL Ground Water Board (CGWB) has extended the deadline for installing rainwater harvesting systems in certain areas to June 2004.

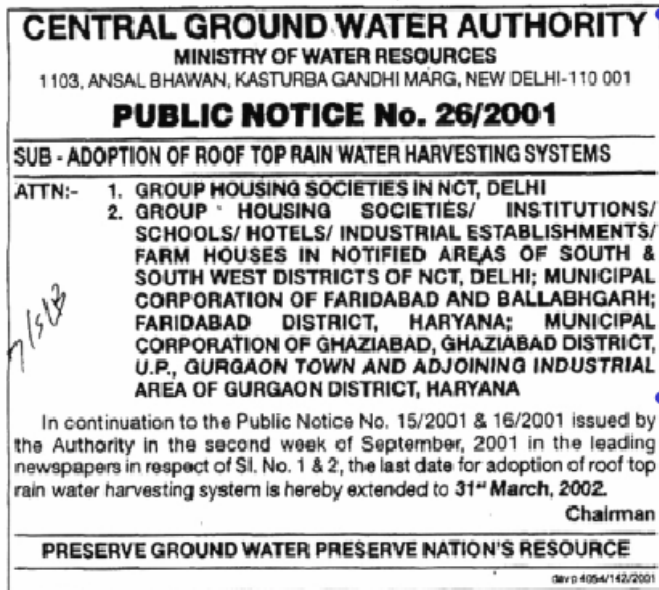
"The deadline for South and South West Delhi, Faridabad, Gurgaon, Bal-labgarh and Ghaziabad is June 30, 2004," CGWB chairman J.S. Burjia told the Hindustan Times.

Not harvesting rain in these place could invite the penalty of having ground-water extraction systems sealed or seized.

However, hardly any action has been taken against offenders till date as the CGWB says it is a scientific body without enough manpower for policing.

The board been extending its deadlines since the first one in May 2001. The next deadline was March 2002, then September 2002, November 2003, November 2003 and now June 2004.

By CGWB's own admission, just two per cent of Delhiites are equipped to harvest rainwater. "It is not possible to act when 98 per cent of the people are violating the law. Had there been two percent defaulters then we could have acted in tandem with local bodies," an official said.



Other Indian cities and their By- Laws

Mumbai

- Mumbai Municipal Corporation has made RWH mandatory to properties more than 1000m². The deadline was set for October 2002
- The condition will be made applicable to existing buildings in the near future.
- Recycling has been made compulsory for buildings having centralized A/C plants.
- Bombay Municipal Corporation (BMC) will supply 90 l/p/d instead of 135 l/p/d to ensure that RWH will supplement the gap.

Indore

- Rainwater harvesting has been made mandatory in all new buildings with an area of 250 m² or more from Jan 2000.
- A rebate of 6 per cent on property tax has been offered as an incentive for implementing rainwater harvesting systems.
- Indore Development Authority given Rs 1000 for houses that comply.

BANGALORE

- Every building with a plinth area of exceeding 100 m² and built on a site measuring not less than 200 m² shall have one or more Rain Water Harvesting structures having a minimum total capacity as detailed in Schedule XII.
- The Authority may approve the Rain Water Harvesting structures of specifications different from those in Schedules – XII, subject to the minimum capacity of Rain Water Harvesting being ensured in each case.
- The owner of every building mentioned in the bye-law 32 (a) shall ensure that the Rain Water Harvesting structure is maintained in good repair for storage of water for non potable purposes or recharge of groundwater at all times.
- The Authority may impose a levy of not exceeding Rs. 1000/- per annum for every 100 sq. mtr of built up area for the failure of the owner of any building

mentioned in the bye-law 32(a) to provide or to maintain Rain Water Harvesting structures as required under these byelaws.

TAMILNADU ACTS AND ORDINANCES

The following Ordinance which was promulgated by the Governor on the 19th July, 2003 is hereby published for general information – **TAMIL NADU ORDINANCE No.4 of 2003** *An Ordinance further to amend the Laws relating to the Municipal Corporation and Municipalities in the State of Tamil Nadu*

WHEREAS the Legislative Assembly of the State is not in session and the Governor of Tamil Nadu is satisfied that circumstances exist which render it necessary for him to take immediate action for the purpose hereinafter appearing:

NOW, THEREFORE, in exercise of the powers conferred by Clause (1) Article 213 of the Constitution, the Governor hereby promulgate the Ordinance –

- (1) This Ordinance may be called the Tamil Nadu Municipal Laws (Second Amendment) Ordinance, 2003.
- (2) It shall come into force at once.

Where the rain water harvesting structure is not provided as required under sub-section (2), the Commissioner or any person authorized by him in this behalf may, after giving notice to the owner or occupier of the building, cause rain water harvesting structure to be provided in such building and recover the cost of such provision along with the incidental expense thereof in the same manner as property tax.

Notwithstanding any action taken under sub-section (3), where the owner or occupier of the building fails to provide the rain water harvesting structure in the building before the date as may be prescribed, the water supply connection provided to such building shall be disconnected till rain water harvesting structure is provided.

19th July 2003 P.S. RAMAMOHAN RAO
Governor of Tamil Nadu

Centre for Science and Environment (CSE)

The issue is not how much water you have, the issue is how you relate to the water, how you use that water, how you learn to store that water, how you distribute that water. These are the central questions in water management. In other words the Culture of dealing with water is far more important than any issues of technology. If Culture is correct we will have enough water for all household needs, industrial needs and all our rural needs. Rainwater harvesting is not just technology it is equally about governance.

