Public Water Corporation

MIWR – GONU

MWRI - GOSS

Technical Guidelines
for the Construction and Management of
Protected Springs and Roof Water Harvesting

A Manual for Field Staff and Practitioners

April 2009

DEVELOPED IN PARTNERSHIP WITH

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Ministry of Irrigation and Water Resources – Government of National Unity

Foreword

Significant progress in the provision of water and sanitation services in Sudan has been achieved in the last few years. This is attributed to the increased access to many remote villages as a result of the three major peace agreements, the Comprehensive Peace Agreement (CPA) between north and south Sudan, the Darfur Peace Agreement (DPA) and the Eastern Sudan Peace Agreement (ESPA), that were signed in 2005 and 2006 respectively. This access has allowed the Ministries of Irrigation and Water Resource (MIWR) of the Government of National Unity (GoNU), state governments and sector partners (including NGOs and the private sector) to expand water and sanitation services in many areas. This prioritizing of the expansion and sustainability of water and sanitation services in urban and rural areas throughout the county, including to the nomadic population has resulted in a steady annual increase in water and sanitation coverage for the citizens of Sudan.

With this expansion in implementation, the MIWR recognized the need to harmonize the various methodologies utilized by the various actors in the implementation of water and sanitation interventions. It was agreed that this could be best achieved through the development and distribution of Technical Guidelines, outlining best practices for the development of the 14 types of water supply and sanitation facilities in the Sudan. These Technical Guidelines, compiled in a systematic manner will undoubtedly set standards and provide guidance for all water and sanitation sector implementing partners.

The MIWR of the GoNU of the Sudan is grateful to UNICEF, Sudan for financial and technical support in the preparation of the Technical Guidelines.

I believe these Technical Guidelines will go a long way to improving WES sector programmes, allowing for scaling up implementation of activities towards achieving the MDG goal for water supply and sanitation in Sudan.

Minister
Ministry of Irrigation and Water Resources
Government of National Unity, Khartoum

Date ………………………………………

Foreword

The historic signing of the Comprehensive Peace Agreement (CPA) in January 2005, culminated in the establishment of an autonomous Government of Southern Sudan (GOSS) and its various ministries, including the Ministry of Water Resources and Irrigation (MWRI). The CPA has enabled the GOSS to focus on the rehabilitation and development of the basic services. The processing of the Southern Sudan Water Policy within the framework of the 2005 Interim Constitution of Southern Sudan (ICSS) and the Interim National Constitution (INC) was led by the MWRI. This Water Policy is expected to guide the sector in the planning and monitoring of water facilities during implementation. The Water Policy addresses issues like Rural Water Supply and Sanitation (RWSS) and Urban Water Supply and Sanitation (UWSS). The Southern Sudan Legislative Assembly (SSLA) of GOSS approved the Water Policy of Southern Sudan in November 2007.

The importance of developing effective water supply and sanitation services is universally recognized as a basis for improving the overall health and productivity of the population, and is particularly important for the welfare of women and children under five. Considering the current low coverage of safe drinking water supply and basic sanitation facilities as a result of the protracted civil war in the country during the last five decades, there are enormous challenges ahead. With the unrecorded number of IDPs and returnees that have resettled in their traditional homelands and the emergence of new settlements/towns in all ten states of SS, the demand for water and sanitation services is immense. There is need for implicit policies, strategies, guidelines and manuals to ensure provision of sustainable supply of quality and accessible water and sanitation services.

The preparation of these WES Technical Guidelines at this stage is very timely, as it enables us to further develop our strategies and prepare action plans for the implementation of the Water Policy. It will also allow us to strengthen existing best practices as well as to test new experiences that will create room for future development.

During the development and finalization of these Guidelines for water supply and sanitation facilities, we have consulted WASH sector partners at State level and partner non-government agencies through successive consultative meetings, and appreciate their contribution, which has assisted in finalizing these documents.

The MIWR of the GOSS is thankful to UNICEF, Juba for financial and technical support for the preparation of these Technical Guidelines.

We call upon our WASH sector partners to give us their continuous feedback from the field for the improvement of these Guidelines. We believe that successful implementation and future sustainable service provision will depend on effective coordination and close collaboration among all partners including government, non-government and beneficiary communities.

Mr. Joseph Duer Jakok,
Minister of Water Resources and Irrigation
Government of Southern Sudan, Juba
Date ……………………………………….

Acknowledgements

Special thanks go to Mr Mohammed Hassan Mahmud Amar, Mr Eisa Mohammed and Mr Mudawi Ibrahim, for their directions on GONU's sector policy; Engineer Isaac Liabwel, on GOSS's water policy; Mr Sampath Kumar and Dr. Maxwell Stephen Donkor, for their direction on the WASH sector from the UNICEF perspective, and for the provision of relevant documents & information, and facilitating & organizing a number of forums to discuss draft documents.

The author would also like to thank WES and UNICEF staff of North Darfur, North Kordofan, South Kordofan, Sinnar, Gedaref, Kassala, Red Sea and Blue Nile States; the staff of DRWSS, and UWC in Central Equatoria, Western Bahr el Ghazal, Warap and Upper Nile States; and the staff of UNICEF Zonal Offices responsible for the arrangement of meetings with sector partners and successful field trips to the various facilities.

Many thanks to Emmanuel Parmenas from MWRI, and Mr Mohammed Habib and Mr Jemal Al Amin from PWC, for their contribution in collecting documents and information at the national and state levels, facilitating field trips and contacting relevant persons at state level and to the latter two for their support in translating documents and information from Arabic into English.

The completion of this document would not have been possible without the contributions and comments of staff of SWC, PWC, MIWR, MCRD, MWRI, MOH in GONU, MAF, MARF, MOH MHLE, MWLCT and SSMO in GOSS, UNICEF, National and International NGOs like Oxfam GB, Pact Sudan, SNV, SC-UK, and Medair, and review workshop participants at state and national levels and members of technical working groups.

Acronyms

CPA	**- Comprehensive Peace Agreement**
DPA	**- Darfur Peace Agreement**
ESPA	**- Eastern Sudan Peace Agreement**
GONU	**-Government of National Unity**
GOSS	**-Government of Southern Sudan**
MCRD	**-Ministry of Cooperatives and Rural Development of GOSS**
MIWR	**-Ministry of Irrigation and Water Resources of GONU**
MWRI	**-Ministry of Water Resources and Irrigation of GOSS**
PWC	**- Public Water Corporation**
RC	**- Reinforced Concrete**
SWC	**- State Water Corporation**
UNICEF	**- United Nation Children's Fund**
PVC	**- Plasticized Polyvinyl Chloride (or Plastic Pipes)**
WATSAN	**- Water and Sanitation**
WES	**- Water and Environmental Sanitation**

Document Summary

This summary provides a brief overview of the document and is only meant as a quick reference to the main norms. Reference to the whole document is advised for accurate implementation.

Norms

a) Spring developments

- The physical and chemical quality of spring water depends on the type of mineral contents of the aquifer, differing from spring to spring. In terms of microbiological content, spring water is believed to be clean, as the filtration process through the soil media removes any microbes. However the quality of spring water needs to be checked.
- The quantity of spring water varies from season to season and the quantity should be measured at least twice a year to determine the minimum and maximum yields.
- Designers should always think of the downstream users of every spring. Where there are downstream users, equitable share should be released in order to avoid any possible conflict between communities. The minimum flow from the spring should also be allowed for the natural fauna and flora population.
- Cultivation of plants that require huge amount of water, like bananas/sugar cane should be avoided at the immediate upstream location. Natural vegetation enhances the recharging of a spring. Removal of this vegetation should not be allowed and users must be made aware of this at the outset of the project.
- Water from the spring should not directly emerge at the surface but to flow into a covered box known as a spring box to protect the flowing water from surface contamination.
- Spring water should be filtered through layers of gravel pack before entering to the spring box.
- Where the yield of a spring is small and the development of this spring would be advantageous, a night time storage tank should be constructed.
- Construction of spring boxes should be undertaken by a qualified person, ideally, one that has experience of water tight structures.

b) Roof water harvesting

- The quantity of rain water harvesting depends on various characteristics of the catchment such as the size of the roof, quality of workmanship etc, and rainfall characteristics such as intensity, duration, distribution pattern etc., and the amount of runoff that can be harvested.
- Rainfall is the most unpredictable variable. To determine the potential rainwater supply for a given catchment, reliable rainfall data preferably over a period of at least 10 years must be consulted.
- The runoff from a catchment depends upon the area and type of the catchment, and consideration of the runoff coefficient.

