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TECHNICAL INVESTIGATION OF RURAL SCHOOLS ROOF WATER HARVESTING SCHEMES

(THE CASE OF CHACHA AND CHOKI SCHOOL SCHEMES, IN AMHARA REGION NORTH SHOA ZONE ANGOLALLA TERANA ASAGIRT WEREDA)

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Addis Ababa,

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Thesis submitted to Addis Ababa University, School of Graduate studies in partial fulfillment of the requirements for the degree of Master of Science in Hydraulic engineering.

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Certification

The undersigned certify that I have read the thesis entitled: **Technical Investigation of Rural Schools Roof Water Harvesting Schemes (The Case of Chacha and Choki School Schemes, in Amhara Region North Shoa Zone Angolalla Terana Asagirt Wereda)** and hereby recommend for acceptance by the Addis Ababa University in partial fulfillment of the requirements for the degree of Master of Science.

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Date

Declaration

I, the undersigned, declare that this thesis is my original work, has not been presented for a degree in any other university and that all source of material used for the thesis have been duly acknowledged.

Eyob Betru

School of Graduate Studies

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May, 2015

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Abstract

The objective of this study is to assess and identify technical performance, structural conditions and water quality of Chacha and Choki School domestic roof water harvesting schemes implemented by water Action in Amhara region North Shoa Zone Angolela Terana Asagirt Wereda. The selected technical performance evaluation parameters are reservoir capacity, performance of gutter and down pipes and water quality.

This research was formulated through literature review, analysis of some case studies on rainwater harvesting, and to a certain extent, semi-structured interviews and questionnaires, Data from primary and secondary sources also used for the purpose. The Tangaki Nahrim software is also used to evaluate optimal tank/reservoir/ usage.

Using existed data on rainwater harvesting systems, a graph was established to figure out the relationship between tank size, roof area and number of users with percentage of time tank empty, coefficient of water utilization and reliability ratio so that easily understand and design economical water harvesting structures and cistern sizes for collection of rainwater.

As a result the paper showed performance of rainwater harvesting schemes so that to indicate how to implement proposed rainwater harvesting system that may be used as a tool to further design and also propose research ideas that could be done to support current work being done in the research of DRWH.

The research find out that, in general, lack of standardization and awareness, policy issues, poor system operation or management; lack of regular monitoring and maintenances are among the main technical performance problems on the promotion and implementation of the technology.

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LIST OF ACRONYMS

AAU……………………………….………... ADDIS ABABA UNIVERSITY

AMSL…….…………………………….…..ABOVE MEAN SEA LEVEL

CSA……….………………………….......CENTRAL STATISTICS AUTHORITY

DRWH ……….……………………..…. DOMESTIC ROOF WATER HARVESTING

ERHA……………………………….....….ETHIOPIA RAINWATER HARVESTING ASSOCIATION

GI……………………………………..…....GALVANIZED IRON

HH/HHS ……………………………...…HOUSEHOLD/HOUSEHOLDS

L/C/D ……………………………….…...LITTERS PER CAPITA PER DAY

MOFED …………………………….....…MINISTRY OF FINANCE AND ECONOMIC DEVELOPMENT

MOWR……………………………….......MINISTRY OF WATER RESOURCE

NAHRIM..NATIONAL HYDRAULIC RESEARCH INSTITUTE OF MALAYSIA

NGO/NGOS………….………….…..........NON-GOVERNMENTAL ORGANIZATION/NONE GOVERNMENTAL ORGANIZATIONS

NMSA..NATIONAL METROLOGICAL SERVICE AGENCY

O & M……………………………….........OPERATION AND MAINTENANCE

PASDEP...PLAN FOR ACCELERATED AND SUSTAINED DEVELOPMENT TO END POVERTY

PVC……………………………………........POLYVINYL CHLORIDE

RWH …………………………………......RAINWATER HARVESTING

SAP..STRATEGIC ACTION PLAN

TPL/TPS ………………...………….......TRADITION PIT LATRINE/TRADITION PIT LATRINES

UV ……………………….……….......ULTRA VIOLET

WAT SAN …………………………….....WATER SUPPLY AND SANITATION

WASH...WATER SANITATION AND HEALTH

WHO ………………………………........WORLD HEALTH ORGANIZATION

WMS ………………………………….....WELFARE MONITORING SURVEY

WWDSE..WATER WORKS DESIGN AND SUPERVISION ENTERPRISE

CHAPTER ONE

1. Introduction

1.1 Background

Ethiopia is a country where 81% of its population is gathered in rural areas where 30% of these rural households obtain water from unprotected wells outside of the yard, however to rural community the provision of access to safe drinking water is a social problem; no longer can remote rural schools wait for government engineers to provide them drinking water. The provision of hand pumps and pipe water supply systems have prone to various economical and technical problems and alternatives need to be found. Roof top rain water harvesting is a viable alternative. (CSA: Ethiopian Time Use Survey report, 2014)

Different non-governmental organization, individuals and also government have made efforts on the implementation of domestic rain water harvesting (DRWH) system. However the technological option of DRWH is an infant practice. Hence, this calls the need to evaluate the performance of existing DRWH schemes in terms of technical, social, economic and environmental aspects such evaluation enables to measure or reviews the appropriateness of the technology; the technical approach in terms of design and construction standard; the outcome of the system management setup and its contribution to the national effort to improve the level of water coverage.

One of the indicators of the well-being of the household sanitation is the availability and quality of toilet facility. According to the survey results of national water sanitation and health (WASH) inventory;-

- National Sanitation Coverage is (Rural 60.39% and Urban 80.35%)
- National level Water supply coverage is 52.12% (Rural 48.85% and Urban74.64%)
- Schools accessed to latrine facilities (80.58%) and water supply (31.39%)

Other important hygiene and sanitation related targets under Sanitation Strategic Action Plan (SAP) are to achieve;-

- 82 % open defecation free Ethiopia,
- 84 % access to improved sanitation,
- 77% practicing hand washing with soap at critical times and
- 77 % practices household water treatment and safe storage

(CSA: Ethiopian Welfare Monitoring Survey summary report, 2013)

Considering sustainable service and management; Government, non-government organizations (NGOs), Multilateral and Bilateral international financer have been promoting and implementing community managed rural Water and Sanitation (WatSan) projects through utilization and dissemination of appropriate technologies. Among the various options DRWH system becoming one of the most appropriate technological option; especially where the quantity, quality and the development techniques of both surface and sub-surface water sources are complex and remote.

DRWH has been a traditional practice in some cultures for centuries and as such many technologies are the result of a long evolutionary process. Even the current resurgence of interest in RWH as sources of water supply has been in existence for over thirty-one years and more in some countries like Australia (Warwick University, 2011).

Water action is non-governmental institution established to alleviate poverty through provision of safe and adequate water supply and sanitation which has been promoting and implementing a number of DRWH projects in many parts of the country since 1996; mainly in Amhara and SNNPRS.

Chacha and Choki School DRWH schemes are parts of projects implemented by Water Action on Amhara region North Shoa zone. Choki primary first cycle school constructed at 1998 with three blocks where two are teaching blocks, which have $40m^3$ reservoir to harvest roof water.

Chacha primary second cycle school constructed at 1997 with four block; two are teaching blocks and the remaining are residential blocks for the teachers which have $75m^3$ masonry and $10m^3$ Ferro cement reservoirs.

Various scholars in Ethiopia conducted viable researches in DRWH schemes that may surely help for further insight in the same field of researchable area but most of the researcher‟s attention is on the technical feasibility of urban DRWH systems and little was done on rural school schemes; "Kassahun, 2008" thesis on DRWH is one of the rare examples in the same area. Due to vastness of the problem area and economic resource limitations this research shall focus on technical investigation of specific user groups DRWH schemes of Chacha and Choki Schools. Long service period is the major criteria to select these specific schemes.

1.2 Statement of the problem

The rainfall of Ethiopia is unpredictable, although the majority of Ethiopian citizens do not have access to reliable and clean water resources, the utilization of rainwater harvesting will be able to preserve and take advantage of each drop of rain and it is essential that action is taken to improve the water conditions of the country. The objectives that are displayed in growth and transformation plan and plan for accelerated and sustained development to end poverty (PASDEP) have established to be insufficient and a new plan must be implemented in order to boost the access to clean water with shorter period of time in Ethiopia. Governmental programs have thus far failed to produce remarkable improvements in countryside water resources, and the implementation of rainwater harvesting could prove to have positive lasting effects. (Matthew, 2013)

Absence of technological awareness, skill/knowledge and standards are some of the major problems that hindered the efficient utilization and dissemination of DRWH technique. For instance both the national water resource management policy as well the regional sector development programs are not given emphasizes about rainwater harvesting as an alternative sources of domestic water supply.

However, recently realizing the multidimensional benefits of RWH a number of institutions (government and non-government) and individual have made efforts on the dissemination and utilization of the RWH systems to improve the low level food security and safe water supply coverage of the country.(Amha, 2014)

The implementation of rain water harvesting techniques will lessen the user"s reliance on the government to provide clean water. Once the systems are in place, Ethiopian water consumers will have access to clean water on their own, irrespective of whether the government decides to utilize essential funds. The domestic users will be able to maintain the harvesting systems on their own without government intervention.

A potential challenge regarding rainwater harvesting is about the cleanliness of gathered water. The majority of the water that is gathered in tanks through the harvesting system first contacts a surface exposed to the elements, creating a concern regarding the cleanliness of this water as these surfaces could have been contaminated during dry seasons, it is a strong possibility that dust and dirt will accumulate on exposed surfaces. This concern will be overcome by conducting researches so that domestic users become trained with the proper harvesting technique.

Even if governmental and non-governmental organizations efforts of household level water harvesting schemes are wide spread in North Shoa Ethiopia, the technical performance obtained was not assessed. Due to this reason, there was a need to assess the existing rainwater harvesting systems in this region to determine their effectiveness and sustainability. Hence, this study is aimed to fill this gap of knowledge in the region.

1.3 Research questions

- How effective were these projects to the targeted community and its drawbacks?
- How was the technical performance of these DRWH schemes?
- How was water quality condition for domestic use at these specific sites?
- What measures should be taken to alleviate the problem and sustain the project?

1.4 Objectives

1.4.1 General Objective

The general objective of this study is to assess and identify technical performance, structural conditions and water quality of Chacha and Choki School domestic roof water harvesting schemes.

1.4.2 Specific Objective

- To provide an overview of the study area DRWH technology;
- To assess the overall technical performance of DRWH schemes in terms of reservoir capacity, roof size, and number of user;
- To examine and perform physical and chemical laboratory tests of rain water in DRWH tanks;
- To propose guiding principles to help school community groups make informed decisions about sustain and developing their local non-potable water resources.

1.5. Justification for the Study Area

The DRWH schemes implemented by Water Action in Angolalla Terana Asagrt Woreda are selected for the assessment due to the following main reasons:

- The projects were implemented in 1997 and 1998 for Chacha and Choki school respectively, so it may be a fair time frame to evaluate the technical performance of a WatSan schemes;
- DRWH has been exercised as an appropriate technological option to improve the safe and adequate water supply provision in the Woreda.

1.6. Challenges of the Study

- Institutional DRWH schemes like those implemented in school compounds, the turnover of the water committee is nearly every year, so basic information about income and expenditure and scheme management and other information can‟t be easily found.
- It is also found difficult to know the exact number of beneficiaries of each of the schemes as the number of beneficiaries depends on the availability of water in the traditional ponds or more specifically on the length of dry period.
- It is difficult to find information such as the reservoirs operation i.e. tanks filling and empting time, the total services duration or the fraction of time when the tank is completely depleted and the like.
- Unwillingness of water committees to discuss about water revenue and current capital and financial management system etc.

CHAPTER TWO

2. Literature review

2.1. General.

The dimensions of the global water crisis are massive: Some 1.2 billion peoples do not have access to safe drinking water, 2.6 billion lack accesses to adequate sanitation and at least two million people die per year from lack of clean water and large portion of them are children. An analysis of these numbers finds that by 2020, some 34 to 76 million people may perish from water related disease potentially a greater toll than that of the AIDS crisis over a similar time scale (Nicolas, 2014).

As the global water crisis has received increasing attention from policy makers, activists, corporations and governments, a debate has grown over the best way to help those who suffer without clean water. Despite years of discussion, small-scale approaches like rainwater harvesting continue to get scant attention or support at the international level (Nicolas, 2014).

Many efforts have been made by the government and non-governmental organization to improve the provision of safe and adequate water supply to the rural communities by employing different techniques. The technical options in some case are so simple but in most of the cases the solutions are to some extent complicated or difficult to insure sustainable service and management at the capacity /technical knowledge/ of the intended beneficiary community.

Rainwater harvesting technology is gaining popularity in a new way. Rainwater harvesting is enjoying renaissance of sorts in the world, but its traces its history to biblical times. Extensive rainwater harvesting apparatus existed 4000 years ago in the Palestine and Greece. In ancient Rome, residents were built with individual cisterns and paved courtyards to capture rainwater to augment water from city‟s aqueducts (kerur, 2014).

The history of rainwater harvesting in Ethiopia dated back as early as the pre Axumit period (560BC). It was a time when rainwater was harvested and stored in ponds for agricultural and water supply purposes. Anthropologist has documented evidences of the remains of ponds that were once used for irrigation during this period (Fattoyich, 1990).

Other evidences include the remains of one of the old castles in Gonder (Fasiludus), constructed in the 15-16th century, which used to have water harvesting set up and pool that was used for religious rituals by the king (Alem,1999).

RWH systems can be categorized in to two categories based on type of catchment surface and uses. According to catchment type, RWH could be roof catchments, rock catchments, ground catchment and according to use check and sand dams. Roof and rock catchment systems could be directly used for domestic purposes with little effort exerted on improving water quality while ground and check or sand dams could be used for livestock watering, nurseries and small-scale irrigation and some domestic purposes.

DRWH system provides an innovation solution to meet local water needs. In recent years, the system has become cheaper and more predictable in the performance. DRWH systems deliver a good quality water directly (at the Get) or at every shorter distance to the targeted community or house hold. This qualifies it to be one of the options of water supply via reducing burden of water caring particularly for women and female children who are traditionally believed to be responsible. Moreover, RWH is not limited as mean for provision of water supply rather it is more importantly practiced in the developing countries as supplementary water sources during long dry spells for food production i.e. vegetables and subsistence crop production (Lakew, 2004).

A number of researches have been carried out in the world to improve the technology of DRWH techniques to be a chipper (affordable to the community), sustainable, safe source of water supply. Subsequent sections shall discuss the definition and Principles, benefits, components, overviews of Global and national DRWH experiences.

2.2 Conceptual Frame work

As per the information obtained from national water resources management policy water is a naturally endowment to all citizen and as far as possible it should be deliver to the people in safe way. Population is regressively increasing and the world climate is changing and worsens from time to time due to natural and manmade ecological disturbances.

Thus, the degradation of the natural resource and the increase in population causes water to be a scares resource So sustainable utilization of the available water resources for socio-economic transformation becoming a strategic objectives of both the developing and the develop world (MoWR, 2010).

The basic source of all water on the earth is rainfall / precipitation, snow etc. about 70 Percent of the precipitation that reach on the land area is evaporated or transpired directly back to the atmosphere; 10 Percent socks in and becomes ground water, and 20 Percent runs off in to lakes, streams and rivers (Punmia et al, 1995).

Thus using DRWH system we can use the rainwater/rainfall before any of the losses mentioned in the above paragraph and avoid the difficult to regain it back by investing huge amount of money for pumping, construction of Dams or reservoirs, construction of purifications or treatment plants and convey the stored water from head works to each house through various pipes size and length etc. (Thomas, 2003)

2.3. <u>Definition of DRWH</u>

The term DRWH has two elements Domestic and RWH. So it may be useful to define both of the terms to clearly understand the meaning and scope of DRWH.

World Health Organization (WHO) defines domestic water supply as being „Water used for all usual domestic purposes including consumption, bathing and food preparation‟ (WHO, 1993; 2002).

We may define RWH as a system of which Roofs are an obvious choice of a catchment surface (as their elevation protects them from contamination and damage) to harvest the natural endowed rainfall and store for pre-specified domestic purposes (Thomas, 2003).

2.4. Why and when RWH/DRWH?

RWH is essential because on the one hand surface water is inadequate to meet all of our demands and we have to depend on groundwater, which in most of the cases is an expensive option; on the other hand due to rapid urbanization of rural environment, infiltration of rainwater into the sub-soil has decreased drastically and recharging of groundwater has diminished. Therefore we required to harvest rainwater for future uses such as crop production, domestic water supply; garden watering etc.

DRWH has a number of areas of technical options depending on the prevailing natural water resources condition of a specific area; these include:

- Where groundwater is either difficult to access or need special treatment to remove excess minerals such as Fluorine, salinity (salt intrusion), Arsenic etc.
- Where limited rainfall, Poor surface water quality and distances between individual consumers make this an attractive option;
- Where annual rainfall is plentiful but long dry season exist;
- Area where housing development is resulting in new Roof materials replacing traditional thatched materials; and where clear water is needed for drinking purpose; and
- Where existing water price is significant (urban centers) and to subsidized in relatively wet season (Thomas et al,2007).

2.5. Advantages and disadvantages of DRWH system

2.5.1. Advantages

DRWH surpass the conventional sources of safe water supply schemes in terms of:

- An available natural resource that should not simply wasted;
- Rather than noting the opportunity of capitalizing on cases of abundant rainfall, it was felt that DRWH/RWH was particularly advantageous in areas where more conventional (communal or piped) water supply technologies were not available, either due to an existing lack of coverage or perhaps due to a shortage of surface and groundwater supplies;
- The quality of rainwater is high, especially in developing country (where the level of industrialization is very low and the occurrence of acidic rain is minimal);

- The system is independent, and therefore suitable for scattered settlement;
- It empowers users, placing the authority and responsibility to manage, operate and maintain the system right at the hh (consumer) level. This includes control over the quality of harvested water overtime;
- Systems built on a family basis and attached to the family home generate a powerful sense of ownership and responsibility;
- Local materials and craftsmanship can be used in DRWH system construction;
- No energy costs are needed to run the system;
- Ease of maintenance by the owner/user;
- It is inclusive; all members of the family can become involved;
- Convenience and accessibility of water; and
- Valuable time and energy is saved in collecting water

2.5.2. Disadvantages

Some of the disadvantages or limitation of DRWH system are:

- High initial capital cost may prevent a family (specially the poor) from buying the system;
- The amount of water harvested is limited by rainfall amount and available Roof area or size and quality. Supplementary water sources may be needed; for long dry seasons, the required storage volume may be too high/ expensive;
- Mineral-free water has a flat taste while people may prefer the test of mineral-rich water and;
- Mineral-free water may cause nutrition deficiencies in people who already on mineral-deficient diet (Petersen et al, 1990).

2.6. Challenges to Overcome

- Systems need to be carefully designed to optimize the coverage that a system can provide each year for a given level of investment. Systems that are more reliable need greater storage capacity and are more expensive to build. System reliability follows the law of diminishing returns and 100% reliability is prohibitively expensive to achieve;
- System reliability depends on statistical analysis of rainfall data. Data quality is therefore very important;

- Harvested water quality is a concern. Potential for contamination is high and is related to system design especially true for first-flush systems, unseen seepage into underground tanks (leakage of stored water can also be a problem and water management/abstraction techniques).
- Systems can become a health hazard due to breeding of vectors such as mosquitoes and
- Systems require expensive roofing and are therefore less accessible to poorer families. (Agarwall et al, 1997)

2.7 Economics

DRWH must be economically justifiable or feasible to the households or user community. Investment cost of proposed DRWH system must be evaluated and compared with the cost of alternative water supply improvements. It has been discussed that DRWH is a feasible option if other conventional sources are not feasible option.

Cost of renovation of building in general or only the catchment (roof) depends on the local price of building materials and associated storage requirement. The system may be economically justifiable but it must also be affordable to the hh or users community.