We have documented the water management traditions of India. There were hundreds of thousands of tanks all over India, on which the villagers and townspeople survived. The kings never made them, and, that's fascinating, they were all made by the people. So how did it happen? Essentially, a very decentralized form of government was working, a highly democratic form of government, in which the community had much of

the control on natural resources, and it did things for itself, much more carefully than we do now. They made channels to bring water to the tank and they would make sure that nobody could pollute the channel or the watershed. Today, nobody cares. It's all the responsibility of the State. And the State has proved to be extremely incompetent in the developing world in dealing with these problems. It is extremely centralized and extremely corrupt. If this is the case for India, for China, you can imagine what will be the situation in Africa, in the Middle and Central American countries. So the 21st century is going to see one of the biggest changes -- not an environmental issue -- in the governance system, which will have major implications for the environment. In that sense, the 21st century of India will be going back to the 15th century. This is the only way to solve the problem.

One of the major problems of all governance is that policy makers and law implementers respond to persons—groups of humans with specific interests—but ignore people, a term that cuts across ethnic, social, economic, religious and other barriers.

Died January 2002

APPENDIX D

DETAILED CALCULATIONS FOR TANK SIZING

NOTES ON CALCULATIONS:

The calculations to determine the potential harvest of rainwater was based on an iterative process and certain assumptions as explained below.

The potential harvest of rainwater is calculate here by means of an iterative process based on certain assumptions as explained below:

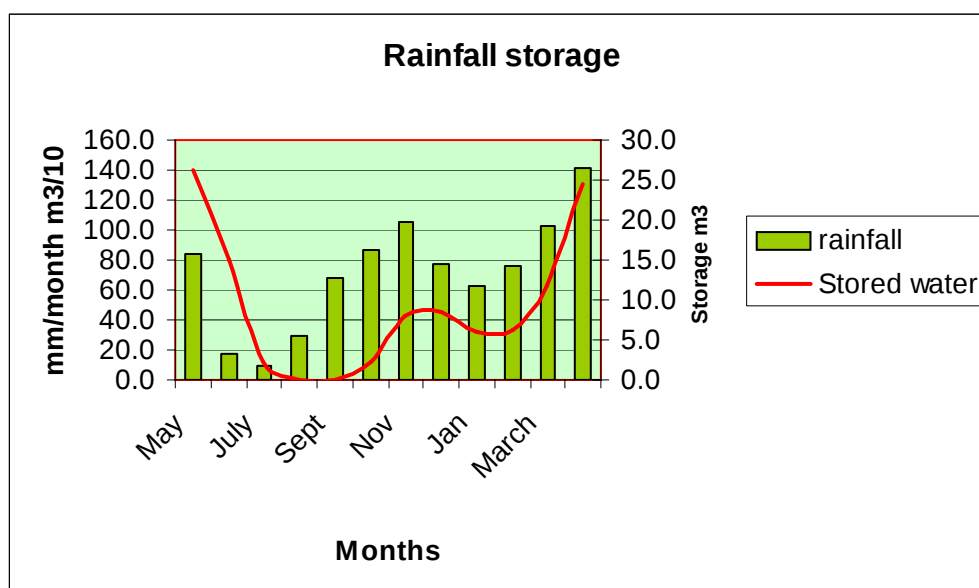
- The daily rainfall records from the Rwandan Meteorological office were used to arrive at an average monthly rainfall after removing 2mm from all measured rainfall events. The removal of the 2mm is to compensate for initial evaporation and the use of **first flush** systems.
- The calculation requires the following input data and runs until the calculation stabilizes.

INPUT DATA	
Average annual monthly rainfalls	mm
Area of catchment	m ²
Number of persons served	No
Assumed Consumption	liters/person/day
Runoff coefficient	%
Chosen Tank Volume	m ³

- The output is in the form of a graphic representation of the amount of water stored in the tank.
- The advantage of this approach is that it can be applied to drought events spanning a number of years.
- The calculations are performed on a spreadsheet.

House “A”
Calculation of optimal storage capacity in KIGALI for
domestic RWH.