- The simplest source of rainwater for collection is a roof. This can be done using traditional roofing materials such as thatch (although the water may get discolored), improved local material like fiber-cement tiles, or corrugated iron sheeting. Guttering for conveying the water down to the collection vessel or storage tank may be adapted using traditional materials, such as split bamboo, or modern plastic gutters.
- Rain water storage tanks may be built either above or below ground. The size and construction of the storage tank will depend on local materials, available skills and requirements of the community. There may be little advantage in calculating storage tank size from the catchments area, rainfall and water use, as size is almost always limited by cost, local construction skills and materials.
- Precautions required in the use of storage tanks include provision of an adequate enclosure to minimize contamination from human, animal or other environmental contaminants, and a tight cover to prevent algal growth and the breeding of mosquitoes. Open containers are not recommended for collecting water for drinking purposes.
- The various methods used for treating water in the home include: boiling, filtration, disinfection with chlorination or solar disinfection.

1. Introduction

1.1 The purpose of this document and frequency of updating

The Ministry of Irrigation and Water Resources (MIWR), GONU, and the Ministry of Water Resources and Irrigation, (MWRI), GOSS, are responsible for the policy and strategy development, coordination, planning, management, monitoring and evaluation of water supply and sanitation facilities in the country. In order to reduce disparities, improve standards, accelerate implementation and to standardise design and costs, the two ministries agreed to harmonize the methodologies utilised in the implementation of WATSAN interventions Currently, there is no standardised document providing Technical Guidelines for implementation by WES or other water and sanitation agencies and this is detrimental to the longevity of structures and the sustainability of interventions.

In 2006 MIWR and MWRI decided to develop Technical Guidelines for the construction and management of rural water supply and sanitation facilities. These Guidelines are a collection of global and national good practices in water and sanitation that have been collated. The process of the development of the Technical Guidelines is outlined in Annex 2.

These simple Guidelines are primarily intended as a reference for field staff and practitioners in the water and sanitation sector challenged by situations and conditions in the field.

Updating of the Guidelines is recommended biennially; to ensure newer and better practices are incorporated as they are developed/ introduced. Water and sanitation sector implementing partners should contribute in providing feedback to the MIWR and MWRI as necessary during the updating.

2. Springs

Springs are places where groundwater naturally emerges at the surface. This water has been filtered through soil and rock as it moves upwards, and is usually free from microbial contamination, making it safe to drink. This, however, should be confirmed by bacteriological tests.

Sometimes rivers or streams pass underground and reappear downstream. This is especially common in the areas of limestone. These can look like springs but the water has not been filtered in the same way and is less likely to be safe.

Water on the surface of the ground will filter down through soil and rocks until it reaches a level through which it cannot pass (an impervious layer), or a level where the soil or rock is saturated with water (the water table). Groundwater will flow down slopes in the water table until the level intersects with the land surface or is forced to the surface by an impervious layer.

2.1 Types of springs

There are two main types of springs, namely: gravity and artesian springs. Gravity springs are divided into, stratum or contact spring, valley springs, and fault springs.

- **Stratum Spring:** This type of spring is formed when the downward passage of groundwater in a permeable deposit is blocked by an impervious layer. The groundwater emerges as a spring at the contact of the formations, and hence is also known as a contact spring (Figure 1). Another kind of stratum spring may arise at the junction of two formations where permeable beds dip beneath an impermeable cover. This is called an overflow spring, since the groundwater overflows at the edge of the impervious stratum (Figure 2).
- **Valley spring:** This spring is formed by the emergence of the water table where the topography falls below its level such as that shown in Figure 1. Water flows out at the surface and feeds the surface stream.
- **Fault spring:** When a permeable formation meets an impermeable one due to a fault, groundwater in the permeable bed may escape along the fault line and appear at the surface as a fault spring (Figure 3).
- **Artesian spring:** This occurs where groundwater emerges at the surface due to hydrostatic pressure after being confined and pressurized between two impervious layers.

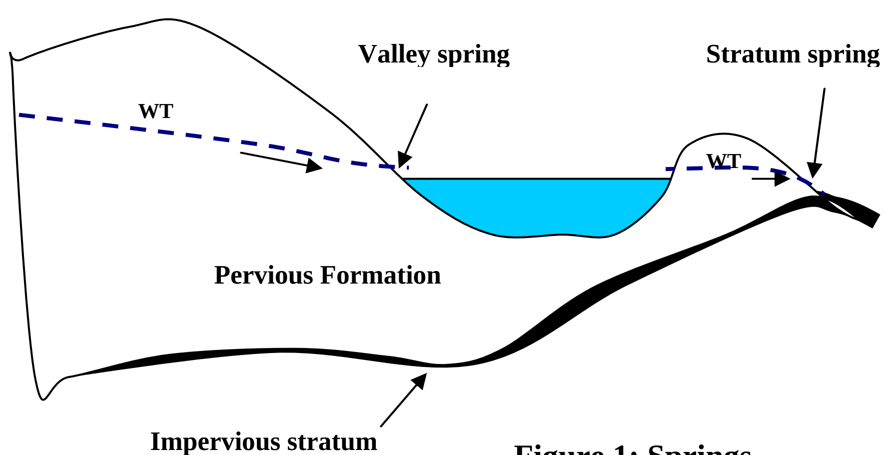


Figure 1: Springs

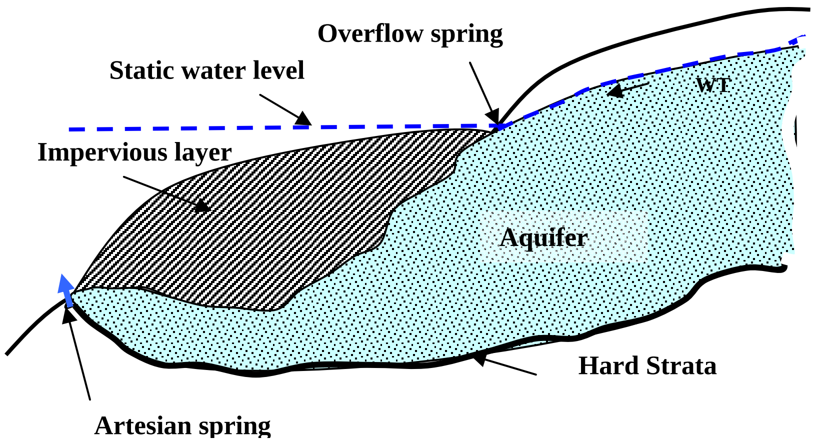


Figure 2: Springs

2.2 Quality and quantity of spring water

The physical and chemical quality of spring water depends on the type of mineral content of the aquifer, varying from spring to spring. In general, the quality of water from every spring should be checked and its physical, chemical and bacteriological parameters determined, although spring water is believed free of microbes due to the filtration process through the soil

The flow of gravity springs changes with variations in the height of the water table and is dependant on the time of the year. The nature of the permeable formation, will decide whether the spring flow increases during the wet season or the dry season.
On the other hand, the flow of artesian springs is very nearly constant through the year.

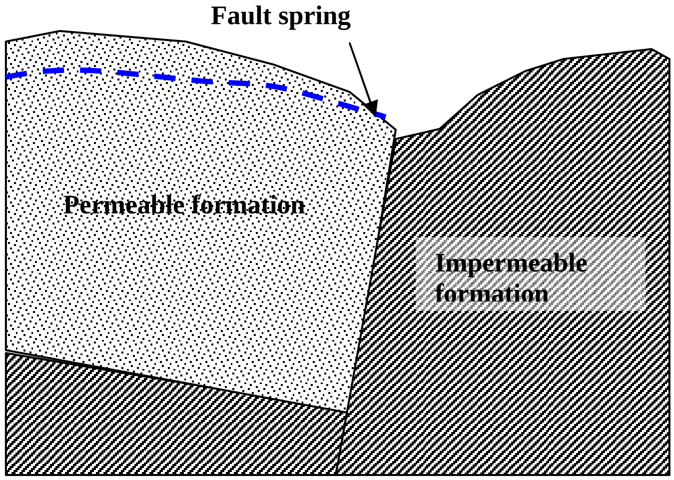


Figure 3: Fault spring

2.3 Methods, design and construction of spring development, including the spring box (figures 4 & 5)

The flow of spring water is determined either by gravity or by pressure (in the case of artesian springs). Any additional structure (such as flow diversion walls or spring box backside wall) built around the spring's eye will hinder the flow. Water from the spring should not directly emerge at the surface but to flow into a covered box known as a spring box to protect the flowing water from surface contamination.