The tank forms the largest single cost in DRWH system and in higher capacity system it will dominate totally, accounting for 90 Percent of the total system cost. In smaller capacities low cost systems, the tank will be command about 70 Percent of the system cost. It is therefore vital to get this component rightly.

Tanks can be made cheaper by reducing either the size of the tank, the quality of material used or increasing the fraction of hh contribution either money or time in production (Thomas, 2003).

The selection of the tank size involves the right composition of a number of variables, some are easily measurable and others are more difficult to quantify. The most important to a water supply organization are the cost, coverage and service delivery.

Selecting a tank design with too high cost will have several ramifications. Like:-

- There will be low service coverage
- The technology will not be replicated, as it is too expensive
- Full cost recovery will prove impossible

In general, we might say a RWH system is "economically viable" if the benefit of harvesting is greater than the cost. There are various ways of making the comparison; of these the payback time is fairly easy for a water agency to use as in a test for economic viability, because it can compare with whatever is the "acceptable" upper limit on payback time used by that agency for other water investment of comparable risk.

Some studies shows like a case in Hararghe where projects are being initiated. The cost at house hold level for 2 to 3 m^3 capacity set up will cost in the range between US$ 75 and 88, for example 15 m^3 capacity circular Ferro cement tank with its accessories costs approximately US$ 1500 (Alem, 2013).

The use of Roof water harvesting is to be widespread in a region where the demand is acute; financing for the tanks should be available from the community and NGOs. In some special cases or arrangement capital can be made available in the form of a revolving fund (Alem, 2013).

2.8. Rainwater Harvesting Techniques

There are two main techniques of rainwater harvesting:

- Storage of rainwater on surface for future use; and
- Recharge to ground water

The storage of rainwater on surface is a traditional technique and structures used were surfaces and underground tanks, ponds, check dams, weir etc. while recharge to ground water is a new concept of rainwater harvesting (Kerur, 2014).

The structures generally used for groundwater recharging are:

Pits: - Recharge pits are construed for recharging the shallow aquifer. These are constructed 1to 2 m, wide and 3 m deep which are back filled with boulders, gravels, coarse sand;

Trenches: -These are constructed when the permeable strata is available at shallow depth. Trench may be 0.5 to 1m wide, 1 to1.5 m deep and 10 to 20 m long depending up on availability of water. These are back filled with filter materials;

Dug wells: - Existing dug wells may be utilized as recharge structure and water should pass through filter media before putting into dug well;

Hand Pumps: -The existing hand pump may be used for recharging the shallow/deep aquifer, if the availability of water is limited. Water should pass through filter media before diverting into hand pumps;

Recharge wells: -Recharge wells of 100 to 300 mm diameter are generally constructed for recharging the deeper aquifers and water is passed through filter media to avoid choking of recharge wells;

Recharge Shafts:- For recharging the shallow aquifer which are located below clayey surface, recharge shafts of 0.5 to 3 m diameter and 10 to 15 m deep are constructed and back filled with boulders, gravel and coarse sand; Lateral Shaft with bore wells: For recharging the upper as well deeper aquifers lateral shafts of 1.5 to 2 m wide and 10 to 30 m long depending upon availability of water with one or two bore wells are constructed. The lateral shafts are back filled with boulders, gravel and coarse sand;

Spreading techniques:- When permeable strata start from top then this technique is used. Spread the water in streams by making check dams, bunds, cement plugs, gabion structures or percolation pond may be constructed.

(Morgan, 1998)

CHAPTER THREE

3. General Over View of the Study Area

Angolela Teran Asagrt woreda is known of its poor surface and sub-surface water resource potential and to relieve this problem normally wells are drilled up to a depth of 250 m and the yield is also discouraging in most of the cases. This has been ascertained by the attempt made by Water Aid Ethiopia in 2002 and the regional water Bureau in different times.

The most common sources of water supply in this Woreda both for community and livestock watering are ponds. Whereas the most common source of safe water supply for human being is deep well.

The field survey is carried out from October 25 to 30, 2014 shows that Angolalla Teran Asagrt Woreda is mainly rural area and well known of its subsistence agricultural products; Teff, barley and different types of beans are the major substance crops grown in the Woreda. Information obtained from the community indicate the Woreda is food sufficient and has not been received any Food Aid from government or NGO.

Chacha School was constructed in 1991/92 with three blocks; two are teaching blocks. The school is constructed with wood and mud wall. Since the school is constructed 16 to 17 years before the blocks are at poor condition. Walls are started collapsing and hence gutter lack support.

The reservoir is functional however the fencing of the 75 m^3 reservoir is fully damage and the reservoir is easily accessed by animals and children. Pavement around the reservoir and cover slab of valve box is damaged. The reservoir has never been filled and it serves only rarely during the dry period.

Similarly reservoir constructed in Choki primary second cycle school compound; As per the information obtained from the user community wire mesh filter was fixed at the inlet of all of the reservoirs but during the survey it was observed that all are corroded and damaged. Due to this the rain water inters into the reservoirs without any proof that might contribute to the overall contamination of the harvested water.

3.1 Physical Aspect of Angolalla Terana Asagirt Wereda

3.1.1 Location and topography

Angolalla Terana Asagirt Wereda was one of 105 Weredas in the Amhara regions of Ethiopia. It is named in part after one of the capital of the former principality of Shewa, Angolalla located at the eastern edge of the Ethiopian highlands in the north Shoa zone. Angolalla Terana Asagirt wereda was bordered on the southwest by Hagere Mariam on the west by Oromia region on the north by Basona Werana, on the north east by Ankober and on south east by Berehet. The administer center of this Woreda was Chacha other towns in Angolalla Terana Asagirt Wereda included Choki and Gina ager, elevation in this Wereda ranges from 1000 to 2100 meters above sea level.

3.1.2. Climate and Rainfall

3.1.2.1. Rainfall

To design country‟s hydro metrological network rainfall is the most important parameter. Ethiopia‟s climate is characterized by high rainfall variability, it is therefore country‟s rainfall types divided into four regions, when the rainfall occurs in one continuous period of time in a year this is termed as monomodal and when this occurs in two discontinuous periods in a year this is termed as bimodal. Again, each of these is divided into type 1 or 2, based on the time of occurrence of the continuous periods or by the prominence of rainy periods. As per the National Metrological Service Agency (NMSA) classification, Angolalla Terana Asagirt Woreda could be classified under region A Bimodal Type-1. Since, there is no metrological station, any class, in Angolalla Terana Asagirt Wereda the research uses the nearest metrology station located in Debire Birhan town which is located about 12 Km from the Woreda town. (Refer Annex: Mean Monthly Rainfall; Debre Birhan Station). Angolalla Terana Asagirt wereda could be categorized under Dega and Woyna-Dega agro climatic Zones.

The small rain BELG occurs from March to May and the main rain MEHER occurs from June to August. The annual rainfall ranges from 580 to 1106 mm and the mean is about 953mm. The rainfall amount is higher at the northern part while decreasing as it moves towards the south-east, as the altitude descends from north to south-eastern direction.

3.1.2.2. Temperature and Evaporation

The mean annual maximum temperature varies from 23 to 29 C^0 and the mean minimum temperature varies from 4 to 8 C^0. The average annual evaporation is estimated to be 2041mm. (Refer Annex: Mean Monthly Maximum and Minimum Temperature, Debre Birhan Station).

3.1.3 Population

Based on figures published by the central statistical agency in 2007, This woreda has an estimated total population of 121,727 of whom 60,736 are men and 60,991 are women: 7,406 or 6.12% of its population are urban dwellers, which is less than the zone average of 11.95% with an estimated area of 992.35 km^2, Angolalla Teran Asagrt has an estimated population density of 122.6 people per km^2 which is less than the zone average of 135.31.

The two largest ethnic groups reported in this Woreda were Amhara (80.21%) and the Oromo (18.28%) all other ethnic groups made up 1.51% of the population. The majority of the inhabitants practiced orthodox Christianity with 96.59% reporting that as their religion while 1.48% were Muslims. Based on the 2007 population data and assuming constant population growth rate (2.56 percent) the current projected population is estimated to be about 149,772(CSA, 2007).

3.2 Chacha and Choki School DRWH Schemes

3.2.1 Back ground information

The DRWH schemes implemented in Chacha and Choki school is planned to serve a total of 800 and 600 people respectively and Chacha DRWH project was commenced in February 1998 whereas Choki DRWH project on July 1997, The projects were mainly financed by water action (an indigenous NGO) (Alemu et al,2000).

The total project cost was estimated to be Birr 207,925.66. Accordingly the cost sharing among the project stakeholders was as follows:

Water Action	Birr 201,000.00
Community (in Labor)	Birr 6,925.66
Total	Birr 207,925.66

On the course of implementing the construction, Water Action, recommend sanitation and hygiene education to be a component of the project to meet the envisaged objectives of the project. Thus the project is re-formulated in such a way that provision of hygiene and sanitation education and community developments activities is part of the project.

The objectives of the project includes improve the health status of the targeted communities through provision of safe water, reduce the time and energy unduly wasted by women and children in fetching water so that they will have more time for other important activities, minimize mortality and morbidity hazards on children who are by comparison more vulnerable to health problems than adults and Develop the skill of the communities to be served by the project.

3.3. Existing water supply and sanitation situation

The woreda is characterized by poor surfaces and subsurface water resources potential. Regardless the quality of water runoff harvesting via construction of pond is the most common sources of water supply both for domestic and animal watering. Construction and system management of ponds is becoming a typical practice of the Angolalla Teran Asagrt wereda people.

Though there are a number of limitations of using ponds as sources of domestic water supply; the limited period of services in a particular year, storage of polluted water and regular desilting are the major problems with the system. These characterized the low level performance of the major existing sources of water supply in the study area. Thus, it is evident that people in the woreda have been suffering from multi-dimensional safe water supply problem such as long travel time; regular desilting and health problems are among others. The other types of existing sources of water supply are rivers and deep wells. In most of the cases wells are drilled to a depth ranging from 200 to 260 m and yields 0 to 11 l/sec. A typical well drilled to a depth of 240 m within the catchment area of the DRWH schemes yields a discharge of 0.61 l/sec, these revels that the ground water potential is very low in the study area (Water Action, 1996).

CHAPTER FOUR

4. Methodology

4.1. General methodology

The purpose of this study is to evaluate DRWH schemes; therefore qualitative and quantitative data are used for this research. For the better understanding of the site situation both primary and secondary data sources are used.

In order to assess the water harvesting system, various approaches are adopted in the field survey and data analysis.

The unit of analysis for the study is specifically related to the numbers of schemes or observed sample schemes that have been implemented by the institution in different time frame which are Choki and Chacha school schemes.

Guided by the research objectives, the methodology of this research includes these major parts, namely data collection from the field and form secondary sources, data analysis for appropriate system (Both quantitative and qualitative) and Formulating findings. The whole methodology of the research is described below.

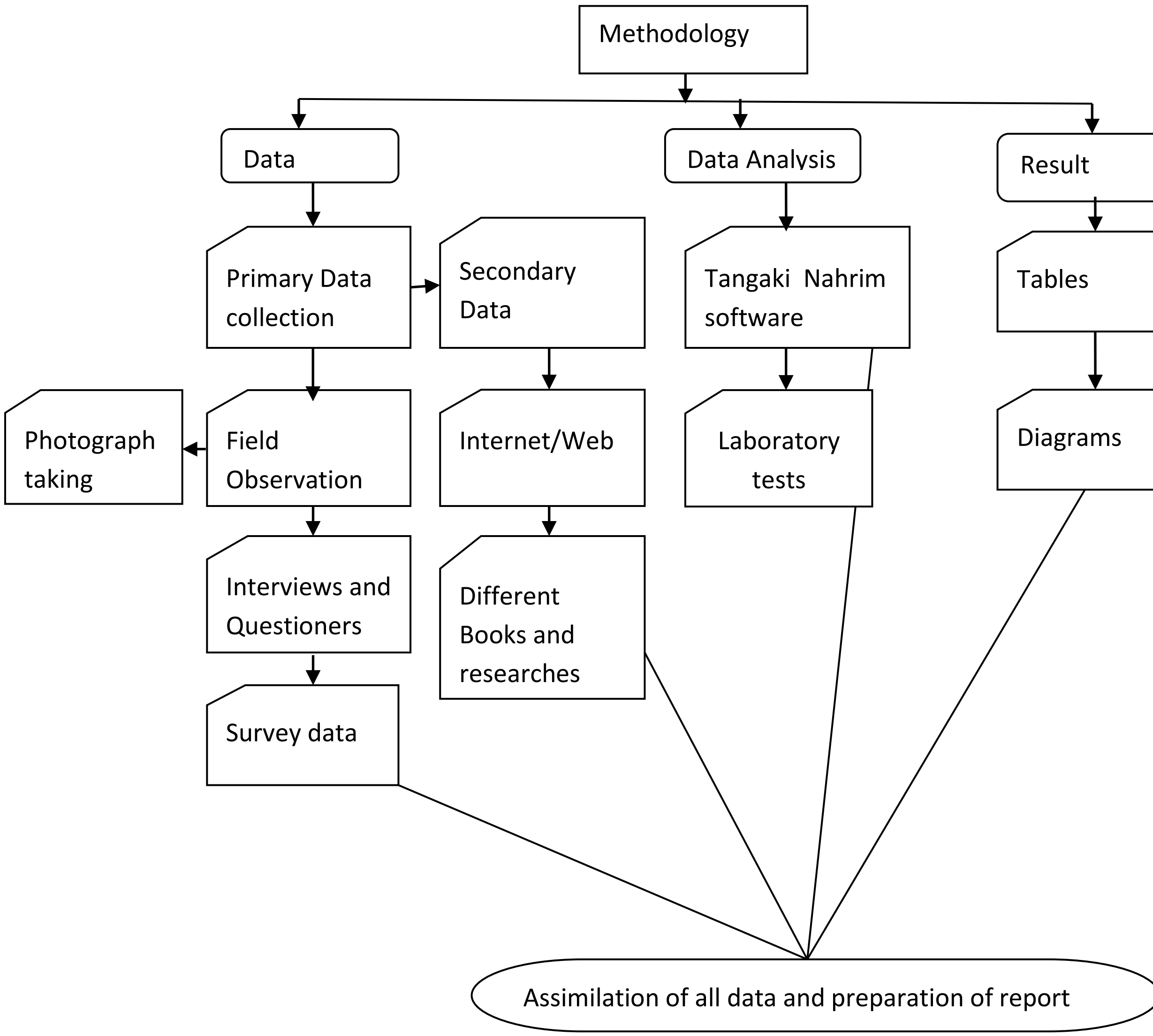


Figure 4.1: Diagrammatic presentation of research work

The above described (Figure 4.1) method is used in the field. The analysis of all data has been done by acquiring sufficient knowledge about the field and method of study used. During the field visit, close observation and documentation is done properly.

4.2. Data Sources

Data were collected using semi-structure interviews, different questionnaires, discussion with the WatSan committee and water management boards, discussion with the user community, physical observation and measurement of components, water sampling from selected schemes. In addition to these literatures, different webpages, project documents or proposals, project evaluation and completion reports are also referred.

4.3. Data collection methods

The study area and data available is somewhat difficult to assess and for the convenience of this work some secondary data has been used to support the primary information. Mainly two types of data; primary and secondary data have been collected for the research purpose.

4.3.1 Primary data

To compose a valuable research paper on this site a study has been conducted for water harvesting system at household and community level. Primary data has been used to identify the knowledge about the water harvesting system. Other Subordinate data such as roof area, number of user, tank size has been gathered from the field by a survey which has been done at the initial stage of the project.

To justify the data and find out the causes of the problems discussion with the community and physical observation has been made directly in the field. The methodology of this study also used survey data from structured questionnaire (APPENDIX 3): The survey data is the base for identification of Water sanitation and hygiene related basic problems of the community. It gives the overview about the dimension of problem and causes of the problem. It also gives the answer how much water a family required for their daily consumption.

4.3.2 Secondary Data

Literature review gave the major strength for justifying the problems and find out the appropriate design recommendation for DRWH. Further the approach which has been taken by the different organizations for the water harvesting system is taken into consideration. In the working area, different NGOs supported facilities like awareness program and training also taken into consideration.

4.4 Data Analysis

4.4.1 Data Analysis Method

Data analysis has been maintained by a process. According to the objectives of this paper the whole study has two main parts of analysis.

4.4.1.1 Design

To design and evaluate different DRWH structures the following design criteria and assumptions were used in the preparation and design of the water supply system:

(a) Design criteria‟s

- Mean annual rainfall is considered;
- Losses due to leakage, evaporation, wind effect etc.
- Effective run-off yield from roof catchments is considered.
- Average daily per capita water demand also considered.

(b). Available roof area.

(c). Total number of beneficiary at Chacha and Choki school schemes are collected.

With this specific data we can analyze the schemes using one of the specific approaches; Tangaki Nahrim software has been used for simulation to determine the optimal capacity of reservoirs or tanks size.

4.4.1.2 Water quality

To check water quality different standards was researched including Ethiopian water quality guidelines and WHO standards but for this research purpose because of limited resources, it is even more important to establish priorities, and this should be done by considering the impact on health in each case. So considering very basic international standard (WHO), which Ethiopian water quality standard also based upon the following basic parameters taken to verify the quality of the harvested water samples.

Physical and biological tests have been carried out by an authorized institution, since there was no water storage during dry season three samples were taken in wet season from every tank then output of the lab analysis showed us the PH value, Turbidity and conductivity of sample water which is basically used to analyses the quality of water samples.

- **Sampling and measurements**

Sampling was carried out in august 2014. Water samples were collected from the tank and from the outside tap. All samples were placed in polyethylene bottles for chemical analysis or individual sterile bottles for microbiological analysis, and transported to the laboratory in a chilled cold-box. Temperatures of the samples were measured insitu before transfer and assessed within 24h for microbiological analysis or frozen to await chemical analysis.

Quantitative services indictors established by World Health Organization (WHO) and Ethiopian water quality standard has been used in this study (WHO, 1996).

Table 4.1: WHO Standard for Water Quality

Parameter	Recommended Level
Faecal coli forms	0 per 100ml
Turbidity	< 5 NTU
Disinfectants chlorine residual	0.2 – 0.5 mg/l
PH	6.5 – 8.5

4.4.2 Technical data analysis methods

4.4.2.1 Supply

The initial consideration of the feasibility of DRWH concentrates on availability or depth of Rainfall as compared to its use or demand.

The yield or supply of water depends on how much depth of rainfall the area received under normal and worst condition or the dependable average annual rainfall of the area.

As per the National Metrological Survey Agency (NMSA) of Ethiopia the country is divided into four (4) regions based on rainfall types. These are (i) Region B: mono modal type-1 (ii) Region D: Mono modal type-2 (iii) Region A: Bimodal type-1; and (iv) Region C: Bimodal type-2 (NMSA, 1996).

When the rainfall occurs in one continuous period of time in a year, this is termed as mono modal and when this occurs in two discontinuous periods in a year, this is termed as bimodal. Again, each of these is divided into type 1 or 2 based on the time of occurrence of the continuous period/s or by the prominence of rainy period.

Mono modal type-1: Dominates by a single maxima rainfall pattern;

Mono modal type-2 /Diffused pattern/: Irregular rainfall pattern (does not have well defined rainfall pattern;

Bimodal type-1: Characterized by quasi-double maximum peak in August;

Bimodal type-2: Dominates by double maxima rainfall pattern with peak during April and October.

In a more comprehensive manner the Ethiopia climate seasons could be classified in three seasons. These are given as Bega; which is generally the dry season that covers the period from October to January, Belg: Refer to a small rain season that covers the period from mid-February to mid-May and Kiremt: Refer to the main rainy season that cover the period from June to September. About 65 to 75 Percent of the main annual rainfall occurs in “Kiremet” season over the principal cropping Zone. In “Bega” season, the rainfall varies between 10 to 400 mm; this is about 25 to 600 mm in “Belg” season and about 10 to 1200 mm in “kiremt” season (NMSA, 2013).