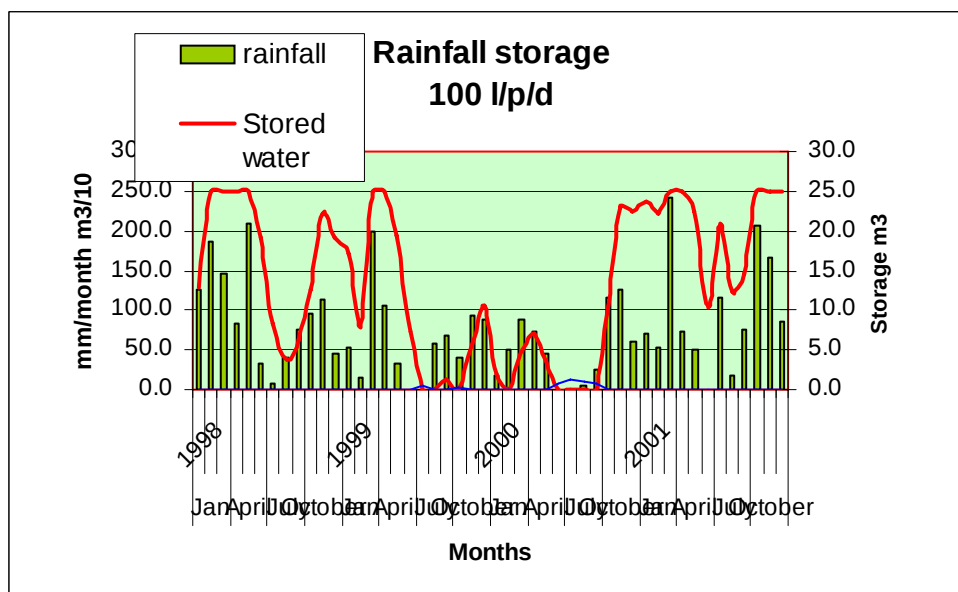
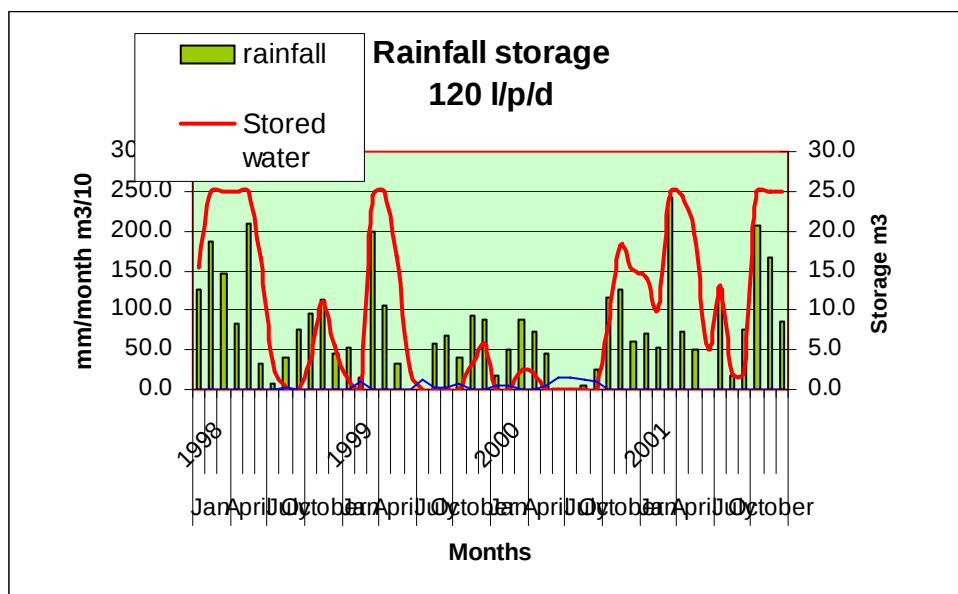
<u>A) INPUT DATA</u>	
Area of catchment	m2 243
Number of persons served	No 4
Consumption	l/p/d 120
Runoff coefficient	% 80%
<u>B) OUTPUT</u>	
Chosen Tank Volume	M3 27
Cumulative cost of supplementary water over 10 years	\$ \$197.55
Rate of supplementary water	\$/m3 \$2.50

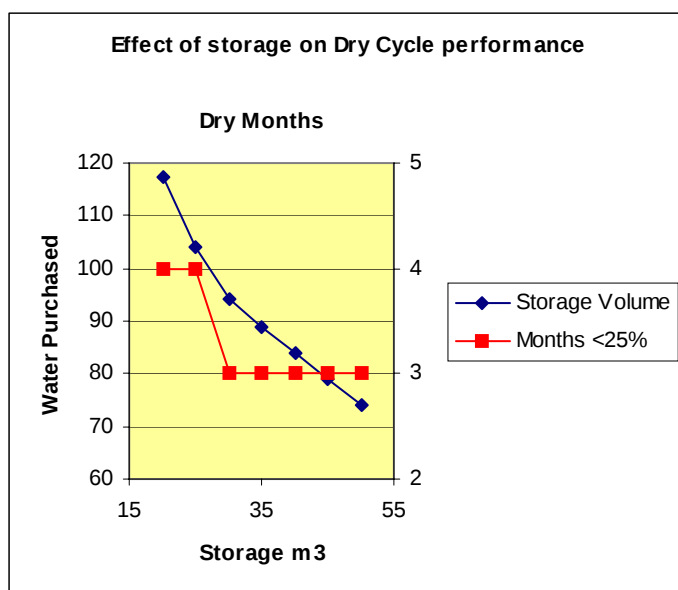
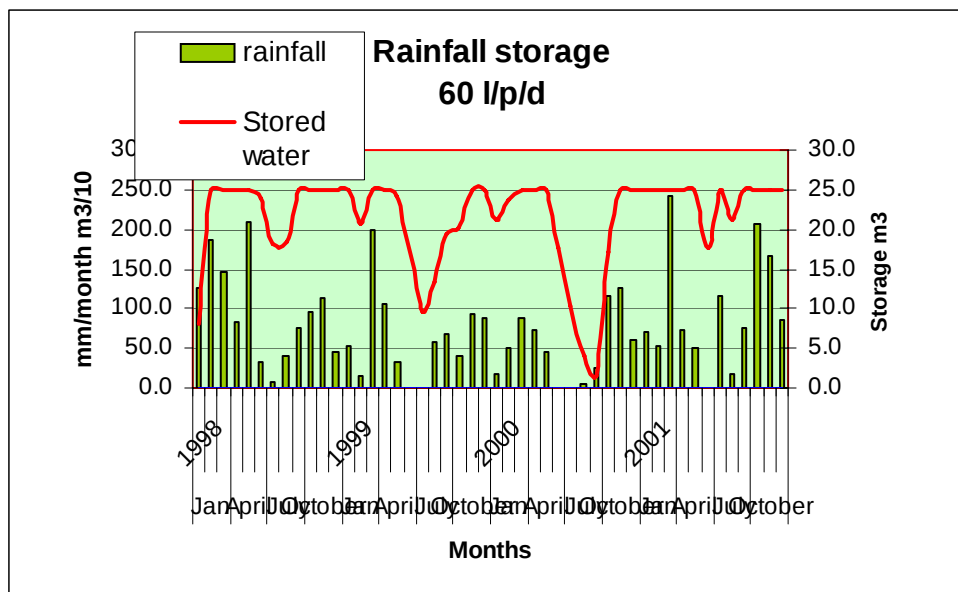