Consideration of the following principles will ensure the facilitation of the natural flow of the spring water into the spring box:

- Designers must always bear in mind the users at the downstream end of the spring, and ensure the release of an equitable share of water to avoid possible conflict between communities. A minimum flow from the spring should also be allowed for the natural fauna and flora in the area.
- Cultivation of plants that require huge amounts of water, like bananas/sugar cane etc. should be avoided at the immediate upstream location, as should construction, farming, deforestation,, as these will impact on the yield and quality of the water. A catchment area of at least 100m around the spring should be demarcated from any human activity. This must be discussed with end users at the outset of the project.
- Spring water should be filtered through layers of gravel pack before it enters the spring box.
- The water can be either directly flows from a pipe running from the box or from taps if the spring is connected to a distribution network.
- The box should be covered with a lid to prevent animals or leaves from entering, and should be kept locked. The lid should be removable to enable cleaning.

- Where the yield of a spring is in excess of demand, there may not be need of a spring box. A sectional wall with overflow and taps may be enough.
- Where the yield of a spring is small and the development of this spring would be advantageous, a night time storage tank should be constructed.
- One, or more, drain pipes can be attached to the spring box depending on the yield of the spring.
- An overflow of the spring box should be allowed below the lowest level of the eye of the spring, which occurs at the lowest level of the groundwater table.
- The uphill area of a spring should be protected by a fence preventing access by animals and humans.
- The quality and yield of the spring should be measured over the year, once during the wet season and once during the dry season, to determine the minimum and maximum yields of a spring.

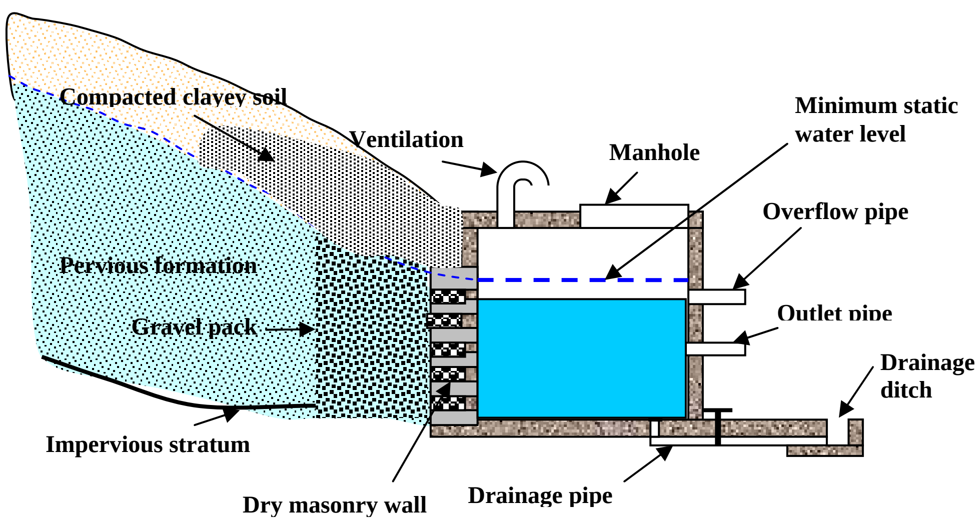


Figure 4: Schematic section of spring development with spring box

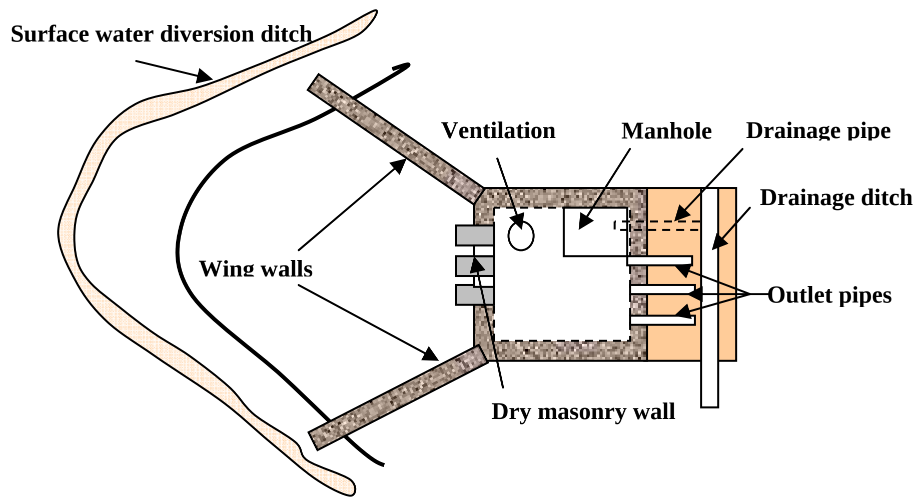


Figure 5: Schematic plan of spring development with spring box

- A surface water diversion ditch should be dug above and around the area of the spring, to avoid surface water, especially during the rainy season, to contaminate the spring with pollutants.
- Construction of spring boxes should be undertaken by a qualified person, ideally, a person who has experience of water tight structures.
- The general procedure for construction of a spring development (protection) is as follows:
  - Dig back until you can see a clear point at which the spring emerges (the eye of the spring). Do not dig down into the impervious layer. If there is more than one point, then dig back further to see if they converge. If the points do not converge, then separate spring boxes will have to be constructed for each, or a seep collector with drains will have to be built.
  - Dig a temporary drainage channel that will take the water away from the spring during construction.
  - Make the edges of the base of the spring box with wooden shuttering so that the base is close to the eye of the spring, extends at least one meter forward from the eye and across its full width.
  - The spring box will need both an overflow pipe and a drainage (cleaning) pipe. Concrete for the floor slab of the spring box should be mixed in the ratio of 1:2:4 (cement: sand: gravel). Compact the concrete and allow it to cure for 7 days, keeping it damp by covering with old cement bags, rags, sacks or similar items. Moisten these at least once a day. On very hot days, the sacks or bags etc will dry out quickly and should be checked and moistened, if necessary, two or three times a day.
  - The back wall, which can be a dry stone wall or a perforated concrete wall, is partly open to allow water from the spring to enter the box.
  - The walls of the box can be made either with locally available stone, or with concrete in a stiff mixture of 1:2:4 (cement: sand: gravel) into shuttering. In

either case the walls should be at least 100mm thick. Note that the minimum amount of water should be used to make the mixture cohesive. If the mixture is too wet, the strength of the dried concrete will be reduced. The inside of the mortared wall should be made waterproof by rendering. The box should not be very large for a small spring. A box of about 80 cm by 80 cm is adequate. The height of the spring is governed by the height of eye of the spring.

- Outlet pipe(s) (size and number of pipe(s) to be determined by the amount of water to be used from the spring) must be incorporated into one of the walls of the spring box. If water is to be collected directly from the spring, the outlet pipe should be of galvanized iron and be well supported. In this case a concrete apron should be built around the spring with a kerb and drainage for spilt water.
- If water is to be collected directly from the spring, the height of the outlet pipe from the apron should comply with the height of common water containers used by the community, being neither too low nor too high. The outlet pipe should always be placed below the overflow pipe.
- Where the overflow pipe is not connected to the drainage pipe, install a piece of pipe to one of the three sides of the box, positioning it below the height of the eye of the spring to prevent water pressure back on the eye which might force the spring to divert. The minimum size of this overflow pipe should not be less than 1 ½ inches.
- While the spring water is diverted to one side of the box, construct a wing wall connected to the other side of the box. The wing wall is to ensure that all the water from the spring enters the box. The wing walls may be constructed in a similar way to the walls of the spring box and the uphill sides of the wing walls should be made waterproof.
- Guide the flow of the water so that it passes into the box and through the drainage pipe. Then construct the second wing wall on the other side
- The area between the eye of the spring and the back of spring box should be filled with gravel, which should then be sealed by pouring a concrete apron over it or by adding puddle clay. This protection should be sloped so that it carries water away from the back of the box to the sides.
- Make a lid (or slab) on top of the box from metal or reinforced concrete.
- Excavate a surface water diversion ditch upstream of the spring box and a minimum of 8 meters away from it.
- Build a fence all around the spring catchment area, ten meters away from the spring box to keep out children and animals.

2.4 Operation and maintenance of spring development systems

Ensure that water emerging from the aquifer can flow freely from the point of emergence, to prevent it getting diverted. Planned diversion may include opening or closing valves to divert the water to a reservoir, a conduit or a drain.

The spring and its surrounding must be kept clean to prevent contamination both in the area where the spring water infiltrates into the ground and in the immediate surrounding.