Quality of rainfall data can be think of at least six categories (Schiller et al, 1996).

- No numerical data available, but of course local people knows quite well the seasonality of precipitation and which crops will grow (with what sort of water-stress failure rate);
- There is no numerical data, but RWH has been practiced for long enough locally for people to have a feel for what is an adequate tank size;
- Only annual average rainfall is available, probably at a somewhat distant recording point, plus local knowledge of seasonality;
- Monthly rainfall, average over at least 4 years, can be obtained;
- Actual monthly rainfall records for at least 4 years, and preferably 7-10 years, are available for the site or for a location sufficiently nearby to give confidence or allow some systematic correction to be applied;
- Daily rainfall data for a relevant location and lasting at least 4 years is available; daily data is adequate for all design methods except perhaps the optimization of gutters for which rainfall intensity data is useful.

Thus, in the planning of DRWH/RWH reliable Rainfall data are required. This information can be obtained from the government methodological office or agency, the ministry of agriculture, university and airports. In our country the NMSA provides this information at reasonable cost for private sector and NGOs and without payment for researchers from Universities.

In our case for this research purpose we used reliable data from NMSA daily rainfall record of 20 years from Debre Birhan station, which has the same rainfall pattern with the study area and the daily rainfall data, was not acquired any significant missing data which means it was adequate for all design methods.

4.4.2.2 Demand

For technical judgment the next most important element is the demand. The demands imposed on the system depend on water use. In the HH, water is used for various purposes such as for drinking, clearing, cooking and washing. In rural part of our country per capita safe water demand is estimated to be „"between"" 20 to 25 l/c/d (African development fund, 2013).

The volume of water needed per person vary from one area to another; water demand in general depends on:

- The range of use or purposes;
- The number of people to be served;
- Climate, religion, culture, living standard (socio-economic condition) and
- Availability and complexity of developing the water resources etc.

(Cunliffee, 1998)

Once the supply (Roof runoff) and the average per capita demand of the hh or group people is fixed the next step is the decision making criteria i.e. estimating the total demand and compare it with the supply. As an example this could be demonstrated roughly as follows: If the roof area of a residential building is 25m^2 and the annual average precipitation of the locality is 1200 mm, then rudimentary maximum supply over a period of a year would be about 30 m^3.

After we calculated total annual safe water demand: If supply exceeds demand, then the rain water harvesting system is feasible from supply-demand point of view. If the supply is less than the demand the possible solutions would be either increasing the catchment area (may be difficult under practical condition) or reducing the demand which reduce the purpose of the harvested water like using the water for drinking and

Cooking purpose only; as demonstrated in the above example and balance the total demand from other sources.

4.5 Design Standards and Approaches

The following sub-sections shall discuss each of the major components of DRWH system from various categories of DRWH system arrangements and the standard design parameters.

4.5.1 Catchments

The part of the land that contributes some or its entire share of rainwater to the target area outside its boundary catchment surfaces can be either natural or treated (runoff inducement). It is a runoff producing area which may include agricultural, rocky or marginal land, rooftop, paved road etc. (Desta, 2004).

Basically, there are two types of rainwater harvesting schemes; those designated for agriculture use and those designated for domestic water supply. DRWH systems can roughly be broken down into four primary processes and three treatment processes (Warwick University, 2005).

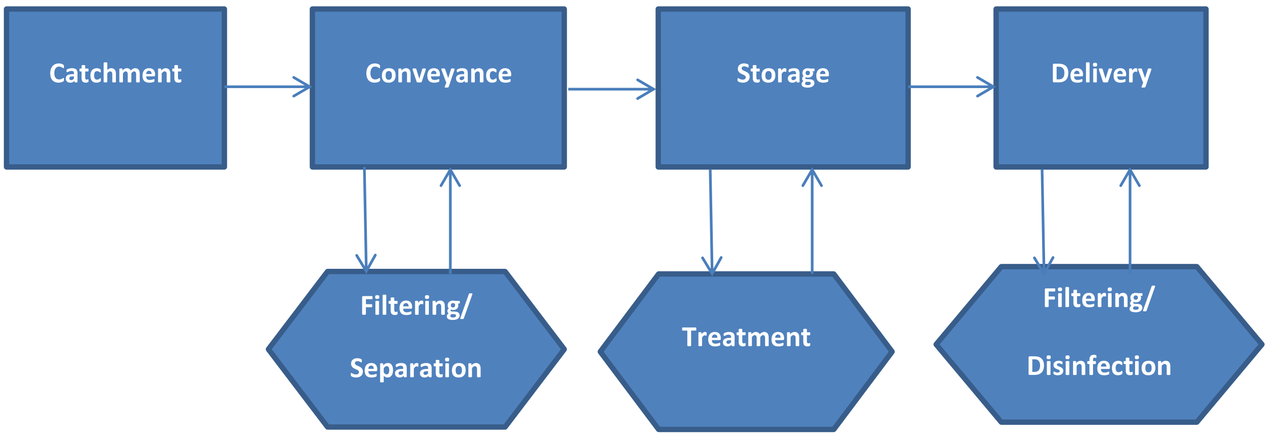


Figure 4.2: Primary Processes of DRWH System (Adopted from Warwick University, 2005)

There is a considerable range in complexity of DRWH systems. Where the simplest may be the use of any form of catchment or roof regardless the quality and size of the roof for instances the use of a banana leaf as a means of conveyance to unknown volume of storage material be from plastic, earth, clay pot or any.

On the contrary, the most complex or sophisticated system might be with automatic treatment at each stage of the process, electronic monitoring and dual reticulation systems.

Typical hh or community level DRWH system in developing countries, like us, comprises corrugated iron sheet roof as a catchment, steel gutter or down pipes as conveyance structure and Barrel or Ferro cement tank as storage with varying capacity.

RWH for agricultural use require large catchment areas and in this case use of ground surface storage is the obvious choice. On the other hand, rainwater for human consumption should be cleaner than water for agricultural use and roofs are obvious choices of catchment surface as their elevation protect it from contamination, which are common to surface water and treatment is needed as a prerequisite for their development as potable water supply. Ground catchments are prone to contamination by human and animal faecal matter, rotting vegetation, Agricultural inputs etc.

In general catchment determines the quantity and quality of water to be harvested. Types of catchment could broadly classify as Roofs (GI sheet, Asbestoses, thatched etc.), Ground (earth soil) and Rock. GI sheet Roofs are best due to their relative smoothness and the sterilizing effect of the metal roof heating under the sun galvanize steel is not inherently resistant to corrosion but it is available with rust resistant coating such as Zincalum and other materials (Cunliffee, 1998).

Asbestos roof material (used on older home) should not be part of a system to provide drinking water. Similarly cementations (concrete tile and fiber-cement shingles) and clay tile are not recommended because they can support mold, bacteria and algae growth and more difficult to clean (Flo True International corp., 2004).

The total rainfall amount or depth can"t be fully trapped from a catchment, whichever the type may be, to the storage thank or reservoir. There are losses that are mostly due to infiltration, wetting the surface and splashing due to either wind effect or size of the Gutter and /or down pipes.

Loss associated with adsorption and wetting of surfaces accounts about 2mm per month or 12mm per year (Martin,1980).

These losses are usually represented by a run-off coefficient, a number between zero and one. A good impermeable roof as corrugated iron sheet will deliver almost all rainwater fall on it. Ground catchment has a lower runoff coefficient as rain infiltrates in the pores of the soil and joins the ground water.

Table 4.2: Runoff Coefficient and Characteristics of Different Roof Types

Type	Run-off coefficient	Notes
Galvanized iron sheets	>0.9	- Excellent quality water surface is smooth and high temperatures help to sterilize bacteria
Tile(glazed)	0.6 – 0.9	- Good quality water from glazed tiles - Unglazed tile can harbor mold - Contamination can exist in tile joints
Asbestos sheets	0.8 – 0.9	- New sheets give good quality water - No evidence of carcinogenic effects by ingestion -Slightly porous so reduced run-off coefficient and older roofs harbor molds and even moss
Organic (thatch, palm)	0.2	- Poor quality water (>200FC/100ml) - Little first- flush effect - High turbidity due to dissolved organic material which cannot easily be filtered or settled out

(Warwick University, 2005)

As one can see from the above table, the poor performance of organic roofs would seem to preclude them from the use for rainwater harvesting system. Nevertheless, organic Roof could be used for secondary purposes and discouraged to use for domestic purposes.

Various techniques have been used to improve Roof to use for domestic water supply like polythene sheeting however; the sheeting tends to degrade in sunlight quickly and could only be used for only one season. The use of thatch roofs for domestic water supply or as secondary source (watering livestock or gardening and the like) is not as such practiced in many developing country. The reason could be cost of the polythene sheet is very expensive including Guttering and other accessories.

As discussed before ground catchment has a much lower runoff coefficient than Roofs (0.1 to 0.3), however they are usually provide much larger catchment area. If it is superimpose with paved (rock, or concrete pavement) yield will be maximized as the runoff coefficient improves to 0.6 to 0.7 (Warwick University, 2005).

4.5.2. Gutter

The arrangement for leading water from the roof to the water store is usually called „guttering". The gutters are open channels carrying water sideways under the edge of the roof to a point just above the water store; The chance of significant losses of rainwater would increase as the conveyance system from roof to the tank is longer i.e. in some arrangements water is conveyed from roof by gutter and then from gutter to down pipes and then to collection box at the foot of each down pipe and then from collection boxes to tank by pipe system. Guttering is the most popular method because it helps to keep run-off water cleans (Thomas, 2007).

The usual Gutter material in developing countries is galvanized sheet metal with triangular (V-shape), rectangular or semi-circle in shape. There are variety of types of gutter in the world such as prefabricated plastic, Aluminum, Steel, Wood and Bamboo, half pipes, Flexible guttering. The selection of the type of the Gutter mainly depends on the cost, difficulty in mounting as well to some extent water quality (Morgan, 1998).

Plastic gutter are less available in developing countries but in countries where industrial bases are good like Mexico, India and Sir Lanka, it is readily available at reasonable cost.

Aluminum Gutters are non-corrosive but too expensive. Steel Gutter is relatively non-corrosive and very common in Africa. Steel Gutters produced in workshops are usually square in shape and the cost of these Gutters is 2 to 3 times a similar Gutter produced on-site (Warwick University, 2005).

On site, Gutters are usual V-shaped. The shape is quite efficient but practices indicate that it has a tendency to block with debris; mounting V-shape Gutter is difficult as it is fixed just under the Roof edge. Rectangular Gutters can be easily fixed on fascia board, which is fixed on the rafter, but the problem is that fascia board might be missed and the distance from the Roof edge is random (Petersen et al, 1990).

It is uncommon to use wooden planks and bamboo as gutter but in theory or in literature, it is possible to use being it is too cheap or no cost to the community (Agarwall et al, 1997).

The problem with bamboo Gutter is durability, it decay and as well, linkage is possible. The porous media of bamboo forms an ideal environment for accumulation of bacteria that might be eventually washed in to the storage tank.

Half and flexible PVC pipes are normally coasty and are not as such durable due to brittle after degradation by UV (Hapugoda,1999).

The flow performance of a gutter varies along its length resulting in a spatially varying flow; however for a long gutter it can be approximated by the usual manning formula. Using this formula an idea of the actual size of gutter need can be developed for any gutter profile (Warwick University, 2005).

Table 4.3: Typical Gutter sizes (Warwick University, 2005).

Sources	Section	Roof size (M^2)	Slope (%)	Cross Sectional Area (cm^2)
(Hermann & Hassen, 1996)	Square	40 -100	0.3 -0.5	70
	Half Round	40-60	0.3 – 0.5	63
(Nissen - Petersen & Lee, 1990)	45^0 Triangle	Not specified	1.0	113
(Edwards etal.,1984)	Not specified	Not specified	0.8 -1.0	70-80

Heggen(1989) undertook a detail theoretical analysis of the hydraulic performance of gutters. The various factors affecting a gutter‟s capacity to carry runoff from the Roof to the tank were examined. These included the gutter‟s length, cross-sectional area, shape, roughness and slope.

As a general guideline to gutter dimension for catchment areas of different sizes, a useful rule of thumb is to make sure that there is at least 1cm^2 of gutter cross-section for every 1m^2 of Roof area (Hasse, 1989).

To avoid overflow during torrential down pours, it take sense to provide a greater gutter capacity. A 10 cm * 10 cm gutter with a cross-sectional area of 100 cm^2 can be used for roof areas measuring up to about 100 m^2 under most rainfall regimes. For large roofs/public roofs, such as at schools the 14 cm * 14 cm V-shape is suitable from roof section up to 50 m long and 8m wide.

Gutter should have sufficient and continuous fall to downpipes to prevent poling of water which could increase accumulation of materials, lead to algal growth and possibly provide a site for mosquito breeding. A fall of 1:100 to 1:500 should be sufficient (Cunliffe, 1998).

The result of Heggen‟s analysis revel a number of interesting insights, which are worth consideration when undertaking gutter design; these included:

- Increasing slope from 0.01 to 0.03 (1:100 to 3:100) increased potential water flow by between 20 and 100 percent- this effect was specially prominent for smaller gutter size;
- Semi-circular gutters were the most efficient at conveying water;
- The rule of thumb of 1cm^2 of gutter cross-section per 1m^2 of roof catchment area seems to apply under realistic conditions i.e. a 20 m-long gutter on a 100 m^2 Roof (20m * 5m) subjected to a storm with rainfall intensity of 20 mm/hr.

To design good guttering we should also:-

- Perform well at catching water as it runs off the roof.
- Carry water towards a downpipe or outlet without overflowing.
- Be cheap.
- Be durable and resistant to „normal abuse‟.
- Be an economic size, neither too small nor too large (in practice, sized to capture about 95% of run-off).
- Be laid at the proper slope and at the proper distance from the house wall / roof edge.
- Have effective joints between sections and to the „downpipe‟ (which may itself be a steep gutter) (Thomas et al, 2007).

4.5.3. Down pipes

Down pipes extend guttering just a little beyond the end of the building and provide a hole in its bottom to let the water drop downwards to tank.

The tank inlet must be lower than the lowest part of the guttering if water is to flow from the gutter to the tank. (Sometimes tanks are mistakenly built so high that inflow is impossible!).(Thomas, 2007)

Down pipes are produced from different material; steel pipe or rolled sheet metal and PVC are the most common types. Down pipe cross-sections are sometimes smaller than those of the gutter as it is assumed that since they are normally vertical, water will pass through them faster than through Gutters. In Roof catchment systems, however down pipes should have similar dimensions to Gutters. This is because the down pipes are often not vertical and act as channel to convey water from the end of the Gutter into tanks.

Suggested sizes of down pipes are given against the roof area feeding the down pipe. These sizes are big enough for a pipe whose length is not more than six times its drop (where drop is the change in height from the pipe entry to the water level in tank). For down pipes laid very flat, whose length is more than six times their drop, the next larger size is recommended.

If tanks inlet filter is provided, then the drop should be measured to the top of the filter, not the water surface in the tank. In any case it is wise to provide a screen above the pipe entry to prevent twigs and leaves from entering it (Thomas, 2003).

Table 4.4: Recommended Size of Down Pipe (Thomas, 2003)

Gutter width /top Width(mm)	Roof area served by one gutter (m^2)	Recommended down pipe size (mm outside diameter)
55	13	20
60	17	25
65	21	25
70	25	32
75	29	32
80	34	32
85	40	40
90	46	40
95	54	40
100	66	40

4.5.4. Jars/Tanks/storage/reservoirs

Water resources in general and rainwater in particular have to be managed comprehensively for sustainable development. Rainfall is a natural phenomenon and it is difficult to predict exactly when shall it fallen or it is not falling when it is needed. Therefore, we required to build or make ready some form of storage structure to trap and save the seasonal rainfall for various purposes in future. The amount of rainwater to be harvested will depend on the amount (depth), distribution and intensity of rainfall and the available of and type catchment area. On the other hand it depends on the various utilities of the harvested water and the number of members of the hh or user group.

DRWH tank must be relatively watertight (say, leakage of less than 5 Percent of the daily abstraction) and hold the required volume at the desired quality (Thomas (ed.), 2003).

Other requirements include:

- The ability to withstand erosion or damage to excess input of rainwater;
- Exclusion of vermin and access to mosquito breeding;
- Exclusion of light so that algae do not grow and larva growth;
- Sufficient ventilation to prevent an aerobic decomposition of any washed in matter;
- Easy access for clearing;
- Sufficient strength to withstand wear and tear and an predictable natural forces;
- No hazard for fallen of children in to the tank and
- Not giving undesirable test

There are a number of different methods for sizing tanks; from a simple to a complex or sophistication option depending on the system component or size and skill of practitioner.

In general, there are two categories of construction of tanks/reservoirs for DRWH system:

1. Surface or above ground-tanks with various shapes; it is most common for DRWH system;
2. Sub-surface or underground tanks; common for ground catchment system and are constructed with various shapes; circular, cylindrical, half sphere, cube or any.

Table 4.5: Pros and Cons of Above and Underground Storage (Warwick University, 2005)

Description	Pros	Cons
Aboveground	• Allow for easy inspection for cracks or leakage; • Water extraction can be done by gravity and tap; • Can be raised above ground level to increase water pressure	• Required spaces; • Generally more expensive; • More easily damaged; • Prone to attack from weather; • Failure can be dangerous
Underground	• Surrounding round gives support allowing lower wall thickness and thus lower costs; • More difficult to empty by leaving tap on; • Require little or no space above ground; • Unobtrusive; • Water is cooler; • Some users prefer it because • "It"s like a well"	• Water extraction is more problematic; often requiring a pump, a long pipe to a downhill location or steps: • Leaks or failures are difficult to detect; • Possible contamination of the tank from groundwater or flood waters; • The structure can be damaged by tree roots or rising ground water; • If tank is left uncovered animals can fall in contaminating the water; • Heavy vehicles driving over a cistern can also cause damage; • Cannot be easily drained for cleaning

Usually, the main calculation in designing a DRWH system will be to size the water tank correctly to give adequate storage capacity. The storage requirement will be determined by a number of interrelated factors. These include:

- Local rainfall data and weather patterns;
- Roof (or other) collection area / more technically catchments;
- Runoff coefficient; and
- Users number and consumption rates

There are a number of different methods for sizing system components. These methods vary in complexity and sophistication. Some are readily carried out by relatively inexperienced first-time practitioners; others required computer software and trained engineers who understand how to use this software. The choice of the method uses to design system components will depend largely on the size and sophistication of the system and its component, availability of tool (like computer) and skill and education level of the practitioner. Generally there are three different methods for sizing tanks (Warwick University, 2005).

Mehtod-1: Demand side approach/ Dry season demand versus supply/

A very simple method is to calculate the largest storage requirement based on the consumption rate and occupancy of the building/catchment. This approach considers the length of dry period as a design constraint. The tank is designed so that it accommodates the hh/beneficiary during the dry season. The length of dry period can be estimated by:-

- Asking farmers/community about the longest drought they remember;
- By estimating from official weather data the number of consecutive dry month per year

Storage requirement, St = (Ca*T)/D; where Ca = Annual consumption, T = Longest average dry period and D = Number of days in a year

This simple method assumes sufficient rainfall and catchment area which is adequate, and is therefore only applicable in this situation however; it does not take into account variations in annual rainfall patterns. It is a method for acquiring rough estimate of thanks size.

Method –2: Supply side approach/ Mass curve technique/

In low Rainfall area or areas where rainfall is of uneven distribution more care has to be taken to size the storage property. During some months of the year there may be an excess of water, which at other times there will be a deficits. If there is sufficient water throughout the year to meet the demand, then sufficient storage will be required to bridge the period of scarcity. In general storage is very expensive; this should be done carefully to avoid unnecessary expenses.