	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	March	April	SUM
Modified rainfall per month (mm)	83.7	17.8	9.5	29.5	68.0	86.1	105.1	77.3	63.0	76.5	103.0	141.2	860.6
Monthly tank inflow	16.3	3.5	1.8	5.7	13.2	16.7	20.4	15.0	12.2	14.9	20.0	27.5	167.3
Monthly water usage	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	175.2
Monthly balance	1.7	-11.1	-12.8	-8.9	-1.4	2.1	5.8	0.4	-2.4	0.3	5.4	12.9	-7.9
Actual Storage	26.2	15.1	2.3	0.0	0.0	2.1	8.0	8.4	6.0	6.3	11.7	24.6	
Over flow	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Supplement required	0.0	0.0	0.0	6.5	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.9

**Calculation of performance of House “A” RWH scheme over
1998-2002 drought with various storage capacities and
consumptions assumed.**

A) INPUT DATA	
Average annual monthly rainfall	mm
Area of catchment	m ² 243
Number of persons served	No 4
Consumption	l/p/d 60
Runoff coefficient	% 80%
B) OUTPUT	
Chosen Tank Volume	M3 25





House "A" Over The Drought Cycle 1998 – 2001
Sensitivity To Volume Of Storage

<i>Selected Storage Volume</i>	<i>Water Bought</i>	<i>% Water Bought</i>	<i>Dry Months</i>
20	117	17%	4
25	104	15%	4
30	94	13%	3
35	89	13%	3
40	84	12%	3
45	79	11%	3
50	74	11%	3

Sensitivity To Rate Of Consumption

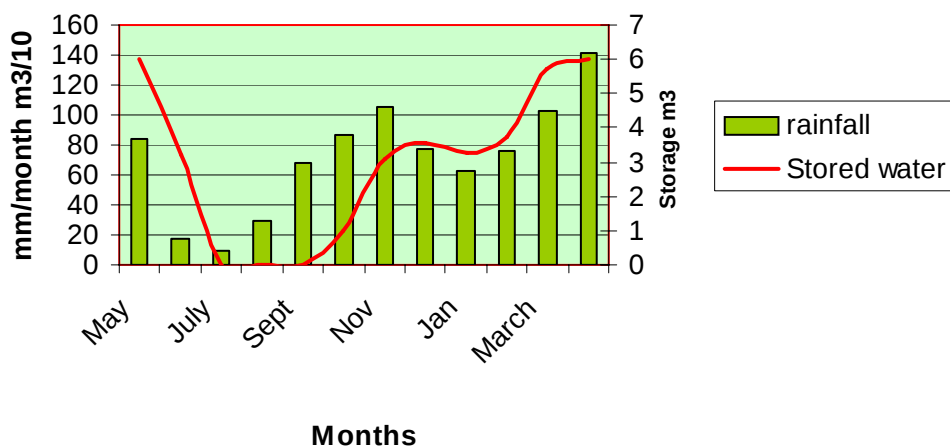
<i>Water Consumption L/P/D</i>	<i>Water Bought</i>	<i>% Water Bought</i>	<i>Dry Months</i>
140	182	22	5
120	104	15	4
100.0	49.0	8.0	2.0
80.0	9.2	2.0	0.0
60	0	0	0

House "B"

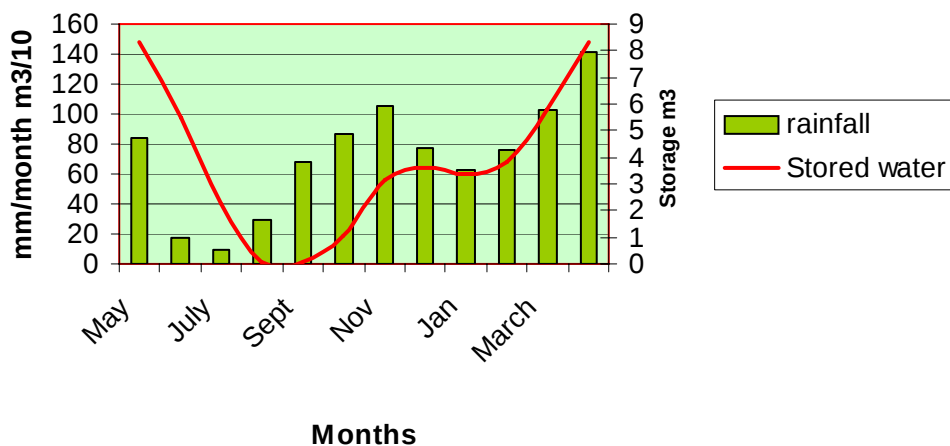
Calculation of optimal storage capacity in KIGALI for domestic RWH.