Check the surface drains, animal proof fence and gate, making any necessary repairs. Protect the vegetative cover both in the area where the spring water infiltrates into the ground (if possible) and in the immediate surroundings of the spring. Vegetative growth support prevention of aquifer clogging.

Check the water flow from the spring box. An increase in the turbidity or flow rate after a rainstorm indicates that the surface run-off that has contaminated the spring water. This needs to be identified and blocked in order not to contaminate the spring. A decrease in the flow rate indicates clogging and/or seeping in the collection system. This requires replacement of the gravel and/or cleaning of the collection pipes. Regular water samples must be taken and analyzed for feicies al contamination.

The washout must be opened annually, and all accumulated silt removed. All screens must be inspected and replaced if damaged or blocked, and cleaned if dirty. Replace the manhole cover after cleaning. The spring must be disinfected, every time a person has entered to clean or repair it or when bacteriological contamination is detected. Leaks of any kind must be repaired immediately.

3. Roof Water Harvesting

Sudan has various multi-climatic and topographic zones. The rainfall intensity in the country ranges from almost nil in the north to more than 1500mm in the far south. The total amount of rainfall is estimated to be around 1000 km^3 per annum[1].

Roof water harvesting is part of the broad rain water harvesting technique. Rainwater harvesting has its origins in many parts of the world. In central Sudan where the Meroetic Kingdom dates back to seven thousand years, runoff agriculture was traditionally used for crop production.

Roof water is collected and used for domestic purposes in many parts of the world, mainly by individual households. Rainwater collection is possible in most areas. Its practicality depends on the expectations of the users in terms of quantity and quality and on the amount of rainfall.

3.1 Components of roof water harvesting

Roof water harvesting systems involve three major stages:

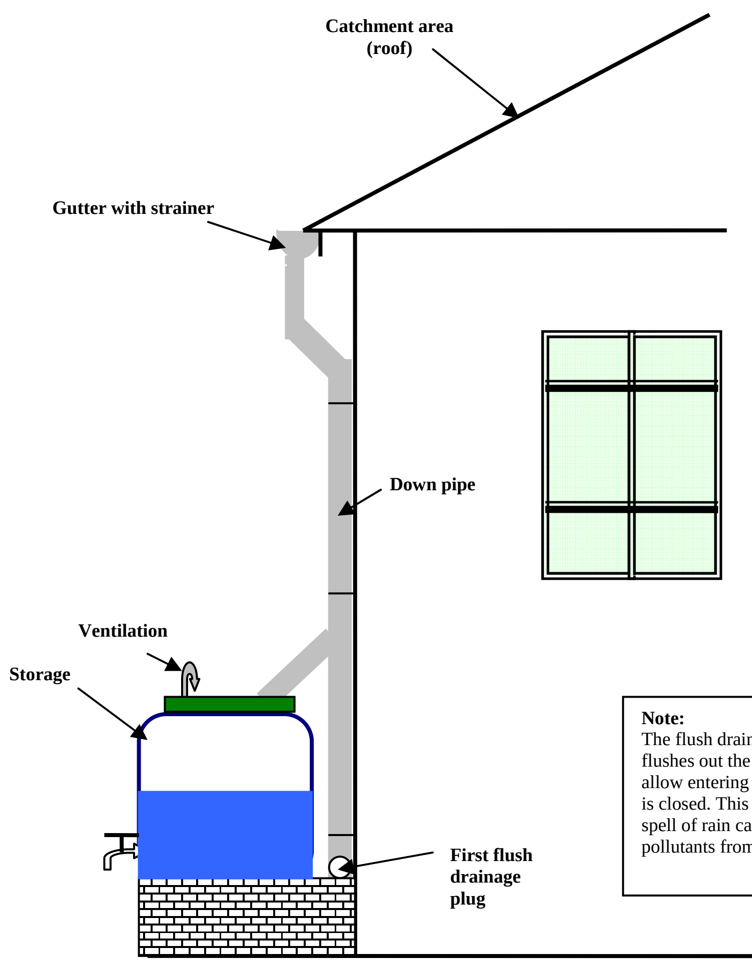
- **Catchments**: A hard impermeable surface (roof) onto which rain falls. Roof for rainwater harvesting can be made of Reinforced Cement Concrete (RCC), galvanized iron sheets, or corrugated iron sheets.
- **Storage**: Storage at household level is limited to a few thousand liters. The shape of storage can be cylindrical, rectangular or square containers. They can be constructed from RCC, ferrocement, masonry, plastic (polyethylene) or metal (galvanized iron) sheets.
- **Gutters and down pipes**: These are the venues through which the water travels down form the to the storage container. Gutters can be semicircular or rectangular and can be made of plain galvanized iron sheets folded to required sizes, semicircular gutters of PVC that can be readily prepared by cutting PVC pipes into two equal semi-circular channels, or bamboo trunks split vertically.. Down pipes can be made of polyvinyl chloride or galvanized iron material. Gutters and down pipes should include a filter for removing solids from the water. The size of the gutters depends on the flow during the highest rain intensity. It is recommended to oversize them by 10 to 15 percent.

3.2 Quantity and quality of water of roof water harvesting

- The quantity of rain water harvesting depends on various characteristics of the catchment such as the size of the roof, quality of workmanship etc, and rainfall characteristics such as intensity, duration, distribution pattern etc., and the amount of runoff that can be harvested.

[1] Optimum Investment of Rainwater Harvesting Techniques: By Osman Mohammed Nagger, Abeed Ali Mohammed, Egbal Mohmmed A/Raheem, Mona Mohammed Tom, Zubaida Mohammed Alseid and Isam Mohammed Abdel Magid; Scientific Paper Series, SPS, No 1, Sudan Academy for Sciences Publishing & Distribution House

- Rainfall is the most unpredictable variable. To determine the potential rainwater supply for a given catchment, reliable rainfall data, preferably over a period of at least 10 years must be consulted. The number of annual rainy days will influence the need and design for rainwater harvesting facilities. The fewer the annual rainy days in a region, the higher is the need for rainwater collection system in order to tap the maximum amount of the rainfall. However, if the dry period is too long, big storage tanks will be needed to store rainwater.
- The runoff from a catchment depends upon the area and type of the catchment, and consideration of the runoff coefficient. The runoff coefficient for any catchment can be defined as the ratio of the volume of water that runs off a surface to the volume of rainfall that falls on the surface. The water harvesting potential of a site can be estimated from the runoff coefficient. Table 1 shows values of runoff coefficient for some catchment surfaces.



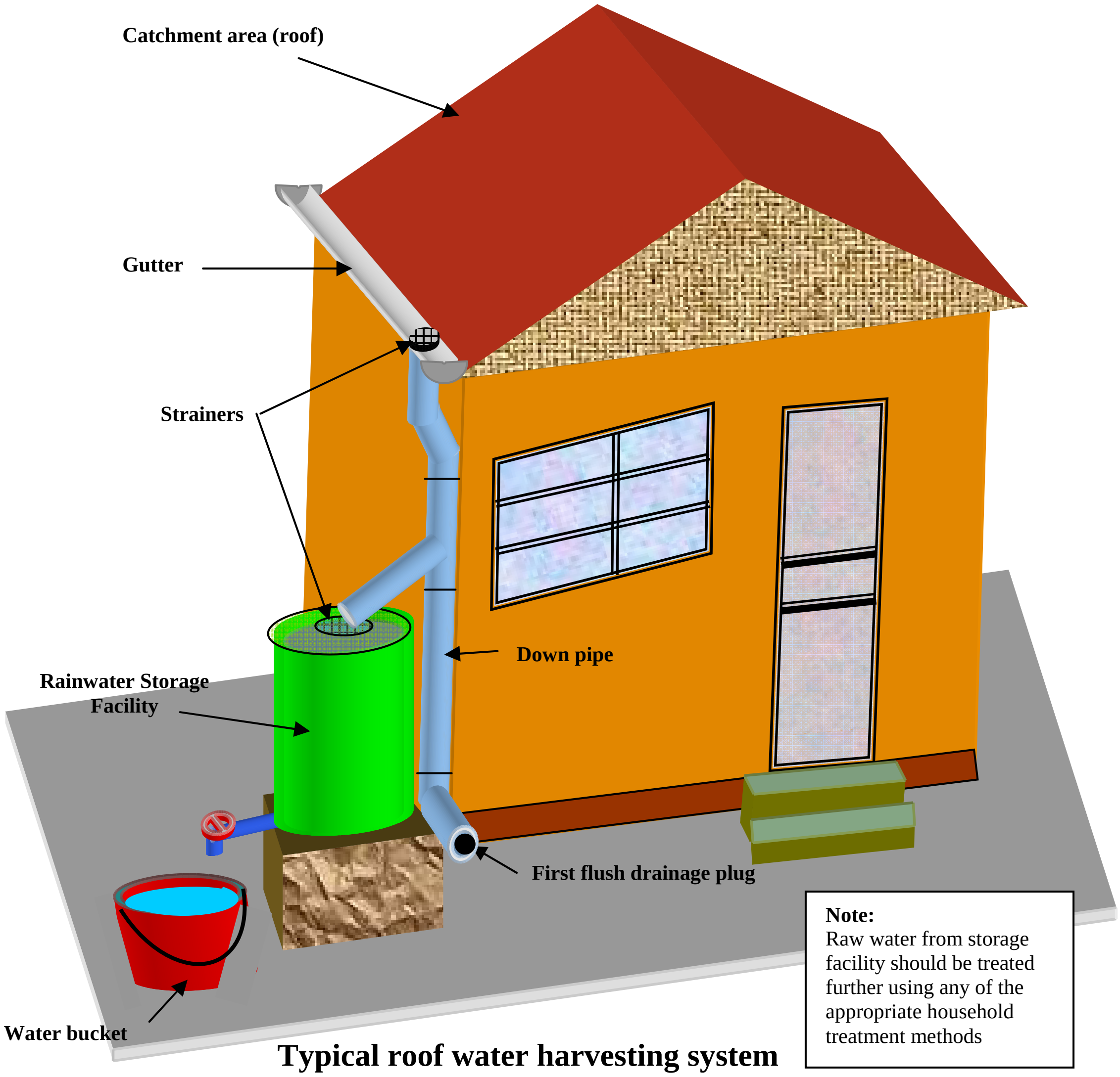
Note:
The flush drainage plug when opened first flushes out the first spell of rain and doesn't allow entering it into the storage tank unless it is closed. This needs to be done since the first spell of rain carries a relatively larger amount of pollutants from the air and catchment surface.