This method is more accurate of sizing a tank involves an analysis of data using the mass curve technique. Successful use of the technique requires (input data):-

- About 10 years monthly rainfall data of the project area or any nearby area with similar rainfall pattern;
- Choice appropriate runoff coefficient that accounts for the losses in relation to the type of the roof/catchment/ type;
- Actually measured roof area;
- Number of targeted user community or household members; and
- Average daily per capita water demand depending on pre specified purposes

While the output of the method yield maximum tank or reservoir capacity that caters the targeted community through the year.

Mehtod-3: Computer Model

There are several computer-based programs for calculating tank size quite accurately; of such programs because of ease accessibility „‟Tangaki Nahrim"‟ software has been used over "Simtanka" which needs online internet for simulation to determine the optimal capacity of reservoirs or tanks size, whereas „‟Tangaki Nahrim"‟ which has been written by National Hydraulic Research Institute of Malaysia (NAHRIM) is available free of charge on World Wide Web. NAHRIM started its operation in September 1995 and move ahead to become an excellent center in hydraulic engineering research and supporting service to meet the demand from both public and private sector in the water related development (Penuaian, 2014).

Tangaki Nahrim is a software program for simulating performance of rainwater harvesting systems with covered water storage tank. The idea of a computer simulation; is to predict the performance of rainwater harvesting systems based on mathematical model of the actual system. In particular Tangaki Nahrim simulates the fluctuating rainfall on which the rainwater harvesting system is dependent.

The result of the simulation allows you to design a rainwater harvesting system that will meet demands reliable, that is, it allows you to find the minimum catchment area and the smallest possible storage tank that will meet your demand with probability of up to 100 Percent in spite of the fluctuation in the rainfall.

Tangaki Nahrim requires at least 15 years of daily rainfall records for the place at which the rainwater harvesting system is located. If you do not have the rainfall record for the place then the rainfall record from the nearest place which has the same pattern of rainfall can be used (Penuaian, 2014).

Thus, successful use of the technique requires (input data):-

- Choice appropriate runoff coefficient that accounts for the losses in relation to the type of the roof/catchment/ type;
- Actually measured roof area;
- Number of targeted user community or household members;
- Average daily per capita water demand depending on pre specified purposes; and Level of confidence of the reservoir meet the demand.

Simulation with Tangki NAHRIM

1. The starting screen (Figure 4.3) is where the user needs to specify the following parameters which are the roof characteristics such as, the length and width of roof, the run-off coefficient which depends on the material of the roof and the first flush volume which accounts for the amount of water needed to wash the roof area with each rainfall event and the water usage characteristics which include the number of users using the tank, daily volume of water used per person and model size of storage tank use to harvest rain water.

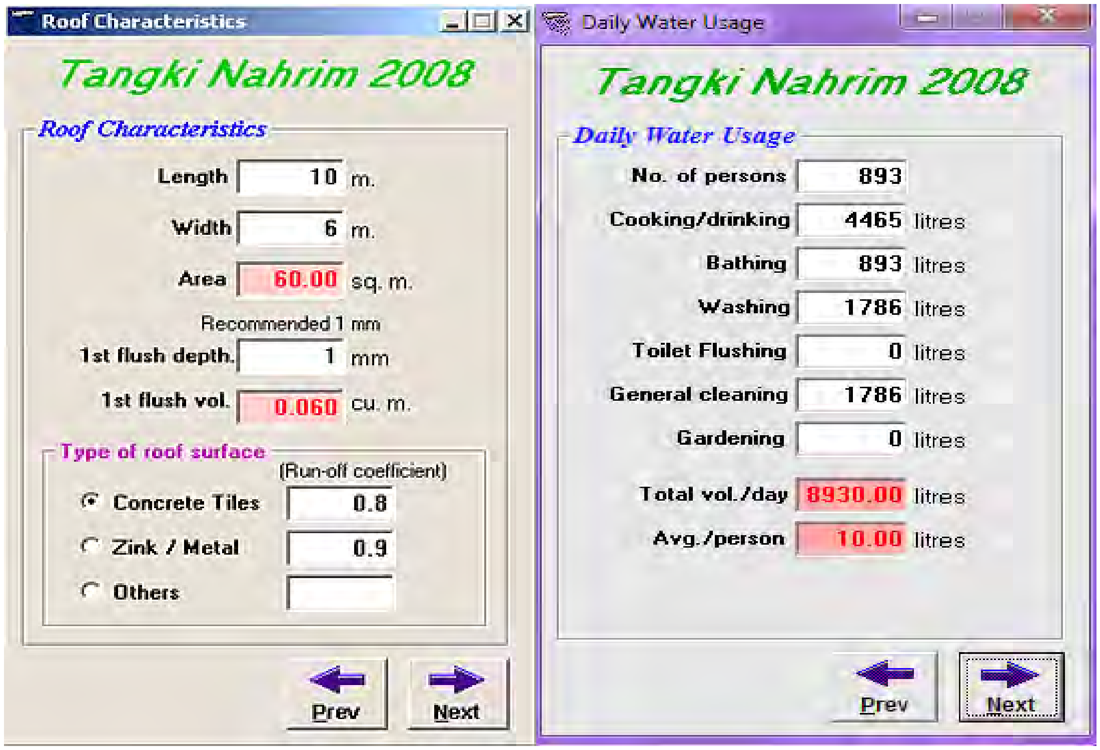


Fig 4.3 Tangaki Nahrim starting screen to input roof characterstics and daily water usage

2. When the simulation is run (Figure 4.4), the user is shown the conditions of water in the storage tank plus the following information:-

1. Total rain water volume delivered.
2. Number of days the demand or usage volume not fully met.
3. Number of days with no rain at all.
4. Number of days when there is no rain and the storage tank empty.

At the end of each simulation run, the following information is also provided:

1. The reliability ratio.
2. The percentage of the total time that the storage tank became empty.
3. The total volume of rainwater collected and delivered to the user.
4. The average volume of rainwater delivered day.

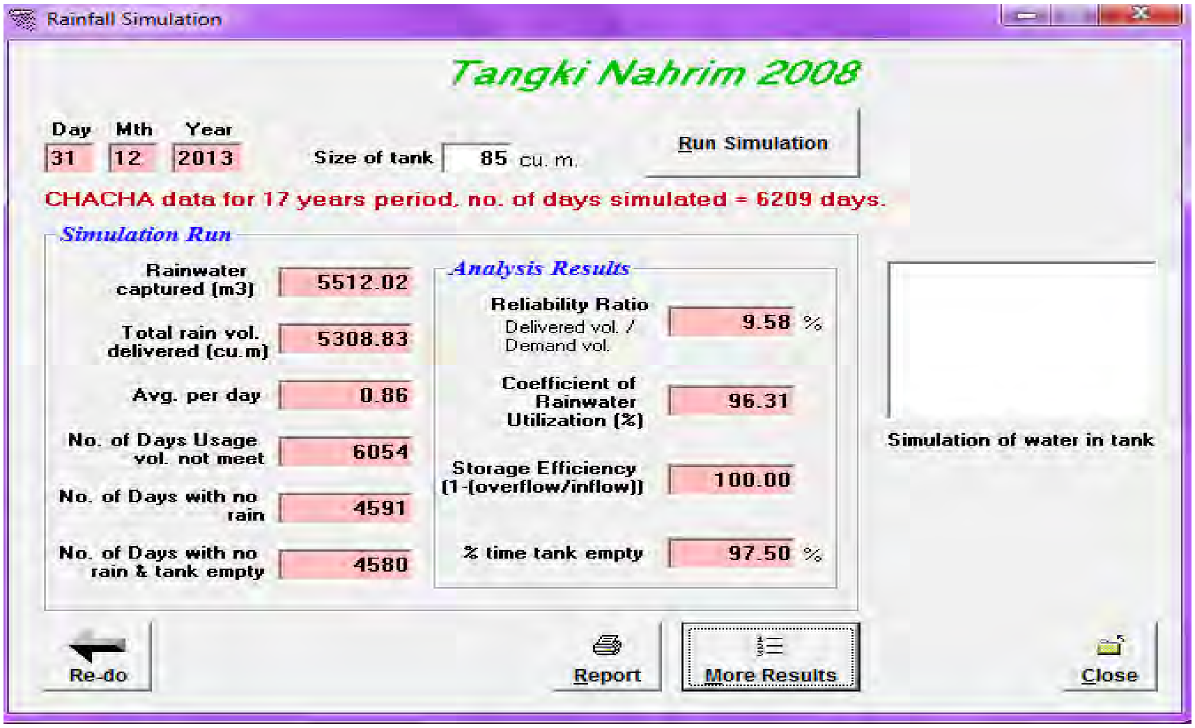


Fig 4.4 Tangaki Nahrim simulation result

The user is also provided with the following analysis results by clicking the respective buttons:

1. The "Analysis Results" button will show the total rainwater captured by the system, the coefficient of rainwater utilization and the storage efficiency.
2. The "Monthly Results" button will display the reliability values for every month from January to December.
3. The "Tank Condition" button will show the percentage of the time that the water level in the tank at the different levels i.e. full, three quarters, half, one quarter and empty.

4.5.5 Other auxiliary components

4.5.5.1 First flush

During periods of no rain, dust, bird droppings, dead plant matter and rodent and other nuisance will accumulate on the roof top. These materials are washed off with the first rain and may contaminate the water in the tank. If we did not provide means to exclude the entry of such materials the quality of the water will be deteriorate (Taye et al, 1998).

Contamination can be avoided by diverting the first 5 liters of rain for small roofs and 20-25 litters of rain for medium roof, from the tank. Flush traps can be used to prevent the first flush from reaching the tank (Cunliffe, 1998).

There are two completely independent variables that make each storm event unique: intensity and duration. Studies have shown that intensity is the critical wash off factor for most storm event. Based on these facts there are two most popular and generally used, first-flush device types: The „Constant-Volume Containers" or "Manual fixed volume" and „First-Flush Valves" or "Fixed mass and flow rate (Flo True International corps, 2004).

4.5.5.2 Constant Volume First Flush Containers

Generally speaking there are three main configurations of constant volume first flush containers. These are:-

- Homemade pipe diverter (vertical pipes that hold a small volume of water, the bottom end is capped by a threaded plug that is used to drain it between rains);
- Roof washer Box (made of Fiberglass) and supported by a metal stand and
- Diversion Tank (typically made of Fiberglas, polypropylene, or metal)

The constant–volume first-flush containers works depends on the capacity of the devices when the rain begins to fall, regardless of the rain intensity, then the excess rainwater is conveyed to the storage vessel or tank. They work on the theory that, if they are sized correctly (for example: 1 gallon capacity per 100 sq.ft of the Roof area), then the rainwater that is sent to the storage vessel will be essentially free of contaminants (Visscher et al, 1992).

The constant-volume method is the simplest and widely recommended, it does, however rely on the user both being home and prepared to go out into the rain to operate the devices much reducing its usefulness.

The major pitfall of constant-volume container is that when rainfall is a low intensity (which is the general pattern) it is likely that a constant-volume container will substantially fill with clean water because wash off does not occur effectively at lower intensities. Then, when more intense rains begin, undesirable contaminants from roof and gutter can wash into the clean water storage vessel. Moreover it is manually operated system after each rain and hence if we didn"t clean after each rain the contamination would be continued (Nissen et al, 1999).

4.5.5.3 First-Flush Valves

There are two types of First-Flush Valves that are commercially available. These are:-

- Valve Kit (the workings of the valve are installed into a standard PVC Tee); and
- Tee Valve (the workings of the valve are integral to PVC Tee)

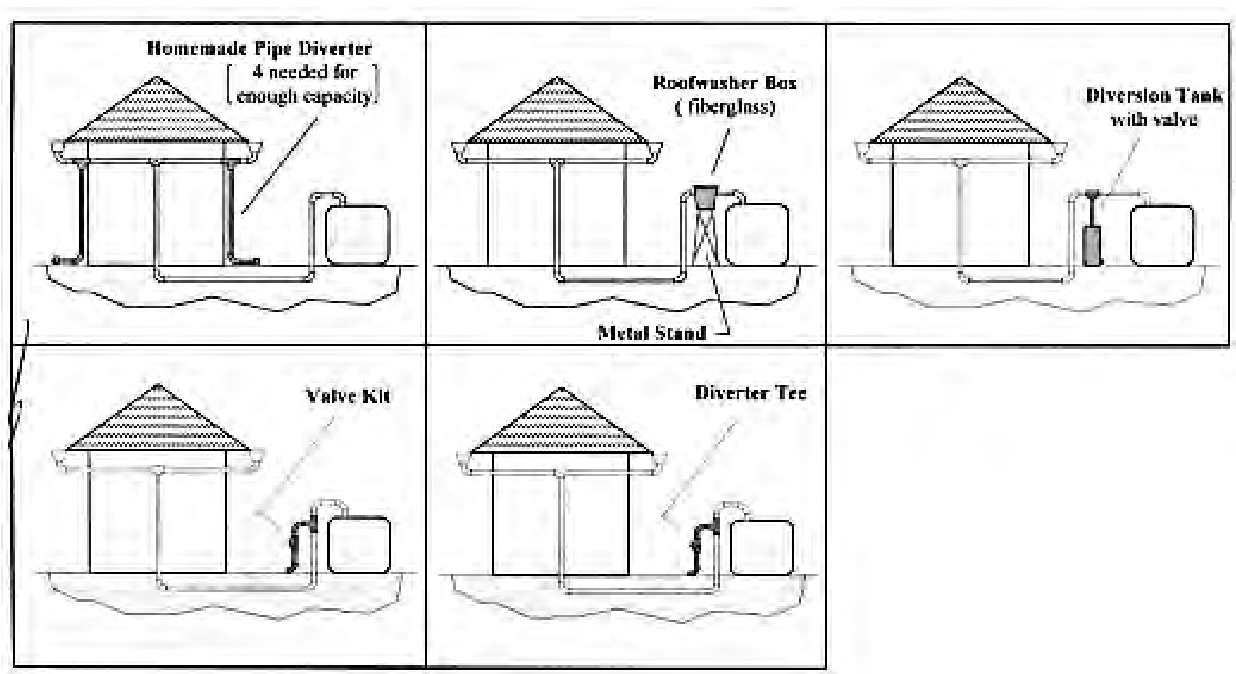


Figure 4.5: Different Arrangements of First Flush Trap (Adopted from FloTrue International Corp, 2004)

First-flush valves unlike constant-volume containers they are sensitive to the rate of the rainwater flow. It works in such a way that when the rainwater flows rate reaches a designed minimum a spring-suspended hollow internal container (i.e. Valve ball) located inside the devise begins to slowly fill with water. Then, when the valve ball has filled the increased weight causes it to contact a valve seat and stop the water flow. The excess rainwater is then conveyed to the storage vessel.

First-flush valves, on the other hand, dump contaminated water and debris to the ground or into a second tank. There are two primary advantages as a result. First, contaminated water is not likely to mix with clean water going into the storage vessel. Second, these devices do not typically needed to be manually cleaned or emptied in order to prepare for the next rain.

Hence, since valves dump rather than fill they can keep the water in the storage vessel cleaner (no mixing) and do not require constant cleaning in order to keep potent blooms of bacterial from becoming a potential health hazard (Nissen-petersen, 1992).

4.5.5.4 Filters

Filters are another possible solution to keeping sediment and contaminants out of the storage tank. A filter unit is chamber filled with filtering media such as fiber, coarse sand, and gravel layers to remove debris and dirt from water before it enters the storage tank. Charcoal can be added for additional filtration (Warwick University, 2007).

There are various types and combination of filter such as charcoal water filter (10 cm gravel layer, 10 cm charcoal layer, 25 cm sand layer and 25 cm gravel layer), Sand filter (20 cm gravel layer, 30 cm sand layer and 20 cm gravel layer); Dews filter (PVC pipe 140 mm in diameter and 1.2 m long; three chamber pebbles first layer 2-6 mm, second layer slightly larger than the first and the third layer 12-20 cm pebbles); VARUN, Horizontal roughing filter and slow sand filter, Filter channel. The Germany manufactures products of WISY and MALLBETON filters are also available (Warwick University, 2007).

Depending on the scale of the DRWH the provision of filter ranges from the conventional standard techniques of filtration i.e. slow sand filter and rapid sand filter could be used.

However for small community or hh DRWH the use of coarse grade sand and gravel chamber fixed at the inlet of the reservoir could be used to remove the larger particles including leaves, dead animals etc.

A typically community sand filter will have a thickness of 20 cm coarse gravel; 30 cm fine sand and 20 gravel layer (Vergas et al, 2007).

4.5.5.5 Splash Guard

Splash guard consists of a long strip of sheet metal and bent at angel and hung over the edge of the Roof to ensure all runoff for the Roof enters the gutter. The splash guard is nailed on to the Roof and the lower half is hung vertically down from the edge of the Roof. Splash Guards can easily manufactured on site form a sheet of metal.

During torrential downpours, large quantities of runoff can be lost due to gutter overflow and spillage. This is particularly a problem on long Roofs where, due to the slope of the gutter, it may hang many centimeters below the eaves of the Roof. To overcome this problem, a device known as a splash-guard can be incorporated on corrugated Iron Roofs.

Splash guard consists of long strip of sheet metal 30 cm wide, bent at angel and hung over the edge of the Roof by 2-3 cm to ensure that all runoff for the Roof enters the gutter. The splash guard is nailed on to the Roof and the lower half is hung vertically down from the edge of the Roof. This is easily manufactured on sit from sheet metal (Nissen et al, 1992).

4.5.5.6 Distribution Point/Water Points

Depending on the prevailing topographic condition types of distribution point or facilities varies from scheme to scheme. Mostly there are two common arrangements of distribution points. The first arrangement is based on the relative position and type of the rainwater conveyance system up to the tank and the second one is based on the size of the tank.

For small hh water tanks, out let (a Tap) is fixed on the wall of the tank and most of the time they are above the prevailing ground level. Whereas, for big water reservoirs the out lets are normally apart from the tank and constructed above or below the prevailing ground level, depending on the available head to insure gravity flow from the tank to the distribution point.

Existing practice teaches us for smaller water tanks up to a capacity of 10 m^3 a tap fixed on the wall of the tank is quite satisfactory while for reservoir capacity bigger than theses value we could use the conventional standard water point above ground level with 4 to 6 faucets.

4.5.5.7 Soak ways /Percolating pit

Sock ways or percolating pits are used to absorb drainage water at water collection point or water points in order to avoid drainage problem. Absences of this facility causes soil erosion or create favorable environment for mosquito breeding.

Practical observation shows us that a pit excavated to 60 cm * 60cm * 60-100cm (depth) quite sufficient for DRWH system. The excavated pit will be filled with crushed stone and river sand to facilitate easily drainage (Vergas, 2007).

CHAPTER FIVE

5. Data Analysis

5.1 Project Data Analysis Activities

The project data analysis includes the performance of $40m^3$ Ferro cement Reservoirs for Choki school and $75m^3$ masonry tank and $10m^3$ Ferro cement Reservoir for Chacha school, analysis also includes 400m Gutters and splash guard PVC pipe (720 m length and dia 25-150mm), water quality and construction of water points.

5.2 Design criteria

The following design criteria, data and assumptions were employed during the analysis exercises of the scheme.

(a) Design criteria

- Mean annual rainfall is 953 mm;
- Runoff coefficient is considered 0.9; since the roof was old galvanized iron sheet.
- Average daily per capita water demand
  - ✓ 9 litres for community (drinking and cooking purpose only) and
  - ✓ 6 litres for students;
  - ✓ 11 litres for teachers and their families

The amount of water demand difference between the community and teachers was formed, because teachers demand was included their family demand and the primary source of water supply was school schemes on the contrary it‟s not the case for the community.