A) INPUT DATA		
Average annual monthly rainfall	mm	
Area of catchment	m2	62
Number of persons served	No	5
Consumption	l/p/d	25
Runoff coefficient	%	90%
B) OUTPUT		
Chosen Tank Volume	M3	6 or 8.3
Rate of supplementary water	\$/m3	\$2.50

Rainfall storage (6m3 storage)



Rainfall storage (8.3 m3 storage)



With 6 m³ storage

	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	March	April	ANNUAL
													SUM
Modified monthly rainfall (mm)	83.65	17.80	9.51	29.48	68.03	86.09	105.12	77.25	62.98	76.48	102.97	141.22	860.59
Monthly tank inflow	4.67	0.99	0.53	1.65	3.80	4.80	5.87	4.31	3.51	4.27	5.75	7.88	48.02
Monthly water usage	3.80	3.80	3.80	3.80	3.80	3.80	3.80	3.80	3.80	3.80	3.80	3.80	45.63
Monthly balance	0.87	-2.81	-3.27	-2.16	-0.01	1.00	2.06	0.51	-0.29	0.47	1.94	4.08	2.40
Actual Storage	6.00	3.19	0.00	0.00	0.00	1.00	3.07	3.57	3.29	3.75	5.70	6.00	
Over flow	0.87	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.77	4.64
Supplement required	0.00	0.00	0.08	2.16	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.24

With 8.3 m³ storage

	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	March	April	ANNUAL
													SUM
Modified monthly rainfall (mm)	83.65	17.80	9.51	29.48	68.03	86.09	105.12	77.25	62.98	76.48	102.97	141.22	860.59
Monthly tank inflow	4.67	0.99	0.53	1.65	3.80	4.80	5.87	4.31	3.51	4.27	5.75	7.88	48.02
Monthly water usage	3.80	3.80	3.80	3.80	3.80	3.80	3.80	3.80	3.80	3.80	3.80	3.80	45.63
Monthly balance	0.87	-2.81	-3.27	-2.16	-0.01	1.00	2.06	0.51	-0.29	0.47	1.94	4.08	2.40
Actual Storage	8.30	5.49	2.22	0.06	0.06	1.06	3.12	3.63	3.34	3.81	5.75	8.30	
Over flow	0.87	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.53	2.40
Supplement required	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Result:

8.3 m³ storage:

No need to get any water

6 m³ storage:

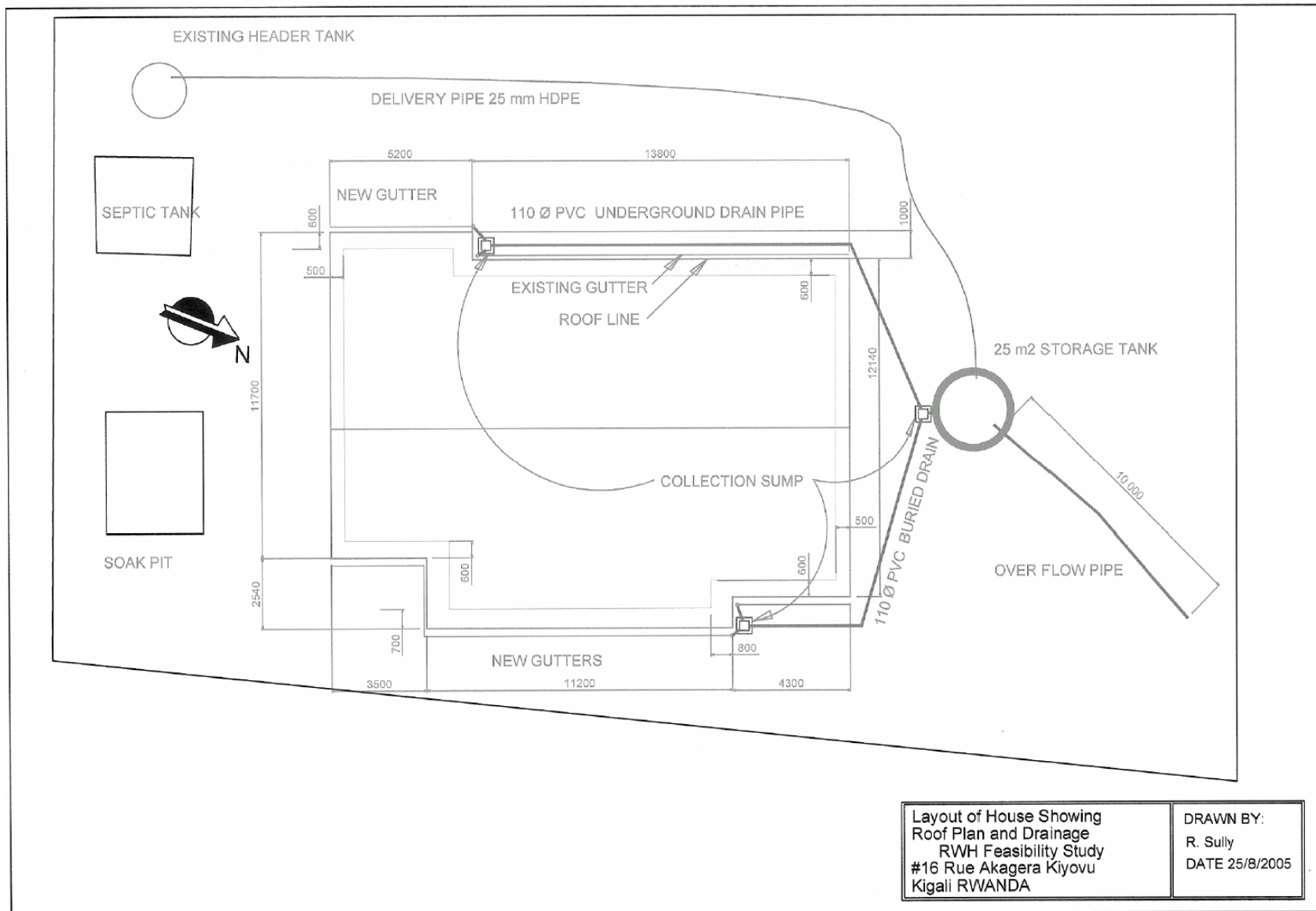
1 day in July and 18 days in August

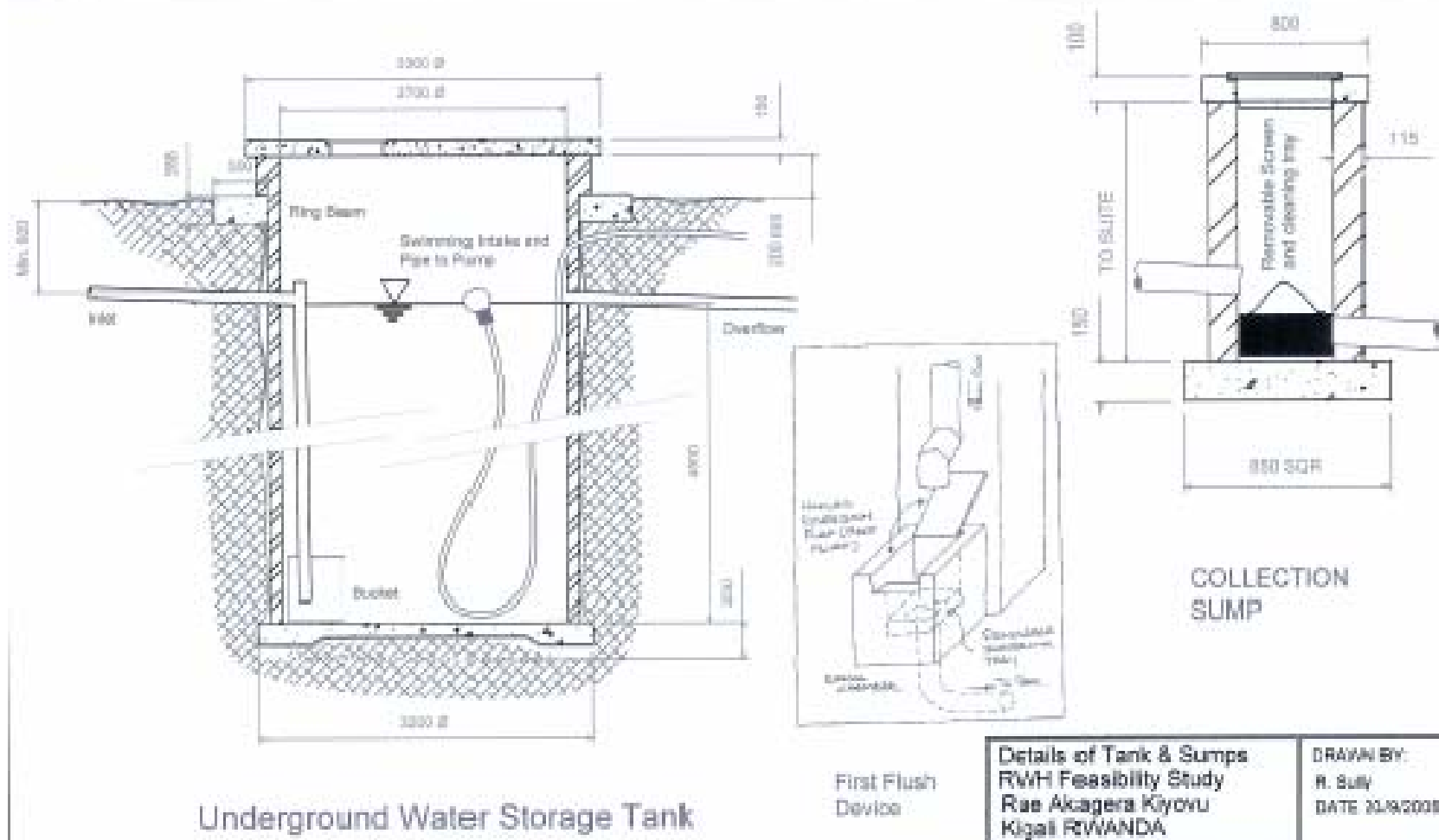
APPENDIX E

Costing of RWH Schemes And Drawing Details.

Estimate of Costs for proposed implementation of RWH system for house 'A'
#16 Rue Akagera, Kiyovu, Kigali