Typical roof water harvesting

- The first flush of rain water usually contains contaminant such as dirt, leaves, bird drops etc. These contaminants need to be removed before the water reaches the storage system. Rainwater that is stored for a long period of time may deteriorate if bacteria begin to grow in it. . Water collected through the roof water harvesting technique must be treated before it is safe to drink. A sustainable method of treatment should be adopted.

Table 1: Runoff coefficient for some catchment surfaces

Type of catchment			Runoff coefficient
Roof catchment		Tiles	0.8 – 0.9
		Corrugated iron sheets	0.7 – 0.9
Ground coverage	Surface	Concrete	0.6 – 0.8
		Brick pavement	0.5 – 0.6
Untreated catchments	Ground	Soil on slopes less than 10%	0.1 – 0.3
		Rocky natural catchments	0.2 – 0.5



Note:
Raw water from storage facility should be treated further using any of the appropriate household treatment methods

Typical roof water harvesting system

3.3 Design and construction of roof water harvesting

- The simplest source of rainwater collection is a roof. This can be done using traditional roofing materials such as thatch (although the water will get discolored), improved local material like fiber-cement tiles, or corrugated iron sheeting. Guttering for carrying water down to the collection vessel or storage tank may be adapted using traditional materials, such as split bamboo, or modern plastic gutters.
- Rain water storage tanks may be built either above or below ground. The size and construction of the storage tank will depend on local materials, available skills and requirements of the community. There may be little advantage in calculating storage tank size from the catchments area, rainfall and water use, as size is almost always limited by cost, local construction skills and materials.
- Precautions required in the use of storage tanks include provision of an adequate enclosure to minimize contamination from human, animal or other environmental contaminants, and a tight cover to prevent algal growth and the breeding of mosquitoes. Open containers are not recommended for collecting water for drinking purposes.
- The various methods used for treating water in the home include: boiling, filtration, disinfection with chlorination or solar disinfection.

Various types of rainwater storage facilities used globally are listed in annex 3. It should be noted that bamboo reinforced tanks are vulnerable to attacks by termites, bacteria and fungus unless preliminary protection measures are taken. These include soaking the bamboo in a solution containing 450g of sodium dichromate, 300g of copper sulphate and 150 g of boric acid dissolved in 10 liters of water (to make it non-biodegradeable.[2])

If the cost of individual household rainwater storage tanks is beyond the reach of families, communal tanks may be built to be shared by several households or in a large public building such as a school. Local decisions are very important in communal systems, with clear mandates for cleaning and maintenance established at community level.

3.4 Methods of water treatment for roof water harvesting

As water from roof water harvesting is likely to be contaminated, treating the water before use is recommended, using any of the following methods:

- Boiling
- Filtration,
- Chlorination
- Solar disinfection

[2] Low cost water tank (1,500 to 23,000 liters) made of bamboo and plastic film, Appropriate Rural Technology Institute (ARTI), Pune, India

Boiling: Although this is the simplest way of killing pathogens, it has several disadvantages:

- It uses a lot of fuel. About 1kg of wood is needed to boil1 liter of water. The cost of fuel may be prohibitive in many areas.
- It can leave an unpleasant taste in the water.
- There is a chance of re-contamination once the water has cooled.

Water must be brought to a rolling boil for at least one minute. If the water is turbid it should be boiled for at least five minutes. Water should be boiled, cooled and stored in the same container. If the water is transferred to another container for cooling, care should be taken to ensure that both the containers are clean and disinfected.

Filtration: There are several types of household filters such as candle filters, stone filters, household sand filters etc. In a candle filter the contaminated water is filtered slowly through a porous ceramic material. Most pathogens are left in the outer layer of the filter material and must be washed away once every month by gently scrubbing the filter under clean, running water. Viruses such as hepatitis A are not removed by candle filters. Candle filters have to be made commercially and their quality carefully controlled. They are often expensive. Some candle filters contain silver which helps to kill pathogens.

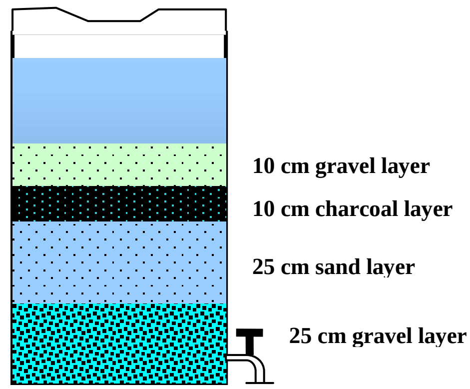
Clay or porous stone filters often remove turbidity only and not pathogens. These types of filter are difficult to clean as they are heavy to lift, but usually quite cheap if the type of stone or skill of manufacturing can be found locally.

Household sand filter: This type of filter will remove solids and silt, and some pathogens, including guinea worm larvae. It does not, however, remove all pathogens. The procedure for making a household sand filter:

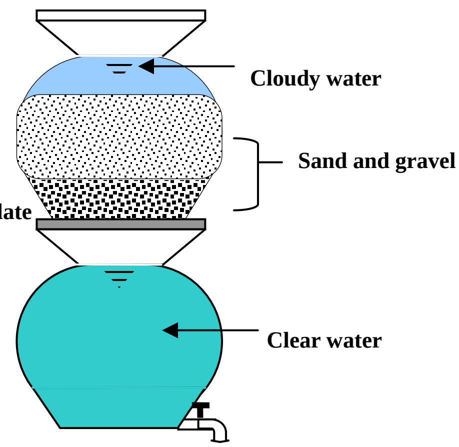
- Line two containers made of fired clay or plastic on top of one another.
- Make some holes in the base of the upper container either when manufacturing the pot or later with a drill, to allow the water to pass through to the lower container.
- Make a hole at the bottom of the lower container and fit it with a tap , using a short length of galvanized iron or plastic pipe and cement if necessary. (The tap prevents contamination of stored water from hands and dirty objects like cups being inserted into the treated water).
- Allow five days for the cement to become fully hardened before using the filter.
- Place washed, clean gravel in the upper container to a depth of 5-7 cm
- Add well washed, clean, river sand on top of the gravel to a depth of 75cm. Leave a 5-10cm space above the sand where the water can stand.
- Once the first lot of water has gone through to the bottom pot, add more water slowly for the next round of filtration. Add water several times a day to the top container, so that there is always plenty of filtered water in the lower container.