(b). Available roof area and beneficiaries

Total Roof area of School blocks is 618 m^2; (378 m^2 for Chacha School; 240 m^2 for Choki School)

- **Total number of current beneficiaries are 1400 inhabitants**

  Chacha School

  - ✓ 581 people to be supplied from the schools schemes and
  - ✓ 277 pupils and 13 teachers (including their family) from the school scheme
  - ✓ 3 guards with 19 of their family‟s

  Choki School

  - ✓ 280 people to be supplied from the schools schemes and
  - ✓ 205 pupils and 10 teachers (including their family) from the school scheme
  - ✓ 2 guards with 10 of their family‟s

- **Total number of projected design beneficiaries are 1156 inhabitants**

  Chacha School

  - ✓ 523 people to be supplied from the schools schemes and
  - ✓ 211 pupils and 9 teachers (including their family) from the school scheme
  - ✓ 2 guards with 12 of their family‟s

  Choki School

  - ✓ 217 people to be supplied from the schools schemes and
  - ✓ 167 pupils and 7 teachers (including their family) from the school scheme
  - ✓ 2 guards with 6 of their family‟s

Minor cracks are observed on the walls of the Ferro cement tanks but it is only oozing of stored water and has trivial effect on the storage. Regarding the 75m3 reservoir; the major problem is cracks on the pavement around the reservoir and the out let of the over flow pipe is fully buried in the ground and hence the reservoir roof slab experience uplift pressure this result separation of the wall and top tie beam of the reservoir. As per the discussion with the school community (tap attendant and teachers) significant water is lost through this section when the reservoir is full.

Another defect observed with the reservoir is that the get valve fixed at the out let is not functional and hence water is controlled by the get valve fixed at the water point only.

Wire mesh filter was fixed at the inlet of all of the reservoirs but during the survey it was observed that all are corroded and damaged. Due to this the rainwater inters in to the reservoirs without any checking that might contribute to the overall contamination of the harvested water in the reservoirs. Sunlight could enter through the inlet to the reservoir and hence the possibility of the development of Algae is very high.

Fig 5.2: 40 m^3 Ferro cement reservoir fixed with a nearly damaged school block (Choki School)

To analyze tank storage condition 30 random sample users are selected which lives nearby the scheme area including all 13 teachers and 3 guards which have permanent residence adjacent to the schemes and all 14 households neighboring the scheme area so as to analyze and gather information about the tank water condition by six levels within the year. In the questioner each samples were asked how many days within the year the tank was in full, 3/4 – full, 1/2 - ¾ full, 1/4 - ½ full, 1/4 - ½ full and tank empty condition and average result of each condition with percentage is tabulated below.

Table 5.1: Field data about tank water condition in Chacha School

Chacha school (75+10)m^3 tank water level	Days this water level occur within the year	Percentage of time (%)
Tank full	7	1.91%
3/4 – full	13	3.56%
1/2 - ¾ full	17	4.66%
1/4 - ½ full	23	6.30%
Empty - ¼	34	9.32%
Tank empty	271	74.25%
Total	365	100%

Analysis of Chacha school (75+10) m^3 tank using Tangki Nahrim rain water harvesting software

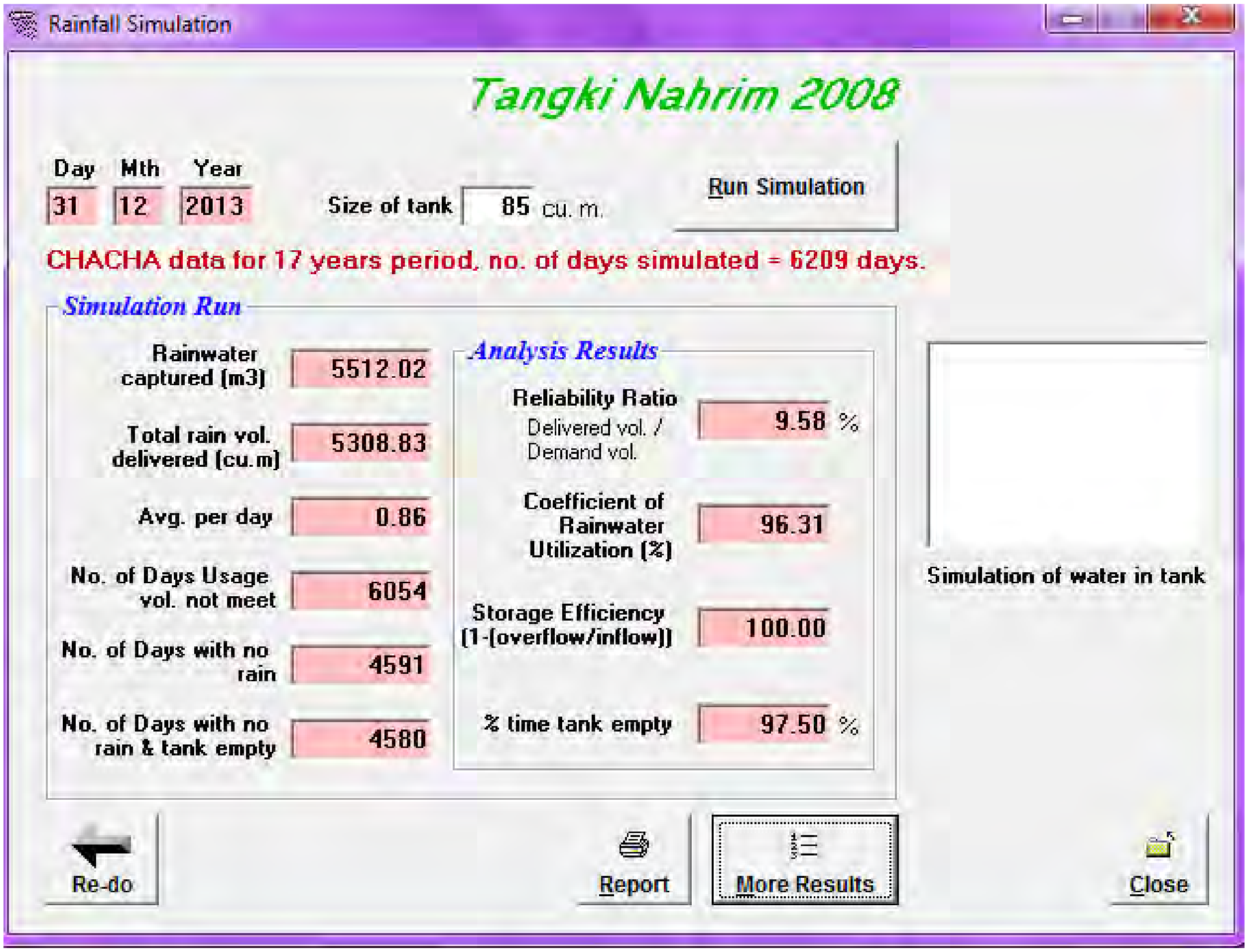


Fig 5.3: (75+10) m^3 simulation summary for Chacha School (Tangaki Nahrim).

5.2.1.3. Gutter and Splash Guard

All the roofs of the school has fixed with Gutter and splash guard that are manufactured on site. The Gutters are V-shapes/Triangular with size 13 cm depth and 14 cm top width and the splash guards are 20cm width. The problem observed with gutters is slope. The gutters have no uniform slope and also the wooden support is getting decayed especially at the end tip that connects to the reservoir inlet. The wooden post requires major maintenance preferably replacing by durable material. The opportunity to see the insides of the gutter is difficult however as per the information collected from the teachers clearing has not been done so far, since construction.

5.2.1.4. Down pipes

All reservoirs constructed in the school compound does not requires down pipe as the water directly conveyed from the roof to the inlet via the v-shaped Gutters.

5.2.1.5. Distribution points

The distribution point of the system is masonry underground water point with three faucets. The water point is constructed below the existing ground level to have a good gravity flow from the tanks. The water point lacks drainage and the retaining wall and the stair case requires major maintenance.

5.2.1.6. Water quality

Quality of water directly determines the drinking water security of a community. The criteria used by the user community in all of the schemes are color; taste; presences of worms; odor. The community perceptions of drinking water are governed by these factors and accordingly they found that rainwater is found to be a good quality as compared to the pond water, which are the most common sources of water supply in the Woreda.

To verify the quality of the harvested water samples are collected and physical and biological tests have been carried out by an authorized institution. The test is conducted in WWDSE laboratory services.

5.2.2 Choki primary school Scheme

The geographic location of Choki School DRWH Schemes constructed in the school compound are found in N-08^{0}56.218 and E-049^{0}21.668

5.2.2.1 Beneficiary

Discussions made with school community (Teachers) in Choki primary second cycle school indicate that the total population that has been used the harvested water are estimated to be almost 507.i.e. (280 communities; 10 Teachers; students 205; and 2 Guards with 10 of their family) whereas, the design beneficiary community that has been using the harvested water is about 399 peoples i.e.217 communities; 7 Teachers; 167 pupils; 2 Guards with 6 of their families.

5.2.2.2 Structural or Build Type and Existing Condition

Choki School was constructed in 1991/92 with three blocks; two are teaching blocks. The schools are constructed with wood and mud wall. Since the school is long aged the walls are on poor condition. Walls are started collapsing and hence gutter lack support. The remaining is residential block for the teachers, which is in a good condition.

5.2.2.3 Reservoirs Types and Condition

Based on the available roof area and the supply-demand analysis $40m^3$ Ferro cement reservoir is constructed in the school compound. The reservoir is functional however the Fencing of this reservoir is fully damage and the reservoir is easily accessed by animals and children. Pavement around the reservoir and cover slab of valve box is damaged.

The get valve fixed to control the realize of the stored water from the $40m^3$ reservoir is damaged as a result the school community collects water by inserting 3-4m long flexible plastic pipes or hosepipe into the reservoir through the inlet opening at the top. This contribute serious contamination of the stored due to poor handling of the hosepipe i.e. the pipe is thrown away everywhere after and before use.

Reservoirs store water harvested from the two teaching blocks. As per the information obtained from the user community wire mesh filter was fixed at the inlet of the reservoir but during the survey it was observed that corroded and damaged. Due to this the rain water inters into the reservoirs without any proof that might contribute to the overall contamination of the harvested water.

To analyze tank storage condition 30 random samples are selected which lives nearby the scheme area including all 10 teachers and 2 guards which have permanent residence adjacent to the schemes and all 18 households neighboring the scheme area so as to analyze and gather information about the tank water condition by six levels within the year. In the questioner each samples were asked how many days within the year the tank was in full, 3/4 – full, 1/2 - ¾ full, 1/4 - ½ full, 1/4 - ½ full and tank empty condition and average result of each condition with percentage is tabulated below.

Table 5.2: Field data about tank water condition in Choki School

Choki school 40m^3 tank water level	Days this water level occur within the year	Percentage of time (%)
Tank full	1	0.27%
3/4 – full	5	1.36%
1/2 - ¾ full	12	3.28%
1/4 - ½ full	15	4.10%
Empty - ¼	37	10.13%
Tank empty	295	80.82%
Total	365	100%

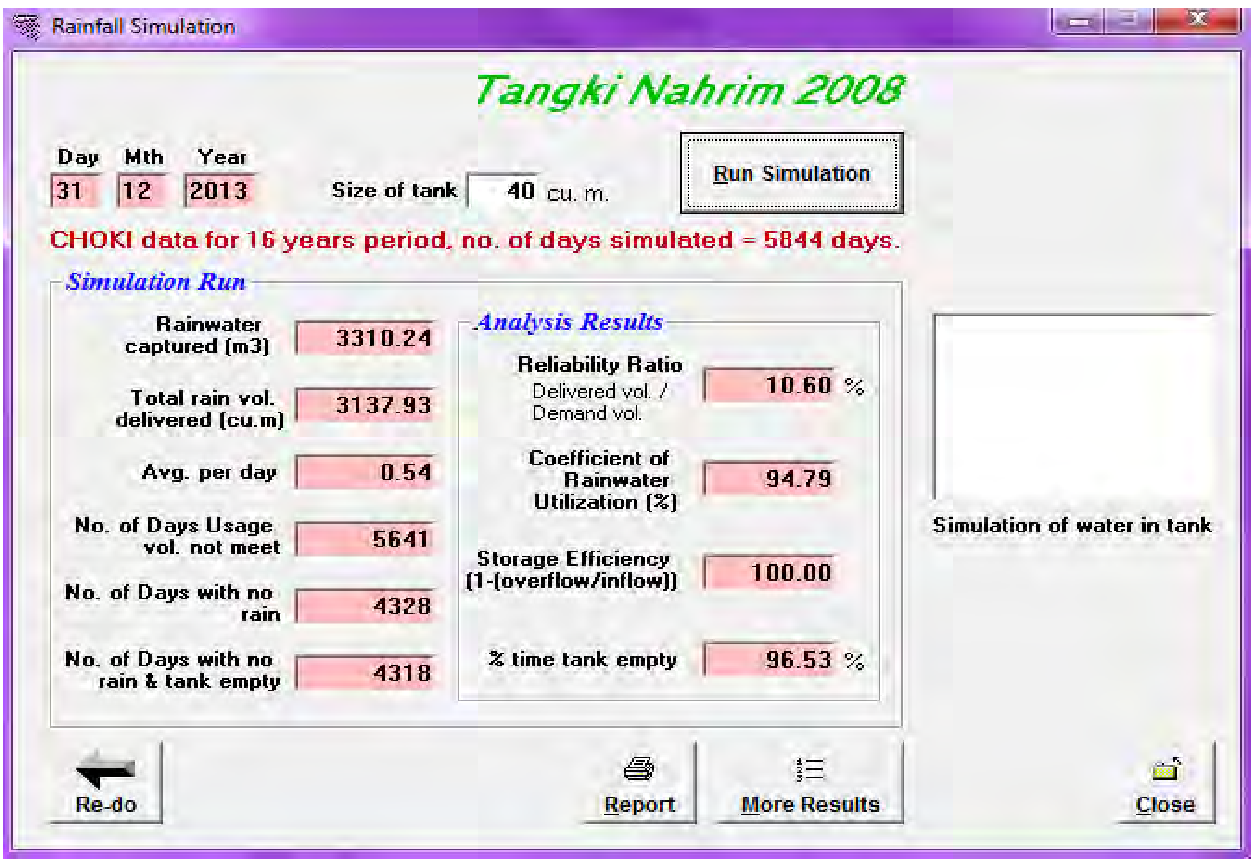


Fig 5.4: 40m^3 tank simulation summary for Choki School (Tangaki Nahrim)

5.2.2.4 Gutter and Splash Guard

All the roof catchments in Choki DRWH Schemes are fixed with Gutter and the roofs have no splash guard. The Gutters are Rectangular in shape with size 13 cm width and 14 cm depth. The problem with gutters is slope. The gutters have no uniform slope and also the wooden support is getting decayed that requires maintenance, preferably replacement by durable posts. The opportunity to see the insides of the gutter is difficult and as per the information collected from the user community; none of the schemes Gutter have been cleared since construction.

5.2.2.5 Down pipes

The reservoir constructed in the school compound does not require down pipe as the water directly conveyed from the roof to the reservoir inlet via Gutters;

5.2.2.6 Distribution points

The distribution point for 40m^3 reservoir is underground masonry water point with three faucets. Out of the three Faucets only one is functional. Based on the information obtained from the teachers and the tap attendant the pipe line from the collection chamber to the water point is clogged and hence the water point is not functional. The school communities collect water at the collection box by dipping that expose the collected water for contamination.

5.2.2.7 Water quality

Quality of water directly determines the drinking water security of a community. The criteria used by the user community in all of the schemes are color; Taste; presences of worms; odor. The community perceptions of drinking water are governed by these factors. To verify the quality of the harvested water three samples was taken from DRWH schemes. The sample physical and biological tests have been carried out by an authorized institution. The test is conducted in WWDSE laboratory services.

CHAPTER SIX

6. RESULT

The chapter will discuss the major technical performances of the schemes in terms of tank capacity and water quality as established in the methodology of the study. Moreover the section shall brief discuses other performance elements like social, institutional and continuity of services to have a full picture of the problems associated with sustainable services delivery.

6.1. Technical performance

6.1.1. Tank size

One of the major indicators to measure the technical performance of DRWH scheme or system is the tanks size or the amount of water secured or made available for the user community with in the specified duration.

In this regard detail analysis is carried out to examine the capacity of the existing tanks in relation to the available roof areas and the number of targeted beneficiaries. As discussed in the methodology there are basically three approaches to determine the capacity of DRWH tanks/reservoirs. The approach followed in the design project document is the same for the two schemes and it is a combination of the two methods i.e. Method-1 Demand side approach and supply side approach. The advantage and disadvantage of each of the methods including Method-3 (computer Model) has been discussed in the methodology.

6.1.2 Water demand

Considering these average daily per capita water demand

- ✓ 9 litres for community (drinking and cooking purpose only) and
- ✓ 6 litres for students;
- ✓ 11 litres for teachers and their families

Water demand for Chacha and Choki school schemes tabulated as follows:-

Table 6.1: Water demand for Chacha school scheme

Number of user‟s	User‟s average daily per capita water demand (lit/day)	Yearly water demand for Chacha school (m^3/year)	Remark
581	9	1908.585 m^3/year	supplied from the schools schemes to the peoples
277	6	606.630 m^3/year	for the pupils
13	11	52.195 m^3/year	for the teachers (including their family)
22	11	88.330 m^3/year	3 guards with 19 of their family‟s
Total		2655.74 m^3/year	

Table 6.2: Water demand for Choki school scheme

Number of user‟s	User‟s average daily per capita water demand (lit/day)	Yearly water demand for Choki school (m^3/year)	Remark
280	9	919.8 m^3/year	Supplied from the schools schemes to the peoples.
205	6	448.95 m^3/year	Supplied for the pupils.
10	11	40.15 m^3/year	Supplied for the teachers (including their family).
12	11	48.18 m^3/year	Supplied for 2 guards with 10 of their families.
Total		1457.08 m^3/year	

Table 6.3: Summary of roof water supply and demand deficit for Chacha and Choki school schemes

No	Scheme	Roof area(m^2)	Annual mean Rainfall of the area mm/year	Amount of rain Water harvested M^3/year (0.9 coefficient)	Total demand M^3/year	Deficit M^3/year
1	Chacha school	378	953	324.2	2655.74	-2331.54
2	Choki school	240	953	205.8	1457.08	-1251.28
	Total	618	953	530	4112.82	-3582.82

Based on the design criteria established a total of 530 m^3 of rainwater can be collected per annum from the school roof catchments of chacha and choki schemes. Similarly the demand is estimated to be about 4112.82 m^3 per annum. This shows a net deficit of about 3585.52 m^3 per annum or the deficit is about 7 times less than the demand of the targeted community.