Item #	Description	Unit	Quantity	Rate	Amount	Amount
				(RWF)	(RWF)	(USD)
1	<u>Earthworks</u>					
1.1	Excavate trenches 600mm wide to depth 600 - 1200mm including backfill and removal of surplus.	m	45	RWF 800	RWF 36,000	\$64.75
1.2	Break out and remove concrete aprons and replace and make good.	m ²	5	RWF 7,500	RWF 37,500	\$67.45
1.3	Excavate for storage tank and chambers including removal of surplus.	m ³	25	RWF 4,500	RWF 112,500	\$202.34
2	<u>Concrete</u>					
2.1	Concrete to bases 20 MPa	m ³	3.17	RWF 140,000	RWF 443,800	\$798.20
2.2	Concrete to cover slabs c/w reinforcing and shuttering steel trowel float.	m ³	2	RWF 190,000	RWF 380,000	\$683.45
2.3	Cast Iron inspection cover and frame	No	4	RWF 50,000	RWF 200,000	\$359.71
3	<u>Masonry</u> - Construct the following in approved masonry units using 1 to 2.5 mix mortar.					
3.1	230 mm clay brick wall to storage tank walls.	m ²	6	RWF 300	RWF 1,800	\$3.24
3.2	115 mm clay brick wall to collection sumps	m ²	58	RWF 240	RWF 13,920	\$25.04
4	<u>Plaster and Screed</u>					
4.1	Plaster 15mm thick smooth rendering to interior of tank and chambers.	m ²	48	RWF 4,500	RWF 216,000	\$388.49
4.2	Apply NIL or similar approved cement-based coating for waterproofing masonry (1.5kg/m ²).	m ²	48	RWF 3,000	RWF 144,000	\$258.99
5	<u>Gutters and down pipes</u>					
5.1	Supply and hang PVC gutters 100mm to falls including all fittings and fixings.	m	20	RWF 2,000	RWF 40,000	\$71.94
5.2	Supply and fit 110mm PVC down pipes c/w fittings and fixtures	m	8	RWF 2,000	RWF 16,000	\$28.78
6	<u>Plumbing</u>					
6.1	Supply, lay and bed 110mm uPVC drainage pipe C/w bends to falls.	m	45	RWF 5000	RWF 225,000	\$404.68
6.2	Connect drain and over flow to tank	SUM	1	RWF 10,000	RWF 10,000	\$17.99
6.3	Excavate for, provide and lay 25mm HDPE class 9 water pipe including all fittings to connect to pump and tanks.	m	40	RWF 5,000	RWF 200,000	\$359.71
7	<u>Pumps</u>					
7.1	Provide 2kw single phase pump to transfer water	No	1	RWF 186,271	RWF 186,271	\$335.02
7.2	Provide and install hand pump as standby	No	1	RWF 116,102	RWF 116,102	\$208.82
8	<u>Electrical</u>					
8.1	Install and connect pump to power supply	SUM	1	RWF 60,000	RWF 60,000	\$107.91
	SUBTOTAL				RWF 2,460,493	\$4,425.35
	VAT @ 18%				RWF 442,889	
	TOTAL				RWF 2,903,382	\$5,221.91





APPENDIX F

Electrogaz Production May 2005 & Typical Electrogaz Invoice.



TVA No 10000837

FACTURE N° 129583 044

Antenne Remera

du 01/2005

Cabine 23

Référence à rappeler

129583

Old No. 222312789

Référence bancaire

B P

KISALI

ICTR

RENERA

RENERA

Rubrique	Compteur Numéro	Cal.	Index		Quantité	Prix unit	Montant
			Ancien	Nouveau			
Gas Location Opér	3333789	1-00	10151	10700	239	80.00	80
Gas (consumation)					25	200.00	5,000
					35	300.00	10,500
					40	350.00	14,000
					335	370.00	88,125
TVA - 10000837 @ 10%							21,187
Montant de la facture							138,892
Remera						avant le	22/03/2005

Le règlement des factures doit se faire uniquement à nos caisses ou à la Banque et non par l'intermédiaire de nos agents.

TALON

Ne pas détacher ce coupon sauf pour le joindre à un règlement par correspondance.

Référence à rappeler		
129583		
old no. 222312789		
ICTR		
Référence bancaire		
RENERA		
RENERA		
Produit	Gas	Electricité
Montant TTC	4,404,582	0

MODE DE REGLEMENT

Vous présentez la facture à la caisse qui conservera le volet TALON et vous rendra le volet FACTURE joint à un acquit de caisse du montant que vous avez réglé. Cet acquit de caisse constitue la seule preuve de votre règlement.

RELEVÉ DE COMPTE

Numéro pièce	Nature Opér.	Date Opération	Période	Date lim. paiement	Montant
Balance N/P	- Dépayse				4,165,788
Electricité	Paiement and Adjustments				0
Gas	Paiement and Adjustments				0
129583-044	01/2005	01/01/2005		22/03/2005	138,892
Produits	Montants	00	TVA	Montant TTC	
Gas	117,125	01,187		138,892	
Electricité	0	0		0	
Balance TTC					4,404,582