Charcoal water filter

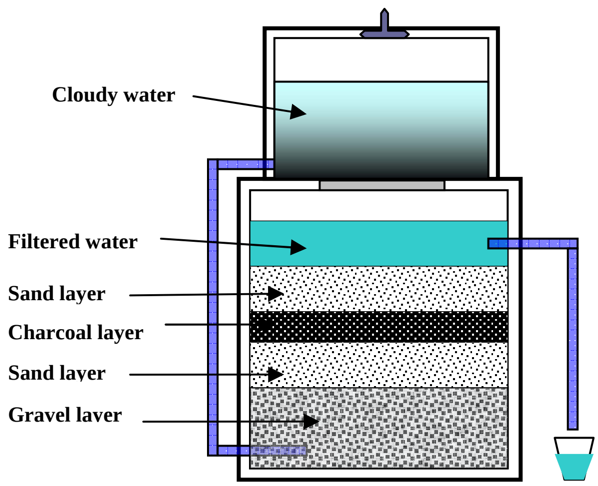
A simple charcoal filter can be made in drum or earthen pot. The filter is made of gravel, sand and charcoal, all of which are easily available in most places



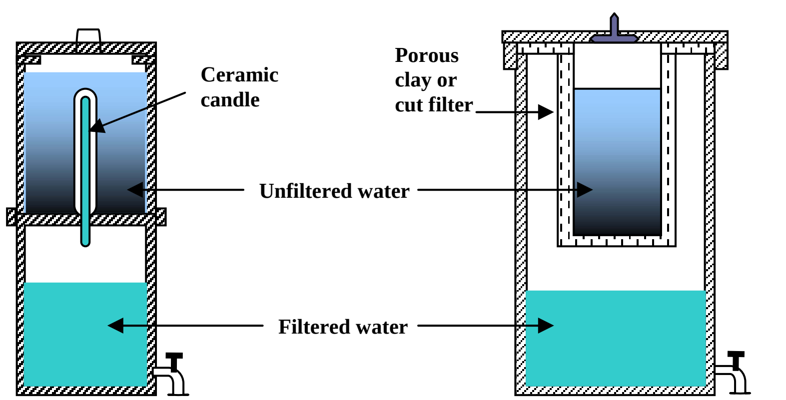
Household clay pot



Household filter from local material



Household upward filter flow



Candle filter **Clay or porous stone filter**

Disinfection: When disinfecting household drinking water one percent chlorine is added to the water and left for 20 minutes to allow sufficient contact time for the chlorine to work. It is important to use the correct amount of chlorine, as too little will not kill all the germs present and too much may make the water unpalatable, causing it to be rejected by the consumer. As a general rule, three drops of chlorine solution should be added to every litre of water. This can be done using a simple dropper tube or syringe. Sodium hypochlorite or liquid bleach and calcium hypochlorite (the best type High Test Hypochlorite (HTH) are commercially available.

If sodium hypochlorite is used, it can be added directly from the bottle, as it comes with a chlorine concentration of 1%. If calcium hypochlorite or HTH is used, they will need to be diluted to one percent. Check the manufacturer's instruction on the container to determine the quantity of powder required to make a one percent solution. A small amount of residual chlorine in the water will continue to keep it germ-free and help prevent re-contamination

Preparation of 1 liter of 1% chlorine stock solution:

Add the quantity indicated below of one of the chemical sources to water, mix and make up to 1 liter in a glass, plastic or wooden container. This stock solution should be fresh, i.e. made every day, and protected from heat and light.

Chemical source	Percentage available chlorine	Quantity required	Approximate measures
Bleaching powder	35	30 g	2 heaped tablespoons
Stabilized/tropical bleach	25	40 g	3 heaped tablespoons
High-test-hypochlorite (HTH)	70	14 g	1 table spoon solution
Liquid household disinfectant	10	100 ml	7 tablespoons
Liquid laundry bleach	5	200 ml	1 teacup or 6-oz milk tin or 14 tablespoons
Liquid laundry bleach	7	145 ml	10 tablespoons
Javelle water or antiseptic solution eg Milton	1	1 liter	No need to adjust as it is a 1% solution

A 1% solution contains 10 g of chlorine per liter which is equal to 10,000 mg/l or 10,000ppm (parts per million).

Container size	1 gallon or 4.5 liter	20 liters	45 gallon drum or 200 liters
Volume of 1% solution required	8 drops	Half teaspoon	1 table spoon + 1 teaspoon

The approximate volume of 1 teaspoon = 5 ml and 1 tablespoon = 15 ml

Solar disinfection: This is an effective water treatment method, especially when no chemical disinfectants are available. Ultraviolet rays from the sun are used to inactivate pathogens present in water. This technique involves exposing water in clear plastic bottles to sunlight for 6 to 8 hours (or for 2 days if the sun is obscured by cloud). Bottles must be cleaned, filled three quarters and shaken thoroughly 20 times, before being filled to the top. The water can be consumed directly from the bottles or transferred to a clean glass for drinking. Solar disinfection is more effective when the water is relatively clear (not turbid).

Storage of treated water: Treated household drinking water can be kept clean by using good storage containers, which need to be well designed to ensure protection from contamination. Two most important factors that influence contamination of water in storage containers are: the presence of a lid or cover and the way water is drawn from the container. A container without a lid or cover will allow water to become contaminated rapidly. Water should be drawn from the container by a ladle or scoop. The ladle should not be used for any other purpose and should be kept in the water storage container. Another good way of preventing water in the storage container from getting contaminated is to pour the water from the container into a cup or to make water containers with narrow necks. In some countries, water storage containers are made with taps so that water can be drawn from the tap. Users should be made aware of the many ways that pathogens can get into the water when water is taken out of the container, and to avoid these.

3.5 Operation and maintenance

Rainwater collection systems must be properly maintained to ensure acceptable water quality. Maintenance is generally limited to the annual cleaning of the tank and regular inspection of the gutters and down pipes, and typically consists of the removal of dirt, leaves and other accumulated materials. This should be done annually before the start of the major rainfall season. Cracks in the storage tanks can create major problems and should be repaired immediately.

Annex

1. Drinking Water Standards
2. The Development of these Technical Guidelines
3. People contacted
4. Technical working group members
5. Sample pictures of storage reservoirs for rainwater harvesting from different countries
6. Some bibliography and references

Annex 1: Drinking Water Standards

No	Dissolved substances in water	Sudanese maximum permissible (mg/l) by SSMO, 2008	WHO guideline value (mg/l), 2006
1	Antimony	**0.013**	0.02
2	Arsenic	**0.007**	0.01 (P)
3	Barium	**0.5**	0.7
4	Boron	**0.33**	0.5 (T)
5	Cadmium	0.002	0.003
6	Chromium (total)	**0.033**	0.05 (P)
7	Copper	**1.5**	2
8	Cyanide	**0.05**	0.07
9	Fluoride	1.5	1.5
10	Lead	**0.007**	0.01
11	Manganese	0.27	0.4 (C)
12	Mercury (for inorganic Mercury)	**0.004**	0.006
13	Molybdenum	**0.05**	0.07
14	Nickel	**0.05**	0.07 (P)
15	Nitrate as NO3	50	50 Short term exposure
16	Nitrite as NO2	**2**	3 Short term exposure
17	Selenium	**0.007**	0.01
18	Uranium	0.01	0.015 (P,T)

Microbiological contents			
No	Organisms	Sudanese guideline value by SSMO	WHO guideline value
1	All water intended for drinking a) E-coli or thermotolerant coliform bacteria b) Pathogenic intestinal protozoa	Must not be detectable in any 100ml sample	Must not be detectable in 100ml sample
2	Treated water entering the distribution system a) E-coli or thermotolerant coliform bacteria b) Total coliform bacteria c) Pathogenic intestinal protozoa	Must not be detectable in any 100ml sample	Must not be detectable in 100ml sample
3	Treated water in the distribution system a) E-coli or thermotolerant coliform bacteria b) Total coliform bacteria c) Pathogenic intestinal protozoa	Must not be detectable in any 100ml sample Must not be detectable in any 100ml sample. In the case of large supplies where sufficient samples are examined, must not be detectable in 95% of samples examined through out any consecutive 12 months period. Must not be detectable in any 100ml sample.	Must not be detectable in 100ml sample