To verify the findings the study has tested the reservoirs capacity of each of tanks with the help of Tangki Nahrim rain water harvesting software. Outputs of the analysis made with this method put as follows:-

- **Result of Tangki Nahrim rain water harvesting software**

Table 6.4: Input data summery of Tangki Nahrim roof water harvesting software for Chacha school scheme

Type	Result	Remark
Roof area	**378.00 m^2**	
Rainfall data from year	**1997 – 2013**	
Roof Characteristics (Length x Width)	**378 m^2**	94.5 m * 4 m
1st flush volume	**0.38 m^3**	Assumed 1mm of rainfall for 1st flush
Type of surface	**GSI**	
Size of tank	**85 m^3**	75 m^3 + 10 m^3
Run-off coefficient	**0.9**	
No. of days simulated	**6209 days**	For 17 years period
Average daily per capita water demand	**10 liters/user**	Calculating average consumption of all user group

Table 6.5: Simulation result summery of Tangki Nahrim roof water harvesting software for Chacha school scheme

Type	Result	Remark
Total rainwater captured	**5512.02 m^3**	
Total rain vol. delivered to beneficiaries	**5308.83 m^3**	
Average volume delivered per day	**0.86 m^3**	No. of days simulated / Total rain vol. delivered
No. of Days Usage vol. not meet	**6054 days**	
No. of Days with no rain	**4591 days**	
No. of Days with no rain & tank empty	**4580 days**	
Tank reliability Ratio	**9.58%**	Delivered vol. / Demand vol.
Coefficient of rainwater utilization	**96.31%**	Rain vol. delivered/Rain water captured
Storage Efficiency	**100%**	1-(overflow/inflow)
Percentage (%) time tank empty	**97.50%**	

Table 6.6: Input data summery of Tangki Nahrim roof water harvesting software for Choki school scheme

Type	Result	Remark
Roof area	**240 m^2**	
Rainfall data from year	**1998 - 2013**	
Roof Characteristics (Length x Width)	**240 m^2**	60 m * 4 m
1st flush volume	**0.24 m^3**	Assumed 1mm of rainfall for 1st flush
Type of surface	**GSI**	
Size of tank	**40 m^3**	
Run-off coefficient	**0.9**	
No. of days simulated	**5844 days**	For 18 years period
Average daily per capita water demand	**10 liters/user**	Calculating average consumption of all user group

Table 6.7: Simulation result summery of Tangki Nahrim roof water harvesting software for Choki school scheme

Type	Result	Remark
Total rainwater captured	**3310.24 m^3**	
Total rain vol. delivered to beneficiaries	**3137.93 m^3**	
Average volume delivered per day	**0.54 m^3**	No. of days simulated / Total rain vol. delivered
No. of Days Usage vol. not meet	**5641 days**	
No. of Days with no rain	**4328 days**	
No. of Days with no rain & tank empty	**4318 days**	
Tank reliability Ratio	**10.60%**	Delivered vol. / Demand vol.
Coefficient of rainwater utilization	**94.79%**	Rain vol. delivered/Rain water captured
Storage Efficiency	**100%**	1-(overflow/inflow)
Percentage (%) time tank empty	**96.53%**	

6.1.3 Reliability

Reliability is the ability of domestic roof water harvesting system or component to perform its required functions which is to supply the demand under stated conditions for a specified period of time and the maximum reliability achieved when all demand is supplied by the system. In our research the system reliability was checked by Tangaki Nahrim software which is solved by comparing delivered volume with demand volume.

Monthly Reliability (%) = Monthly Delivered vol. / Monthly Demand vol.

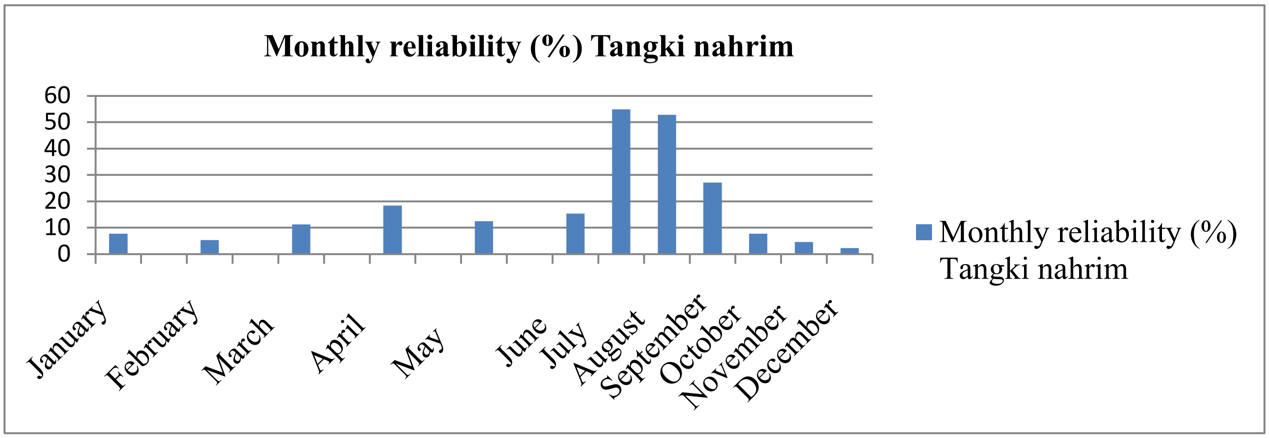
Table 6.8 shows monthly mean rainfall reliability (%) during wet season of July, august and september reliability ranges from 27-55%, whereas for dry season of Oct.-June reliability ranges from 2.3 - 18.5%, hence maximum reliability was achieved in July with 55.03% for Chacha scheme and 54.9% for Choki scheme, on the reverse the minimum reliability was in December with 2.32%.

This simulation output showed us the tanks are designed and constructed without taken into account of the annual expected runoff and projected beneficiaries accordingly the harvested rain water never fully meet the demand of the targeted number of beneficiaries in any of the months of a given year.

Table 6.8: Monthly Mean Rainfall Reliability (%) Tangki Nahrim for Choki and Chacha School schemes

Chacha Monthly Reliability (%)	
January	7.73
February	5.31
March	11.27
April	18.55
May	12.59
June	15.50
July	55.03
August	52.97
September	27.32
October	7.85
November	4.61
December	2.32

Choki Monthly Reliability (%)	
January	7.68
February	5.28
March	11.20
April	18.43
May	12.50
June	15.41
July	54.91
August	52.81
September	27.14
October	7.79
November	4.57
December	2.30



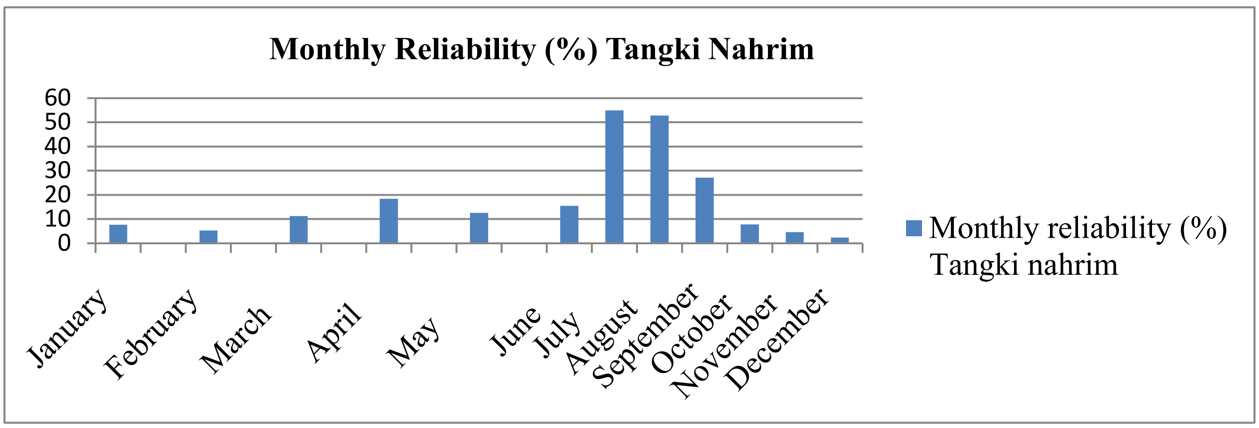


Fig 6.1: Monthly Mean Rainfall Reliability (%) Tangki Nahrim for Chacha and Choki School

To analyze the performance of tanks in both schools with Tangaki Nahrim software different variables are used which are tank sizes, roof areas and number of users to inspect parameters like percentage of time tank empty, storage efficiency, coefficient of rain water utilization and reliability ratio; the following paragraphs discuss in detail the effect of changing these variables result to the parameters.

- **Effect of varying tank size on different parameters with constant roof area and user group in Chacha and Choki School schemes**

Figure 6.2 and 6.3 shows the reliability that can be achieved under different random tank size with constant roof area and number of user varies from 9.2 to 10%, since reliability is (delivered vol. / demand vol.) reliability does not increase significantly by increasing tank volume.

The minimum percentage of time tank empty cannot be achieved by increasing tank size with constant roof area and number of users so it‟s does not decrease significantly beyond 97% and 96% in Chacha and Choki School respectively, this confirmed us the demand is very high to supply with these schemes.

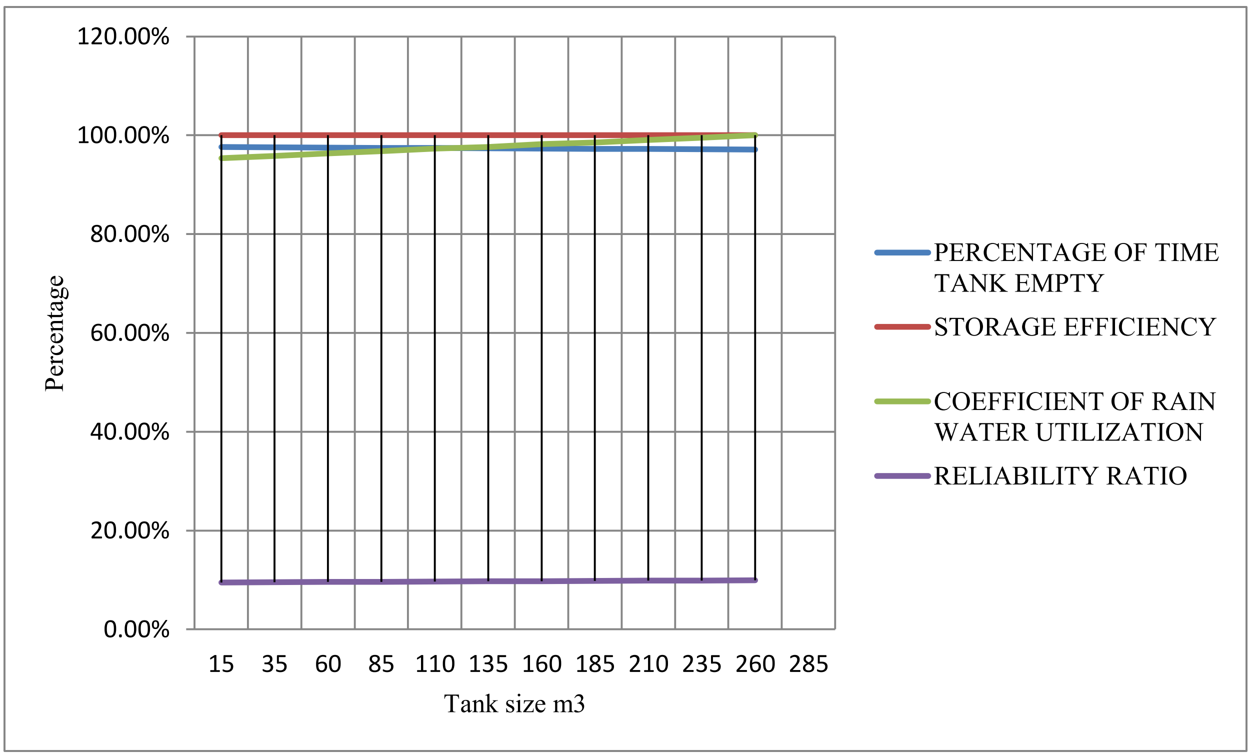


Fig 6.2: Effect of changing tank size on different parameters with constant roof area and user group in Chacha School

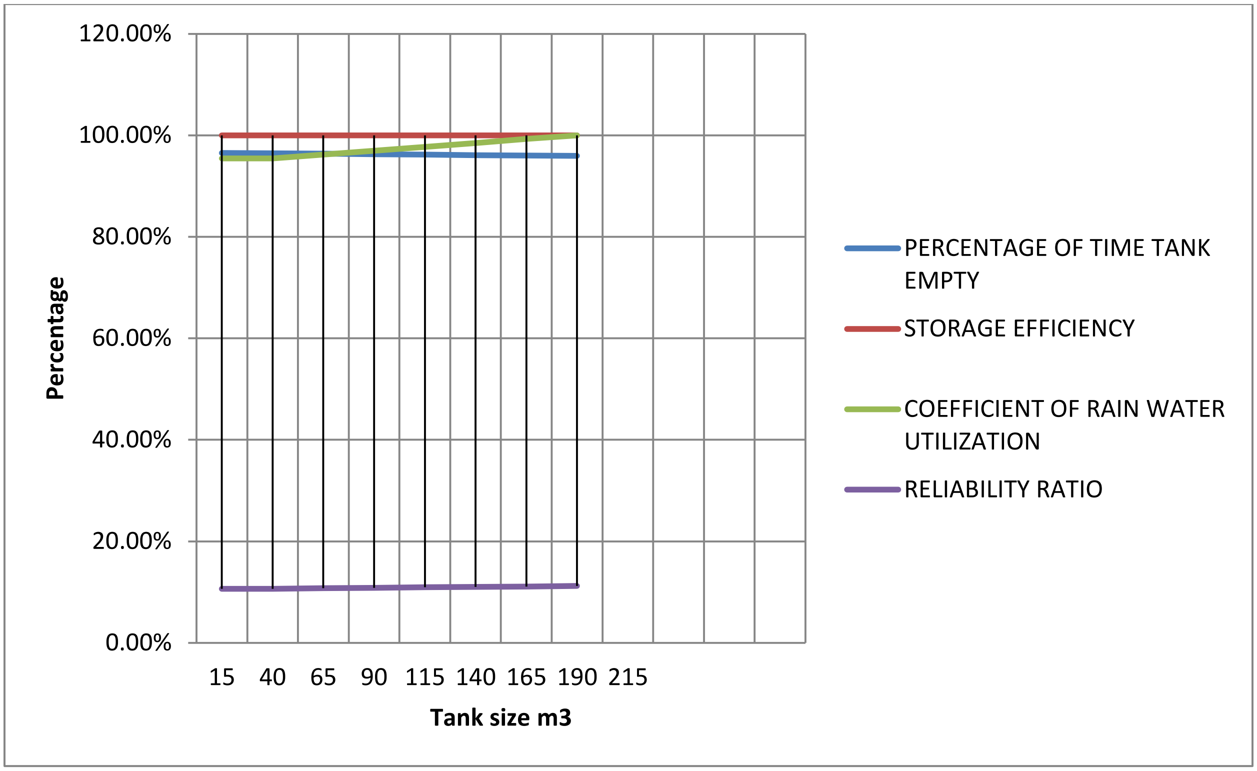


Fig 6.3: Effect of changing tank size on different parameters with constant roof area and user group in Choki School

- **Effect of varying number of users on different parameters with constant roof area and tank size in Chacha and Choki School schemes**

The reliability that can be achieved under different random number of users with constant tank size and roof area size varies from 0 to 100%; In general simulation figure 6.4 and 6.5 shows the maximum 100% reliability can be achieved with 37 users in Chacha School and 15 users for Choki School whereas, the percentage of time tank empty can decrease with decreasing number of users and we can achieve 0% percentage of time tank empty for 37 users in Chacha School and 19 users for Choki School considering constant tank size and roof area.

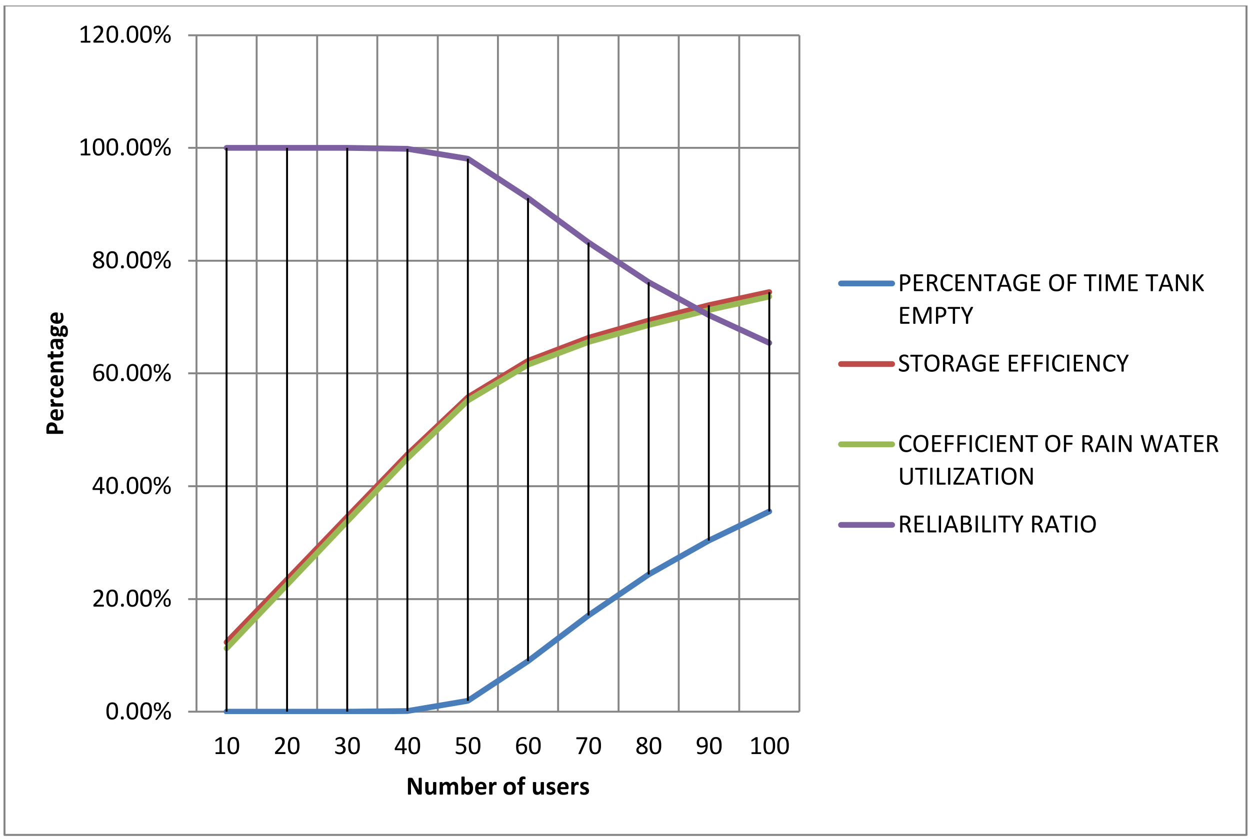


Fig 6.4: Effect of changing number of users on different parameters with constant roof area and tank size in Chacha School

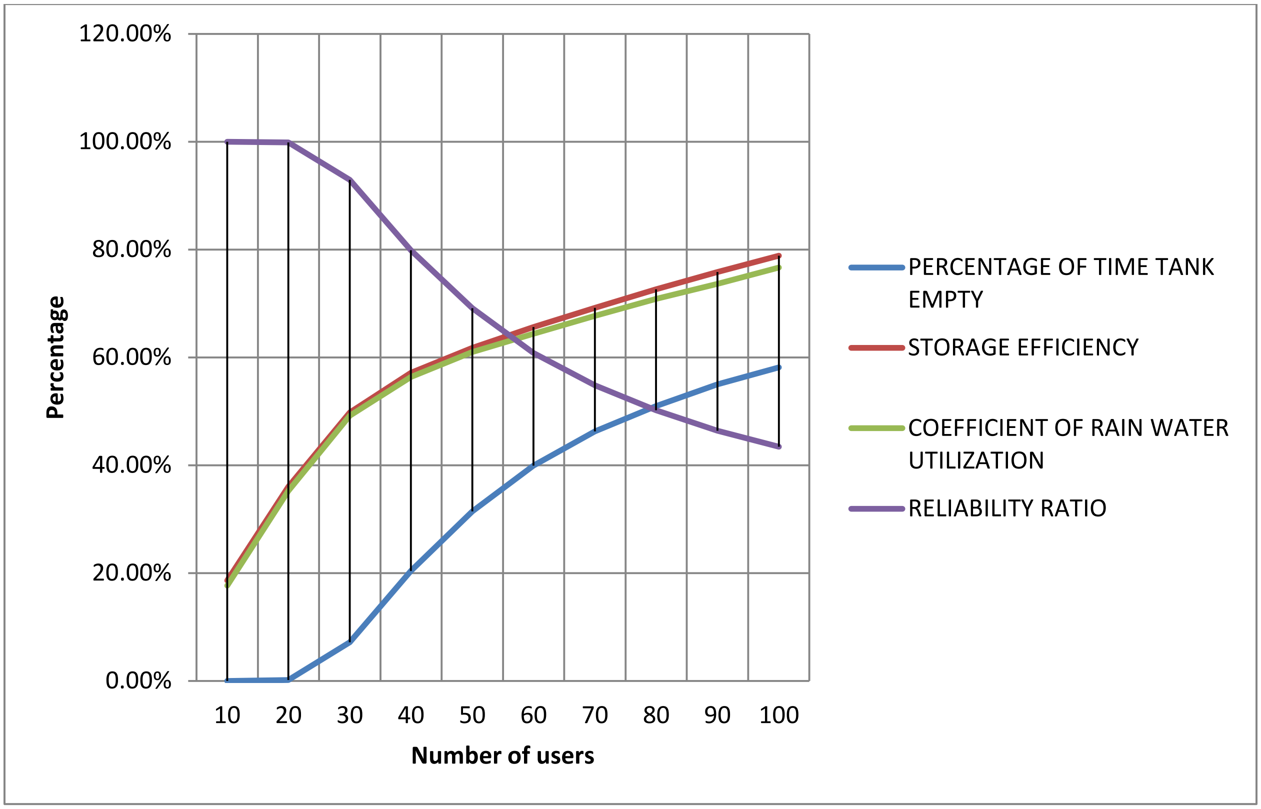


Fig 6.5: Effect of changing number of users on different parameters with constant roof area and tank size in Choki School

- **<u>Effect of varying roof area size on different parameters with constant tank size and user group in Chacha and Choki School schemes.</u>**

The reliability that can be achieved under different random roof area size with constant tank size and number of user showed in figure 6.6 and 6.7 below varies from 0 to 55% in Chacha, 0 to 45% in Choki since the tank size is constant, after 55% in Chacha and 45% in Choki reliability was not changed significantly.