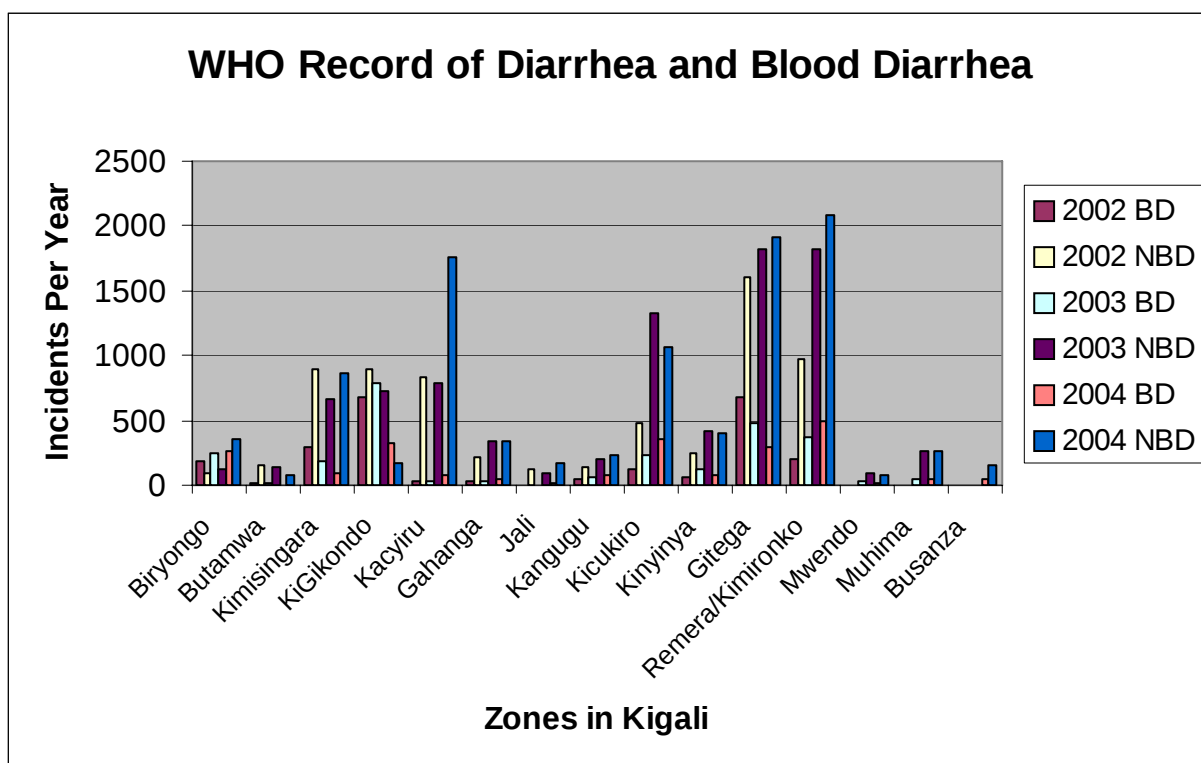
Vous nous êtes redevable de la somme de

APPENDIX G

WHO Diarrhea Results

WHO Diarrhea And Bloody Diarrhea Survey

Period	2002	2002	2003	2003	2004	2004
Zone	Blood	Non Blood	Blood	Non Blood	Blood	Non Blood
Biryongo	192	98	243	130	262	351
Butamwa	20	151	12	142	6	73
Kimisingara	290	891	185	668	88	871
KiGikondo	685	900	793	721	325	170
Kacyiru	35	837	38	784	76	1754
Gahanga	30	215	37	343	47	340
Jali	3	119	6	98	9	165
Kangugu	42	138	57	194	78	235
Kicukiro	129	481	231	1329	354	1060
Kinyinya	64	254	122	415	75	404
Gitega	674	1607	480	1819	294	1921
Remera/Kimironko	205	974	371	1814	487	2086
Mwendo			24	86	19	76
Muhima			51	260	44	269
Busanza					43	160
Totals	2369	6665	2650	8803	2207	9935



APPENDIX H

CSE Course and SEARNET Conference



Centre for Science and Environment

Training programme on rainwater harvesting

This is to certify that Mr./Ms. ROBERT SULLY has participated in the training programme on rainwater harvesting organised by the Centre for Science and Environment, New Delhi on 3rd - 16th June. During this period he/she got exposure to on-site training. He/She also worked out a detailed rainwater harvesting plan.

With best wishes,

Sumita Dasgupta
Sumita Dasgupta
Coordinator

Natural Resource Management Unit

Frugality is India's tradition.
Modernity sees frugality as poverty.



Rwanda Rain Water Harvesting association

RRWA asbl

Réf : mwh/028/2005

Kigali, 16th November 2005

Dear Mr. Robert SULLY
ICTR TPIR
Kigali

Objet: Invitation to the conference on
Rainwater harvesting
28 November 2005 -1December 2005

Dear Mr Robert ,

I have the pleasure of inviting you to the regional conference on rainwater harvesting planned in Kigali on 28 November 2005 up to 1 December 2005 at Novotel Umubano

The conference is organised by Rwanda Rainwater Harvesting Association supported by SEARNET : Green Water Harvesting In Southern and Eastern Africa and South Asia.

I am attaching herewith a copy of the draft program.

Your presence will be highly appreciated.

KABALISA Vincent de Paul

Legal Representative

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RAINWATRE HARVESTING AND ALLIED ORGANIZATION

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3. **fbr - German Professional Association for Water Recycling and Rainwater Utilization** Fachvereinigung Betriebs- und Regenwassernutzung e.V. 64295 Darmstadt, Germany <http://www.fbr.de/>
4. **Warwick University - School of Engineering - Development Technology Unit**
 Coventry, CV4 7AL, UK
<http://www.eng.warwick.ac.uk/DTU/rainwaterharvesting/index.html>
5. **Rocky Mountain Institute** 1739 Snowmass Creek Road, Snowmass, CO 81654-9199, USA <http://www.rmi.org/>
6. **Pacific Institute for Studies in Development, Environment, and Security** 654 13th Street, Preservation Park Oakland, CA 94612 U.S.A. <http://www.pacinst.org/index.html>
7. **Texas Water Development Board** 1700 North Congress Avenue, P.O. Box 13231 Austin, Texas <http://www.twdb.state.tx.us/assistance/conservation/consindex.htm>
8. **WaterWiser-The Water Efficiency Clearinghouse**
 6666 W. Quincy Ave., Denver, CO 80235, USA
<http://www.waterwiser.org>
9. **Sustainable Sources** 108 Royal Way, Suite 1004, Austin, TX 78737 USA
<http://www.greenbuilder.com/Sourcebook/Rainindex.html>
10. **Japanese NGO: People for Rainwater Utilization**
 1-8-1 Higashi Mukojima Sumida-ku, Tokyo Japan
 Web site: http://www.rain-water.org/book_e.html
11. **UNDP-World Bank Water and Sanitation Program (WSP)** 1818 H Street, N.W., Washington, D.C. 20433, US mail <http://www.wsp.org/>
12. **Rainwater Club**
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 Web: <http://www.rainwaterclub.org/>
13. **The International Rainwater Harvesting Alliance**
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