Maximum permissible limit for other parameters which affect the acceptability of water			
	Parameter	Levels likely to give rise to consumer complaints by SSMO, 2008	
1	Physical parameters		
	Colour	15 TCU	
	Taste & odour	Acceptable	
	Temperature	Acceptable	
	Turbidity	5 NTU	
	pH	6.5 – 8.5	
2	Inorganic constituents		
	Aluminum	0.13 mg/l	
	Ammonia	1.5 mg/l	
	Chloride	250 mg/l	
	Hydrogen sulfide	0.05 mg/l	
	Iron (total)	0.3 mg/l	
	Manganese	0.27 mg/l	0.4 mg/l
	Sodium	250 mg/l	
	Sulfate	250 mg/l	
	Total dissolved solids (TDS)	1000 mg/l	
	Zinc	3 mg/l	
3	Organic constituents		
	2-Chlorophenol	5 µg/l	
	2,4-Dichlorophenol	2 µg/l	

Parameter	Permissible level in µg/l by SSMO, 2008	WHO guideline value in mg/l, 2006
Carbontetrachloride	2.7	0.004
Dichloromethane	14	0.02
1,2-Dichloroethane	20	0.03
1,2-Dichloroethene	33	0.05
Trichloroethene	13	0.02 (P)
Tetrachloroethene	27	0.04
Benzene	7	0.01
Toluene	470	0.7(C)
Xylenes	330	0.5 (C)
Ethylbenzene	200	0.3 (C)
Styrene	13	0.02 (C)
1,2-Dichlorobenzene	700	1 (C)
1,4-Dichlorobenzene	200	0.3 (C)
Di(2-ehylhexyl) phthalate	5.4	0.008
Acrylamide	0.3	0.0005
Epichlorohydrin	0.3	0.004 (P)
Edetic acid (EDTA)	400	0.6 Applies to the free acid
Nitrilotriacetic acid (NTA)	130	0.2
Hexachlorobutadiene	0.4	0.0006
Dioxane	33	0.05
Pentachlorophenol	7	0.009 (P)

Parameter	Maximum Permissible level in µg/l	WHO guideline value in mg/l, 2006
Pesticides		
Alachlor	15	0.02
Aldrin/Dieldrin	0.02	0.00003 For combined Aldrin and Dieldrin
Aldicarb	7.5	0.01 Applies to Aldicarb Sulfonide and Aldicard Sulfone
Atrazine	1.5	0.002
Carbofuran	4.5	0.007
Chlordane	0.15	0.0002
Chlorotoluron	20	0.03
1,2-Dibromo-3-Chloropane	0.7	0.001
DDT	0.7	0.001
2,4-Dichlorophenoxy acitic acid	20	0.03
1,2-Dichloropropane (1,2 DCP)	26	0.04 (C)
1,3-Dichloropropene	13	0.02
Isoproturon	6	0.009
Lindane	1.3	0.002
MCPA	1.3	0.002
Methoxychlor	13.5	0.02
Metholachlor	7	0.01
Molinate	4	0.006
Pendimethalin	13.5	0.02
Pentachlorophenol	7	0.009 (P)
Permethrin	200	0.3
Simazine	1.3	0.002
Trifluralin	13.5	0.02
2,4-DB	60	0.09
Dichlorprop	66	0.1
Fenoprop	6	0.009
Mecoprop	7	0.01
2,4,5-T	6	0.009
Cyanazine	0.4	0.0006
1,2 Dibromoethane	0.27	0.0004 (P)
Dimethoate	4	0.006
Edin	0.4	0.0006
Terbuthylazine	5	0.007
Chlorpyrifos	20	0.03
Pyriproxyfer	200	0.3
Disinfectants and disinfectants' byproducts		
Chlorine	3	5
Monochloroacetate	13	0.02

Bromate	6.6	0.01 (A,T)
Chlorate	470	0.7 (D)
2,4,6-Trichlorophenol	135	0.2 (C)
Bromoform	70	0.1
Dibromochloromethane	70	0.1
Bromodichloromethane	66	0.06
Chloroform	200	0.3
Dichloroacetate	33	0.05 (T,D)
Trichloroacetate	133	0.2
Dichloroacetonitrile	13	0.02 (P)
Dibromacetonitrile	50	0.07
Cyanogen Chlorides (CN)	50	0.07
Chlorote	470	0.7 (D)
Disinfectants byproducts		
Gross alpha activity	0.07	
Gross beta activity	0.7	

P= Provisional guideline value as there is evidence of a hazard, but the available information on health effects is limited.
T= Provisional guideline value because calculated guideline value is below the level that can be achieved through practical treatment methods, source protection etc.
C= Concentration of the substance at or below the health-based guideline value may affect the appearance taste or odor of the water, leading to consumer complaints.
A= Provisional guideline value because calculated guideline value is below the achievable quantification level.
D= Provisional value because disinfection is likely to result in the guideline value being exceeded.
TCU = True Colour Unit
NTU = Nephlometric Turbidity Unit

Annex 2: The Development of these Technical Guidelines

The Technical Guidelines development process was completed in two stages: the preparation and the finalization.

A. The Preparation Stage

The preparation stage began in April 2006 with the agreement to select eight WASH facilities. At the request of the GONU, 3 additional water supply facilities were added, making the total eleven. The preparation stage that included information collection and analysis was completed in December 2006.

Collection of Information:
Technical and managerial information related to the development of the 14 Technical Guidelines was collected from the following sources:

- PWC/WES, SWCs and GWWD
- UNICEF, WHO, World bank and NGOs
- National institutions like SSMO
- International institutions like IRC and WEDC
- Donors like DFID.
- Different countries' standards like BS, IS, DIN, etc.
- Field trips to 14 states in the northern and southern states of Sudan to visit the different existing facilities and to have live discussion with the sector professionals and community members.

Analysis of collected information:
The Steering Committee, which comprised senior staff from PWC, WES and UNICEF together with the consultant analysed the collected information, which led to the development of the outlines of the documents in a zero draft. The draft documents were shared with the Steering Committee at Khartoum level. The committee met to discuss the drafts, and provided comments, which were incorporated, resulting in the first draft. .

The first draft was widely circulated to PWC, UNICEF, various SWCs, INGOs and GoSS for information and feedback. All relevant feedback from the sector actors were incorporated into the documents and the second draft prepared and presented to the first national review workshop in December 2006. The relevant recommendations and comments of the national review workshop were incorporated into the documents resulting in a third draft. The first National Review Workshop recommended that this draft of the Technical Guidelines be shared with a wider range of stakeholders, including specific technical working groups.

B. The Finalization Stage

The finalization of the 14 Technical Guidelines involved wider consultation with WASH sector partners through technical working group discussions, 3 regional review workshops, wider consultation and revision by GoSS and a national review workshop at the final stage.

Technical Working Group Discussions:
Professionals from various ministries participated in these technical working group discussions. MIWR, MOH, University of Khartoum, Sudan Academy of Science, private sector, NGOs, PWC/WES, UNICEF and Khartoum Water Corporation were also represented in these groups. This technical consultation process started in July 2007 and continued up to December 2007 resulting in the fourth draft of Technical Guidelines.

Regional Review Workshops:
Three Regional Review Workshops were conducted in Nyala, Wad Medani and Juba in November-December 2007 for GoSS and state level inputs into the documents. The Juba workshop recommended that the need for wider consultation within Southern Sudan to review the documents and to incorporate Southern Sudan specific contexts into the documents such as information relating to the location and different hydrogeological situations. These 3 workshops resulted in the fifth draft.

Wider Consultation by GoSS:
Based on the recommendation of the Juba Review Workshop, a wider consultation process was started in July 2008 and completed in October 2008. The process included state level consultation with sector actors, technical working group discussions and a final consultation workshop in Juba. The process was concluded by the finalization and the approval of the final draft documents which were reviewed at a final National Workshop.

Final National Workshop:
The final National Workshop was conducted in April 2009 in Khartoum under the guidance and the presence of H.E. Eng. Kamal Ali Mohamed, Minister of Irrigation and Water Resources of GONU, Eng. Isaac Liabwel, Undersecretary, Ministry of Water Resources and Irrigation of GoSS, Eng. Mohammed Hassan Mahmud Amar, DG of PWC and Eng. Adam Ibrahim, Minister of Physical Planning and Public Utilities of South Darfur State.

The workshop was attended by ninety two participants representing MIWR, MWRI, MOH, PWC, WES, GWWD, Engineering Council, SWCs, SMoH, University of Khartoum, UNICEF, WHO, IOM, ICRC, NGOs, USAID and private sector.

The National Workshop has reviewed the 14 WASH Technical Guidelines and approved them as the national WASH Technical Guidelines.

The workshop recommendations included:

- Publication and wide distribution of the Guidelines;
- Translation of the Guidelines into Arabic and other major Sudanese languages;
- Organization of training and advocacy courses/workshops related to the Guidelines;
- Adoption of supportive policies, strategies, laws and regulations to ensure best utilization of the Guidelines;

- Development of a system for feedback to receive comments from implementing partners for inclusion in future updates of the Guidelines. MIWR/PWC, MWRI and SWCs were selected as focal points for that purpose.