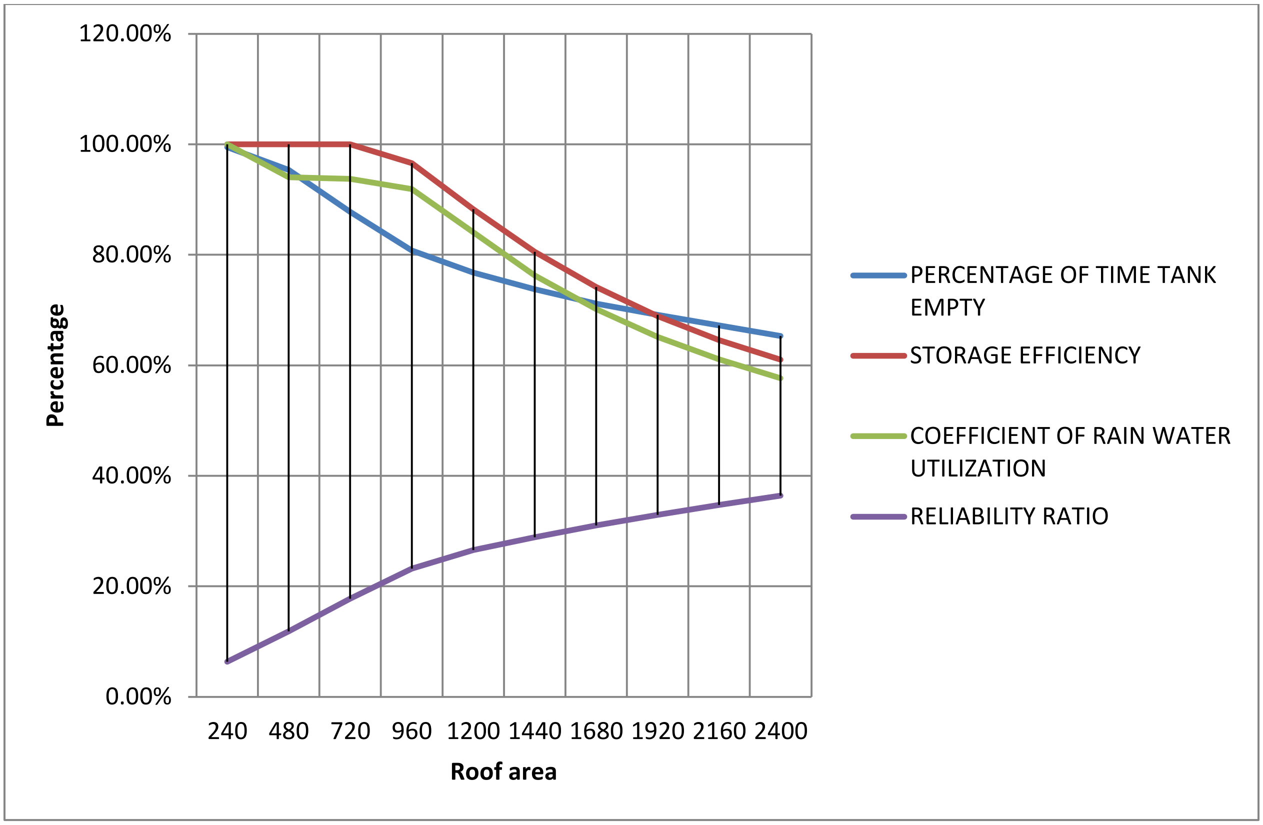


Fig 6.6: Effect of changing roof area size on different parameters with constant tank size and user group in Chacha School

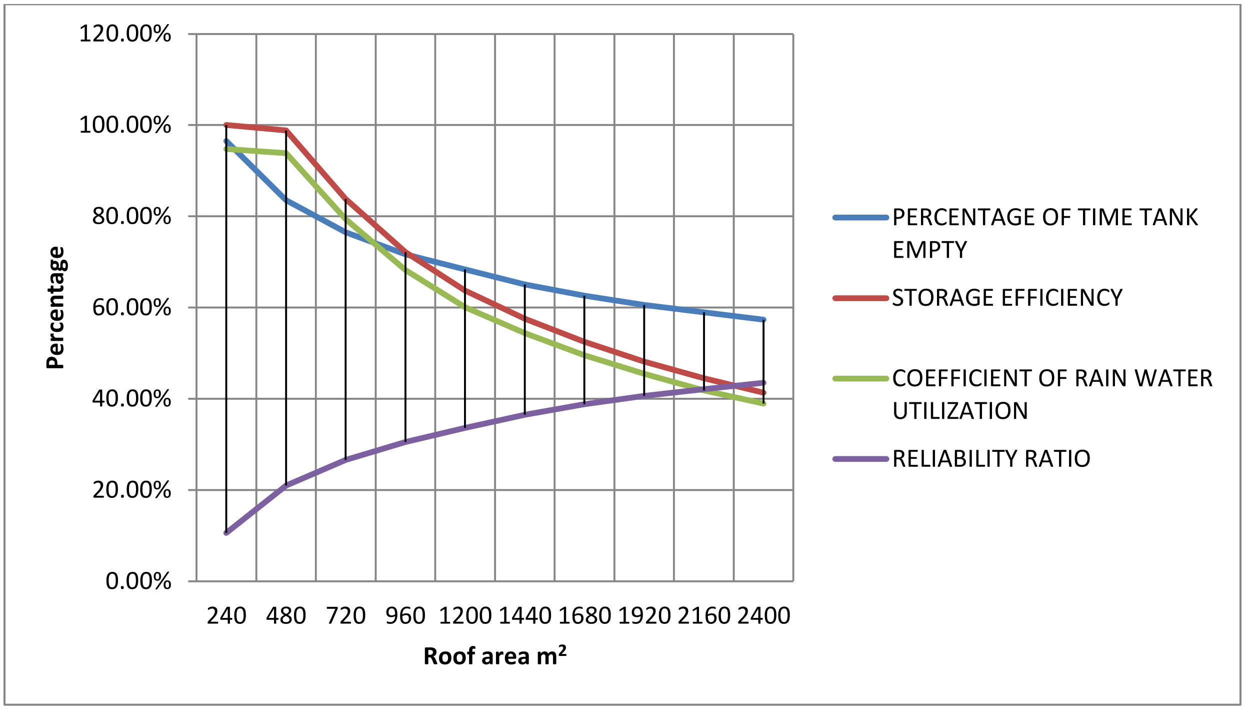


Fig 6.7: Effect of changing roof area size on different parameters with constant tank size and user group in Choki School

6.1.4 <u>Percentage of time tank empty</u>

To verify Tangaki Nahrim software simulation result on percentage of time tank empty we can consider Chacha School Scheme which has 378 m^2 roof catchment and 893 users with daily 10 lit/person demand to satisfy these demand the users need minimum of daily 23.63mm of rainfall amount all over the year.

Roof area * Daily rainfall supply = users * Daily demand

$$378\ m^2 * 0.02363m = 893\ users * 0.01m^3/user$$

But from 17 years or 6209 daily rainfall record its only 138 days (check appendix 4) that had record of 23.63mm or more and by considering more rain fall data to the next day demand we had 151 days satisfied water supply and on the remaining 6058 days the tank not even waits 24 hours to be empty hence we can concluded that the tank is empty 97.50% of the time.

Percentage of time tank empty = (Times with unsatisfied demand (days) / Total simulation time (days)) *100%

Percentage of time tank empty = (6058days / 6209days) * 100% = 97.50%

The analysis of rainfall characteristics is the core of the hydrological design of rainwater harvesting system. In general, the definition of a „dry day‟ is zero rainfall per day taking threshold value of zero rainfall. However, different authors have used different threshold values to define a dry day. Rainfall amount 0.1 mm per day was used as the threshold because it is often used with respect to the usual precision of rain gauges. Some studies employed a threshold of 1.0 mm, on the assumption that rainfall less than this amount is evaporated off directly. Few authors employed 1.5 mm and 2 mm as threshold values respectively in order to remove any events featuring less rainfall. The use of longer threshold eliminates the excessive weight that some isolated rainy days with small amounts have in breaking the long dry spell. However, the threshold value should not be selected in a subjective manner, but it should be related to the type of the application so for this research purpose to estimate longer dry period we choose minimum rainfall amount threshold of 0 mm, assuming there is no significance evaporation loss on the roofs and as we see persistence of rainfall distribution on table 6.9, length of wet and dry spells, almost 69% of the time schemes had zero rainfall amount, mean length of wet spells only had 3.37 days so as to be the reasons for maximum percentage of time tank empty.

Table 6.9: Characteristics of dry and wet spell length of rainfall data

	Dry days	Wet days
Total number of days	4240	1948
General probability (%)	68.52	31.48
Mean length of spells(days)	7.08	3.37
Maximum length of spells(days)	100	61

To analyze users‟ DRWH usage percentage we compared practical site data yearly condition of water in the tank (%) time with ideal Tangaki Nahrim software result.

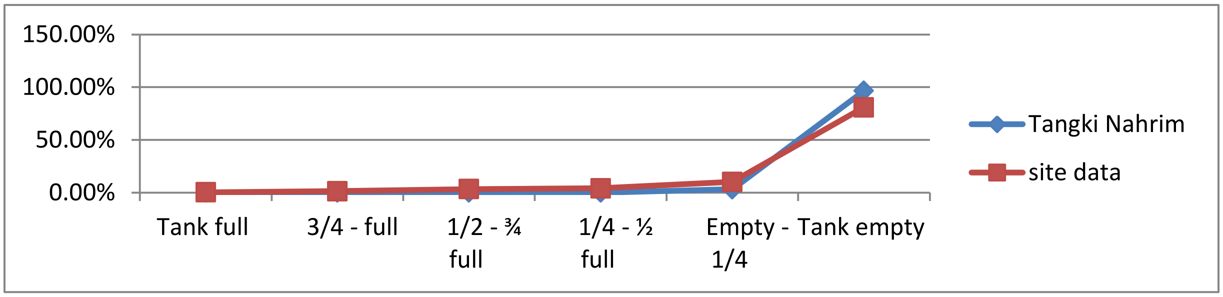
Table 6.10 displays simulation of ideal percentage of time tank empty or full at the existing site condition with different tank water levels, when we analyze tank empty condition it was 97.50% and 96.53% of the time for Chacha and Choki school schemes respectively whereas, practical site data formulated through questioners showed us somewhat below these figures which was 23.25% and 15.3% smaller than ideal Tangaki Nahrim simulation result in Chacha and Choki School respectively hence we may argued that the user supplied their demand with other alternatives and not fully trust the system even in wet seasons.

Tanks ideal water holding condition (%) showed as only 3% of the time was the tank reached the empty to full water level stage this validated the tanks were not designed considering high projected population demand, as a result the tanks were usable only in few days of wet season of the year and not permanently supplied the households .

Table 6.10: Comparing yearly condition of water in the tank (%) of time in Chacha and Choki School schemes: (Tangki Nahrim roof water harvesting software result with practical site data result)

Water in tank (%) Time: Chacha(Tangaki Nahrim)	
Tank full	0.00%
3/4 - full	0.03%
1/2 - ¾ full	0.03%
1/4 - ½ full	0.06%
Empty - 1/4	2.30%
Tank empty	97.50%
TOTAL	100%
(Site data collected from Chacha school)	
Tank full	1.91%
3/4 - full	3.56 %
1/2 - ¾ full	4.66%
1/4 - ½ full	6.30%
Empty - 1/4	9.32%
Tank empty	74.25%
TOTAL	100%

Water in tank (%) Time: Choki (Tangaki Nahrim)	
Tank full	0.00%
3/4 - full	0.03%
1/2 - ¾ full	0.03%
1/4 - ½ full	0.07%
Empty - 1/4	3.27%
Tank empty	96.53%
TOTAL	100%
(Site data collected from Choki school)	
Tank full	0.27
3/4 - full	1.36
1/2 - ¾ full	3.28
1/4 - ½ full	4.1
Empty - 1/4	10.13
Tank empty	80.82
TOTAL	100



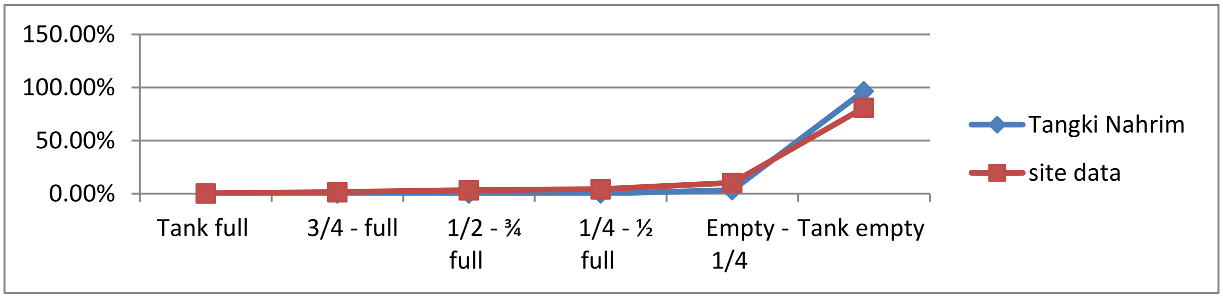


Fig 6.8: Comparing yearly condition of water in the tank (%) Time in Choki School: (Tangki Nahrim rain water harvesting software result with site data)

6.1.5 Reservoir Storage Efficiency

Reservoir storage efficiency is the ability to store and manage water that consumes the least amount of space with little to no impact on performance resulting in a lower total operational cost. Efficiency addresses managing users demand, reducing costs and complexity with limiting risk, so Tangaki Nahrim simulate storage efficiency as follows:-

$$\text{Storage efficiency} = (1- (\text{over flow/inflow}))$$

Figure 6.2 and 6.3 above shows effect of changing tank size on different parameters with constant roof area and user group. Simulation result scores 100% storage efficiency when there is no overflow over the tanks. In our case reservoirs efficiency simulation never showed overflow till 22 m^3 and 17 m^3 in Chacha and Choki schemes respectively (appendix 5).

These displayed results approves designed tank sizes which are (75+10) m^3 in Chacha and 40m^3 in choki School miss considered rainfall runoff amount so that the tank sizes were oversized to increase construction and operational costs.

6.1.6 Quality of Water

Quality of water is one of the basic parameter that affects the performance of DRWH system. The field survey and discussion made with the community show that water collected from the schemes has good quality except some turbidity.

To verify the physical observation three water samples were collected and physical and biological tests were conducted by an authorized institution. The samples are tested in the WWDSE laboratory service. Output of Choki scheme sample lab result shows Turbidity ranges from Trace to 6 NTU; electrical conductivity is from 61 to 95µs/cm; PH ranges from 6.89 to 7.63 and faecal coli form per 100 ml is nil whereas, a sample from Chacha scheme samples lab analysis shows that the PH is 7.09, Turbidity is trace conductivity 75 µS/cm and faecal coliform is nil.

CHAPTER SEVEN

7. Conclusion and Recommendations

7.1 Conclusion

The purpose of this research was to assess and identify technical performance, structural conditions and water quality of DRWH schemes implemented by Water Action in Chacha and Choki School schemes. The research output will contribute to improve the level of services and promotion of DRWH technology in the effort made to improve the low level national safe water supply and sanitation coverage; wherever the technology is a feasible option.

Field observation and discussion with the user community indicate that proper operation and regular maintenances are an ignored aspect in most of the schemes. Gutters have started to fail; distribution boxes are getting damaged; nearly all filters are corroded and out of use; wooden Gutter supports are decayed etc. Damage of Gutter system results significant loss of water due to splashing out of high intensity rainfall and reservoir filling time to be longer; eventually the harvested water may not satisfy the demand.

Some of the design approaches of the major components of DRWH system need to be re-considered. During the survey it is noted that most of the reservoirs never experience over flow or not full. This shows that the demand is much more than the supply. For instance employing Tangaki Nahrim software proves that the existing Chacha School reservoir shall serve only 4 percent of the targeted community.

An effort on optimizing the investment cost of any type of water supply and sanitation project requires a wise engineering consideration. Nevertheless considering cost only may lead to poor judgment and might have some danger. For instance most of the distribution points or water points of the observed schemes are constructed underground to attain gravitational flow from reservoir to the distribution point; in shorter pipe length. However, the approach enable to cut down cost of pipe work the distribution points lacks sufficient drainage system that result stagnant water. Thus, the underground distribution points create a favorable environment for insects breeding.

Site identification of potential roof catchment needs to focus on the existing condition of the building. Some of the schemes are dependent on mud and wood wall buildings or houses that are constructed more than 10 years, on a minimum. A specific site in Terana Asagirt wereda DRWH scheme implemented in Choki School is example for this, which is attached to a 40 m^3 Ferro cement reservoir that cost more than 50,000 Birr. The useful life the school block has gone before implementing the scheme. So during the design or planning exercises it is wise to consider the cost of renovation of the buildings and future site plan changes.

One of the specific objectives of the projects is improving the health situation of the user community; more specifically it benefits children and women as they are vulnerable for water borne and water related diseases. However in all schemes constructed in school compounds has never been giving services to school children. During the field survey it is observed that school children bring water to school for dinking during their stays in the school. This is purely undesirable to the specific objective of the projects.

Moreover Sanitation and Hygiene education and community development are two of the major components of projects. As compared to the water development almost nothing is found on the ground on the promotion of hygiene and sanitation i.e. trained village health communicators and care takers are not providing the expected services to the community.

One of the parameter to evaluate the performance of water supply project is quality of water, therefore the physiochemical and Biological laboratory water quality test result shows that the water is safe for drinking. All samples Faecal Coli form is nil; Turbidity is Trace; PH values ranges 6.89 to 7.63; the reason behind on good water quality is may be that the rainwater is not stored for a longer period of time.

The survey findings and questionnaires feedback from practitioners shows that DRWH is a simple technological option; reliable and controllable sources; gives chemically and bacteriological low risk water; significantly reduced the drudgery of safe water collection for the rural community and has potential of significant financial savings in urban areas. With all these benefits a little has been done on the promotion and implementation of DRWH to solve the very problem of safe water supply both in the rural and urban part of our country.

The ultimate sources of fresh water is rain however information gap among community, water professionals, policy makers, international financers and donors (are more interested for large scale projects and programs) are some of the reasons for the low level promotion and implementation of DRWH. For instance the Ethiopian water resources management policy didn"t point out anything about rainwater harvesting. Growth and transformation plan established in the national water sectored development program indicates that at the end of the transformation plan the country will construct 545 rain water and surface drinking water tankers but, still it would be a challenging task to the ministry to achieve its 15 litres of safe water per person per day in 1.5km radius in rural Ethiopia goal without giving maximum concern for one of the simplest and affordable technological option; DRWH system.

Recently, the government has started promoting and investing significant amount of money on rainwater harvesting for crop production and domestic water supply proposes, which is an encouraging step though more attentions should be given to attain the target.

7.2 Recommendation

Field observation and discussion made with the user community indicate that operation and maintenance of schemes is an ignored aspect. So capacity building through stimulant training to the community, the WatSan committee and the village health communicators/care takers/ are very important steps to sustain the schemes.

Lack of standardization is one of the gaps observed in the most of the schemes. For instance one of the schemes lack splash guard, in one scheme gutters are rectangular in shape and in others they are triangular. So it is recommended to use triangular or semi-circle gutter as their hydraulic efficiency is high. Triangular gutters are very simple if gutters are manufactured on site.

Many research outputs show that provision of first flush devices is found very important to improve the quality of harvested water. Information obtained from the community shows that they are aware of the importance of the devices but the operation is difficult. This is because the first 2-3 minute rainwater is expected to be diverted manually i.e. diverting the gutter from the inlet.

But at the start of the rain it might be rare case where by people to be at home or might be at slept. So for such small community water supply scheme the use of a constant volume first flush device is recommended.

The other important component of DRWH scheme is the filter. Nearly all of the reservoirs and conveyance pipes had been fixed with wire mash filter. But during the survey it is observed that all of the filters are damaged due to corrosion. So the study recommends using plastic filters or sand filters to improve the services age of the filter material.

The woreda water desk is one of the responsible governmental institution need to closely follow up the DRWH schemes and provide the necessary technical and financial support to the water management committee or board. Discussion made with the woreda water desk shows that they are giving more support for large scale water schemes like boreholes than the DRWH schemes. So it is recommended to build the capacity of the woreda water desk staffs through provision of technical training on promotion of DRWH technology.

Some of the design approach and criteria exercised for these schemes needs to be re-considered. For instance tank sizes, which is the most important and expensive facility in the promotion of DRWH system are determined based on an average annual rainfall that does not consider the rainfall pattern. The method is used only for preliminary works and gives a size that does not fit with the demand, so the research recommend to use the most popular online software (freely available) like “Tangaki Nahrim” or “Simtanka” to determine the optimal size of tanks or reservoirs.

Site identification or identification of potential roof catchment needs to focus on the existing condition of the building in general, so failure of the building is totally to mean failure of the system or the services rendered. So during the planning design it is wise to consider cost of renovation of the building.

The promotion of DRWH in general is not a cheap option but in areas where both surface and subsurface water resources potential is poor in terms of quantity and it will be a best option. DRWH could be made a cheapest option if promoter has used innovative knowledge to cut down cost of construction of the various components of the system.

Awareness creation for water professionals, policy makers, international financers and donors through workshops, meetings, publications such as brochures and the like are very important works to be under taken to improve the promotion of DRWH in the effort made to improve the low level safe water supply of the country. In these regard a number of effort has been made but future study should consider larger sample size, geography representation, climate, culture, religion and other parameters that affect the water demand and supply situation. Moreover the study should also need to consider other technical performances elements that are not considered in this study such as social aspect and financial viability.

7.3 Future Research Concepts

Listed below are other ideas for research that could be done to support current work being done in the research of DRWH as a sustainable method of harvesting rainwater for domestic use:-

- Review other existing local methods of water harvesting to be promoted.
- Include detail economic assessment of DRWH in light of physical, social, and technical standpoint.
- Research methods on operation and management to maximize life span of DRWH schemes.
- Research methods on ease of DRWH schemes construction to minimize time and costs.

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APPENDIXES

Appendix 1: Geographic position of DRWH Schemes

No	Description	GPS Location	Elevation meters (amsl)	Remarks
1	Chacha School, Hh 10 m3 Ferro cement Reservoir	N-08^0 55.118' E-039^0 31.638'	1721	
2	Chacha School, Hh 75 m3 Masonry Ferro cement Reservoir	N-08^0 55.418' E-039^0 31.787'	1711	
3	Choki School, Hh 40 m3 Ferro cement Reservoir	N-08^0 51.691' E-039^0 29.84'	1693	

Appendix 2: Mean Monthly Rainfall, Debre Birhan station

Element: Monthly Rainfall (mm)
Region: North Shoa
Station: Debre Birhan

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1997	29.5	4	41.2	42.6	25	88.5	157.7	161.4	20	84.4		
1998	9.6	13.2	0	44.1	17.8	13.5	275.8	198.7	38.6	2	0	0
1999	6.9	0	5.1	2.8	4.5	46.7	275.2	238.9	15.5	13.8	1.4	0
2000	0	0	25.9	44.9	0	45.8	242	253.4	48.3	0.4	1	2
2001	0	0	47.9	18.8	29.4	34.8	315.9	122.6	10.4	0.3	0	0
2002	0	28	24.7	21.7	10.5	19	211.9	171.7	19.1	0	0	8.4
2003	15.6	36.3	60.2	85.7	2.4	86.1	253.7	152.6	49.4	0	0	0
2004	24.4	0	29.7	61.1	0	99	298.7	158.7	58.5	4.3	11.8	0
2005	34.3	4.5	16.4	49.5	40.5	76.1	198.5	173.8	49.2	0.5	1.5	0
2006	17.3	24.4	61	17.3	7.9	35.2	269.1	115	17.5	6.6	0	
2007	2	1.2	8.9	36.4	13.6	93.2	236.1	304.5	22.3	2.4	0	0
2008	0.3	0	0	3.8	32.6	43.8	336.3	89.6	23.1	4.2	0	0
2009	47.2	0	8.1	0	14.9	13.7	313.1	172.3	13.3	18.7	1.2	18.5
2010	47.2	15.9	29.9	100.2	12.8	29.1	197.8	177.7	15.7	0	8.5	3.9
2011	0.3	6.5	58.4	26.1	70.3	73.4	315.7	188.7	41.9	0	2.8	0
2012	0	0	5.2	52.5	10.3	56	250.7	245.5	49	0	0	0
2013	0.8	0	48.4	19.3	5.2	40.1	226.7	137.6	10.4	0	11.5	0

Appendix 3: Questionnaire

Addis Ababa University
Questionnaires to Conduct Technical Investigation of Rural Schools Roof Water Harvesting Schemes
(The Case of Chacha and Choki school schemes, in Amhara Region North Shoa Zone Angolalla Terana Asagirt Wereda)
(The Case of Water Action; Indigenous NGO):
(Field findings to be collected by researcher)

Section I: Water Supply

I. General Information:

Project Name: ....

Region: ....

Zone: ....

Woreda: ....

II. Population Information:

Number of users Hhs/People/ ___________________

III. Structural Situation:

1. When was the building/house/ constructed? _______________________

2. Existing condition of the house/store/school/church etc.

Good ☐ Fair (Star damage of wall, Roof, foundation) ☐ Poor (Close to damage) ☐

3. Type of the indwelling/water harvesting building and its roofing:

Hollow block wall with CIS roof ☐ Mud block wall and CIS roof ☐

CIS wall and roof ☐

4. When was the scheme constructed and start giving services? _________________

5. What is the estimated/available/ capacity of tank or Reservoir? _______________

6. Is the scheme/in general/ functional? Yes ☐ No ☐ If No, please specify the estimated date and reason____

7. Is there any crack on the wall, roof and bottom slab of the tank/reservoir?

Yes ☐ No ☐

If yes, where is the crack formed?

On the Wall ☐ On the Roof ☐ On Bottom Slab ☐ All ☐

If yes, how do you classify the case? Minor crack ☐ Major crack ☐ It does not Store water for longer ☐

7. What is your assessment on the existing condition of the down pipes?

Good ☐ Fair (loss connection and Star leakage) ☐ Poor (doesn"t lead water to tank) ☐

8. What is your assessment on the existing condition of the collection chambers?

Good ☐ Fair (minor crack, damaged cover slab) ☐ Poor (Major crack, damaged cover Slab and leakage) ☐

9. Is the scheme or the facility maintained before? Yes ☐ No ☐

If yes, when and by whom?

____

Section II: Sanitation:

1. Is there any contamination of the Roof catchments area? (Example Plants, Birds dropping, foliage, dust etc.) Yes ☐ No ☐

2. Are the Gutters, which collect water from the roof dirty? Yes ☐ No ☐

3. Is there any defect at the tank intake? (Example lack of filter) Yes ☐ No ☐

4. Is there any other point of entry water to the Reservoir/tank which is not properly covered?

Yes ☐ No ☐

5. Is there any defect on the roof (top of the tank) which could let in water in to the tank?

Yes ☐ No ☐

6. Is the tap leaking or otherwise defective? Yes ☐ No ☐

If yes, how? ______________________________________

Do people collect water from the tank? ______________________________________

7. Is the soak away pit under the tap non-functional or dirty? Yes ☐ No ☐

8. Is the water collection point has adequate drainage? Yes ☐ No ☐

If yes, describe the situation? ____

9. Is there any sources of pollution around the reservoir/tank or water collection areas?

Yes ☐ No ☐ If yes indicate the type ?__________________________

Section III: Water Quality:

1. Are people using the Water? Yes ☐ No ☐ If No, Specify the reason____

2. Is the harvested water has odor? Yes ☐ No ☐ If Yes, What do people expected the causes of the smell_____________________________________

3. Is the harvested water has color? Yes ☐ No ☐ If Yes, What do people expected the causes of the color_____________________________________

4. Is there any water quality tests conducted after the facilities are put in place ?

Yes ☐ No ☐ If yes, When and by whom __________________________________

Section Iv: Quality of services:

1. Is the scheme serves peoples/ population/ that were not considered in the design or in the plan? Yes☐ No ☐ If yes; please specify the number of hhs ______________________

2. Is there any new water supply scheme implemented in the project area that shall contribute to the provision of access for the potable water supply? Yes ☐ No ☐

If yes, Please describe the type and when it is constructed

____

3. How long the harvested water in the tank serves the beneficiaries? Number of days or weeks or months in a year:____

4. What is / are the alternative source of domestic water supply for the people/beneficiary / right after the water in the reservoir or the tank depleted?

____

5. Had it been happen that the reservoir/tank are full and overflow? _________________

6. Is there any duplication of such effort either at hh or institutionally level?

   If yes, by whom (institution) and how many are there? _________________________

Interviewer by ____

Signature: _______ Date _______________________

Addis Ababa University
Technical Investigation of Rural Schools Roof Water Harvesting Schemes
(The Case of Chacha and Choki school schemes, in Amhara Region North Shoa Zone Angolalla Terana Asagirt Wereda)
(The Case of Water Action; Indigenous NGO):
(Views and comments collected from practitioners)

1. How do you define domestic roof water harvesting (RDWH)?

2. Why Roof water harvesting?

3. Do you believe that a little has been done on the promotion of roof water harvesting?

   If yes, what are your assessments for the major problems on the promotion of roof water harvesting? Please describe in detail.

4. Is DRWH a cheaper option? Please describe your opinion.

5. Is the communal or hh DRWH technical are efficient or sustainable, and why?

6. Have you been heard any information about the quality/negative/ of the harvested water?

7. Please include any information based on your practical experiences

Appendix 4: Effect of varying roof area size on different parameters with constant tank size and user group in Chacha and Choki School schemes (Tangaki Nahrim Simulation result).

CHACHA SCHEME

Roof AREA(m^2)	PERCENTAGE OF TIME TANK EMPTY	STORAGE EFFICIENCY	COEFFICIENT OF RAIN WATER UTILIZATION	RELIABILITY RATIO
240	99.45%	100.00%	100.00%	6.34%
480	95.35%	100.00%	94.00%	11.87%
720	87.78%	100.00%	93.76%	17.77%
960	80.77%	96.56%	91.90%	23.22%
1200	76.78%	88.21%	84.07%	26.55%
1440	73.75%	80.54%	76.24%	28.89%
1680	71.14%	74.18%	70.18%	31.03%
1920	69.11%	68.89%	65.15%	32.92%
2160	67.19%	64.54%	61.05%	34.70%
2400	65.31%	60.99%	57.65%	36.41%

CHOKI SCHEME

Roof AREA(m^2)	PERCENTAGE OF TIME TANK EMPTY	STORAGE EFFICIENCY	COEFFICIENT OF RAIN WATER UTILIZATION	RELIABILITY RATIO
240	96.53%	100.00%	94.79%	10.60%
480	83.50%	98.87%	93.82%	20.98%
720	76.49%	83.81%	79.39%	26.63%
960	71.70%	72.16%	68.24%	30.52%
1200	68.34%	63.73%	60.12%	33.61%
1440	65.09%	57.55%	54.38%	36.48%
1680	62.59%	52.50%	49.58%	38.80%
1920	60.56%	48.14%	45.46%	40.66%
2160	58.98%	44.52%	41.83%	42.09%
2400	57.32%	41.34%	38.93%	43.53%

Appendix 5: Effect of varying tank size on different parameters with constant roof area and user group in Chacha and Choki School schemes (Tangaki Nahrim Simulation result).

CHACHA SCHEME

tank size (m^3)	PERCENTAGE OF TIME TANK EMPTY	STORAGE EFFICIENCY	COEFFICIENT OF RAIN WATER UTILIZATION	RELIABILITY RATIO
15	97.65%	99.86%	94.86%	9.44%
35	97.60%	100.00%	95.34%	9.48%
60	97.55%	100.00%	95.83%	9.53%
85	97.50%	100.00%	96.31%	9.58%
110	97.46%	100.00%	96.80%	9.63%
135	97.41%	100.00%	97.29%	9.68%
160	97.37%	100.00%	97.61%	9.71%
185	97.31%	100.00%	98.18%	9.77%
210	97.26%	100.00%	98.56%	9.80%
235	97.21%	100.00%	99.05%	9.85%
260	97.17%	100.00%	99.53%	9.90%
285	97.12%	100.00%	100.00%	9.95%

CHOKI SCHEME

tank size (m^3)	PERCENTAGE OF TIME TANK EMPTY	STORAGE EFFICIENCY	COEFFICIENT OF RAIN WATER UTILIZATION	RELIABILITY RATIO
15	96.61%	99.97%	94.03%	10.51%
40	96.53%	100.00%	95.45%	10.67%
65	96.44%	100.00%	95.45%	10.67%
90	96.36%	100.00%	96.20%	10.76%
115	96.27%	100.00%	96.97%	10.84%
140	96.18%	100.00%	97.74%	10.93%
165	96.10%	100.00%	98.50%	11.01%
190	96.01%	100.00%	99.27%	11.10%
215	95.93%	100.00%	100.00%	11.18%

Appendix 6: Effect of varying number of users on different parameters with constant roof area and tank size in Chacha and Choki School schemes (Tangaki Nahrim Simulation result).

CHACHA SCHEME

No of user	PERCENTAGE OF TIME TANK EMPTY	STORAGE EFFICIENCY	COEFFICIENT OF RAIN WATER UTILIZATION	RELIABILITY RATIO
10	0.00%	12.34%	11.26%	100.00%
20	0.00%	23.45%	22.51%	100.00%
30	0.00%	34.56%	33.77%	100.00%
40	0.14%	45.61%	44.96%	99.85%
50	1.95%	55.76%	55.20%	98.06%
60	8.99%	62.23%	61.55%	91.12%
70	17.10%	66%	65.59%	83.24%
80	24.32%	69%	68.60%	76.17%
90	30.38%	72%	71.24%	70.32%
100	35.51%	74%	73.63%	65.41%

CHOKI SCHEME

No of user	PERCENTAGE OF TIME TANK EMPTY	STORAGE EFFICIENCY	COEFFICIENT OF RAIN WATER UTILIZATION	RELIABILITY RATIO
10	0.00%	18.63%	17.64%	100.00%
20	0.15%	35.98%	35.23%	99.85%
30	7.14%	49.79%	49.16%	92.88%
40	20.36%	57.11%	56.37%	79.87%
50	31.42%	61.76%	60.96%	69.10%
60	39.94%	65.60%	64.37%	60.81%
70	46.25%	69.19%	67.68%	54.80%
80	50.96%	72.60%	70.81%	50.17%
90	55.01%	75.79%	73.62%	46.37%
100	58.16%	78.84%	76.63%	43.43%

Appendix 7: Daily rainfall records that fully supply or exceed daily demand of the school community within 20 years period.

Year	RF (mm)(date)	RF (mm)(date)	RF (mm)(date)	RF (mm)(date)	RF (mm)(date)	RF (mm)(date)	RF (mm)(date)
97	26.6(July.7)	31.6(July.27)	25.8(Aug.15)	24.5(Aug.16)	29.8(Aug.18)	25.2(Aug.30)	
98	27.2(July.8)	27.2(July.20)	24.5(July.21)	30.2(July.23)	26.3(Aug.27)		
99	28.7(July.11)	42.4(July.15)	28.8(July.29)	45.7(Aug.4)	24.4(Aug.6)	34.2(Aug.11)	26.3(Aug.21)
00	41.1(July.8)	30.3(July.9)	33.6(July.12)	31.5(July.27)	30.1(Aug.11)	43.8(Aug.12)	31(Aug.13)
	30.5(Aug.25)						
01	30.1(July.13)	24.7(July.16)	38.2(July.23)	23.7(July.26)	23.5(July.28)	25.4(Aug.1)	24(Aug.3)
	31.3(Aug.8)	31(Aug.9)					
02	34.3(July.19)	31.3(Aug.2)	28.4(Aug.13)	40.6(Sept.8)			
03	26.1(July.10)	36.7(July.13)	28.7(July.27)	23.6(July.29)	25.3(Aug.1)	47.8(Aug.7)	45.2(Aug.29)
04	32.5(April.4)	23.6(Jun.18)	30.4(Jun.21)	45.6(July.11)	29.8(July.14)	31.7(July.19)	27.6(Aug.1)
	31.8(Aug.7)	41.3(Aug.12)	31.2(Aug.15)				
05	27.6(July.6)	39.7(July.10)	46.2(July.17)	29.6(July.23)	26.4(July.30)	27.2(Aug.9)	31.5(Aug.21)
	28.5(Aug.31)						
06	41.2(Aug.5)	29.5(Aug.6)	42.5(Aug.9)	31.3(Aug.11)	26.5(Aug.12)	43.5(Aug.23)	25.8(Sept.1)
07	24.2(Feb.1)	24.6(Jun.21)	28(July.26)	29.7(July.28)	26.2(July.30)	33.7(Aug.5)	29.7(Aug.17)
	57.2(Aug.23)	27.5(Aug.27)	25.5(Aug.31)				
08	27(April.6)	50.4(July.11)	24.3(July.19)	27.4(July.20)	25.6(July.21)	41(Aug.. 6)	27.2(Aug.. 8)
	34.5(Aug.. 9)	32.2(Nov. 6)					
09	24.6(Jan.31)	59.5(July.14)	25.4(July.15)	25.6(July.21)	47(July.23)	30.8(July.29)	28.1(Aug.14)
10	24.6(Jan.31)	26.3(Apr.13)	24.8(July. 5)	25(July.19)	28.3(July.21)	60(Aug. 3)	27.3(Aug. 4)
	27.2(Aug. 9)	46(Aug.12)	28.3(Aug.15)				
11	37.8(May. 1)	47(June.13)	29.7(July.5)	25.2(July.18)	38.5(July.25)	25.6(July.29)	35.3(July.30)
	84.3(July.31)	27(Aug. 5)	26(Aug. 9)	27.5(Aug.16)			
12	27.6(may 6)	25(July. 3)	33(July. 15)	24.5(July.16)	24(July. 22)	32.5(July.31)	34(Aug. 2)
	24(Aug. 3)	27(Aug. 4)	24.2(Aug.11)	25.4(Aug.13)	31.5(Aug.17)	25.7(Aug.30)	
13	34.5(July.10)	25.5(July.15)	27.2(July.19)	29.5(July.24)	29.7(July.29)	24.4(Aug.19)	31.2(Sept. 6)