Annex 3: People Contacted in Southern Sudan, July 2008

1. Juma Chisto, Operator of Kator Emergency Water Supply, Juba
2. Habib Dolas, Member of Watsan committee, Hai Jebel
3. Andew Wan Stephen, Member of Watsan committee, Hai Jebel
4. Francis Yokwe, Member of Watsan committee, Hai Jebel
5. William Ali Jakob, Member of Watsan committee, Hai Jebel
6. William Nadow Simon, Member of Watsan committee, Hai Jebel
7. Ali Sama, Director General, Rural Water Department, Central Equatoria State (CES)
8. Engineer Samuel Toban Longa, Deputy Area Manager, UWC, CES
9. Sabil Sabrino, Director General UWC, WBeG
10. James Morter, Technician, UWC, Wau
11. Carmen Garrigos, RPO, Unicef Wau
12. Sevit Veterino, Director General, RWC, WBeG
13. Stephen Alek, Director General, Ministry of Physical Infrastructure (MPI), Warap
14. John Marie, Director of Finance, MPI, Warap State
15. Angelo Okol, Deputy Director of O&M, Warap State
16. Santino Ohak Yomon, Director, RWSS, Upper Nile State
17. Abdulkadir Musse, RPO, Unicef Malakal
18. Dok Jok Dok, Governor, Upper Nile State
19. Yoanes Agawis, Acting Minister, MPI, Upper Nile State
20. Bruce Pagedud, Watsan Manager, Solidarites, Malakal
21. Garang William Woul, SRCS, Malakal
22. Peter Onak, WVI, Malakal
23. Gailda Kwenda, ACF, Malakal
24. Amardine Atsain, ACF, Malakal
25. Peter Mumo Gathwu, Care, Malakal
26. Engineer John Kangatini, MPI, Upper Nile State
27. Wilson Ajwek Ayik, MoH, Upper Nile State
28. James Deng Akurkuac, Department of RWSS, Upper Nile State
29. Oman Clement Anei, SIM
30. Abuk N. Manyok, Unicef, Malakal
31. Jakob A. Mathiong, Unicef, Malakal
32. Emmanuel Badang, UNMIS/RRR
33. Emmanuel Parmenas, DG of O&M, MCRD GOSS
34. Cosmos Andruga, APO, Unicef Juba

Annex 4. Technical Working Group Members

A) At Khartoum level

1) For Slow Sand Filters

   Dr Mohammed Adam Khadam, University of Khartoum
   Dr V. Haraprasad, UNICEF
   Mr. Ibrahim Adam, PWC
   Mr Eshetu Abate, UNICEF - Consultant

2) For Borehole Hand pumps, Hand dug well Hand pumps, Hand dug well Water yards, Mini Water yards and Water yards

   Mr. Mohamed Hassan Ibrahim, GWW
   Mr. Mohy Al Deen Mohamed Kabeer, GWW
   Mr. Abd el Raziq Mukhtar, Private Consultant
   Mr. Mohamed Salih Mahmoud, PWC
   Mr. Mohamed Ahmed Bukab, PWC
   Mr. Mudawi Ibrahim, PWC/WES
   Mr. Yasir Ismail, PWC/WES
   Mr Eshetu Abate, UNICEF - Consultant

3) For Improved Small Dams

   Dr. Mohamed Osman Akoud, University of Khartoum
   Professor Saif el Deen Hamad, MIWR
   Mr. Mohamed Salih Mohamed Abdulla, PWC
   Mr Eshetu Abate, UNICEF - Consultant

4) For Improved Haffirs

   Mr. Mohamed Hassan Al Tayeb, Private Consultant
   Mr. Hisham Al Amir Yousif, PWC
   Mr. Hamad Abdulla Zayed, PWC
   Mr Eshetu Abate, UNICEF - Consultant

5) For Drinking Water Treatment Plants, Drinking Water Distribution Networks and Protected Springs & Roof Water Harvesting

   Dr Mohamed Adam Khadam, University of Khartoum
   Mr. Burhan Ahmed Al Mustafa, Khartoum State Water Corporation (KSWC)
   Mr Eshetu Abate, UNICEF - Consultant

6) For Household Latrines, School Latrines and Rural Health Institution Latrines

Mr. Sampath Kumar, UNICEF
Mr. Fouad Yassa, UNICEF
Dr. Isam Mohamed Abd Al Magid, Sudan Academy of Science
Mr. Badr Al Deen Ahmed Ali, MOH
Ms Awatif Khalil, UNICEF
Mr Eshetu Abate, UNICEF - Consultant

B) At Juba level:

For all facilities:

Mr. Nyasigin Deng, MWRI-GOSS
Ms. Maryam Said, UNICEF- Consultant
Dr. Bimal Chapagain, UNICEF- Consultant
Mr. Marto Makur, SSMO
Ms. Jennifer Keji, SSMO
Ms. Rose Lidonde, SNV
Mr. Elicad Nyabeeya, UNICEF
Mr. Isaac Liabwel, MWRI
Mr. Moris Monson, SC UK
Mr. Peter Mahal, MWRI
Mr. Alier Oka, MWRI
Mr. Emmanuel Ladu, MWRI
Mr. Menguistu T. Mariam, PACT
Mr. Manhiem Bol, MWRI-GOSS
Mr. Eshetu Abate, UNICEF- Consultant
Ms. Rose Tawil, UNICEF
Mr. Mike Wood, EUROPIAN CONSULT
Mr. Sahr Kemoh, UNICEF
Mr. John Pangech, MCRD
Mr. Joseph Brok, MAF
Mr. Gaitano Victor, MAF
Dr. Lasu Joja, MOH-GOSS
Mr. Kees Van Bemmel, MEDAIR
Mr. Lawrence Muludyang, MHLPU
Ms. Anatonia Wani, MARF
Mr. Acuth Makuae, MCRD-GOSS
Mr. Martin Andrew, RWD/CES
Mr. Feliciano Logira, RWD/CES
Mr. Philip Ayliel, MHLPU
Mr. James Adam, MWRI

Annex 5: Sample pictures of storage reservoirs for rainwater harvesting from different countries

Shape formation and methods of construction of ferrocement storage reservoir (India)

Pumpkin type ferrocement storage reservoir (Srilanka)

Storage reservoir from bamboo internally lined with plastic sheeting (India). This type of storage reservoir requires pre-treatment against termite attack

Annex 6: Selected bibliography and references

1. www. Gdrc.org/uem/water/rainwater/introduction.htm
2. WHO, Water, sanitation and hygiene, Fact Sheet No 2.34
3. WHO, Water, sanitation and hygiene, Fact Sheet No 2.4
4. WHO, Water, sanitation and hygiene, Fact Sheet No 2.6
5. www. Rainwaterharvesting.org/urban/components.htm
6. Linking technology choice with Operation and maintenance, O&M Working Group, Water Supply and Sanitation Collaborative Council, WHO and IRC
7. Optimum Investment of Rainwater Harvesting Techniques: By Osman Mohammed Nagger, Abeed Ali Mohammed, Egbal Mohmmed A/Raheem, Mona Mohammed Tom, Zubaida Mohammed Alseid and Isam Mohammed Abdel Magid; Scientific Paper Series, SPS, No 1, Sudan Academy for Sciences Publishing & Distribution House

Contact Addresses for Feedback by WASH Sector Partners

Mr Mohammed Hassan Mahmud Amar
Director General
Public Water Corporation
Ministry of Irrigation and Water Resources
El Sahafa South-Land Port West
P.O. Box 381, Khartoum
Tel: +249 (0)83 417 699
Fax:+249 (0)83 416 799
Email: nwcarm@sudanmail.net

Eng. Isaac Liabwel
Under Secretary
Ministry of Water Resources and Irrigation (MWRI)
Government of Southern Sudan (GOSS)
Hai el Cinema, Juba
Phone: Office: +249 811 823557
Cellular: +249 912 328686
E-mail: Isaac.liabwel@gmail.com

Mr Sampath Kumar
Chief, WASH Section
Water and Environmental Sanitation (WASH) Section
UNICEF Sudan Country Office
House 74, Street 47, Khartoum 2
P.O.Box 1358 – Khartoum - Sudan
Tel.: +249 1 83471835/37 ext 350
Fax: +249 1 834 73461
Mobile: +249 912390648
Email: skumar@unicef.org

Dr Stephen Maxwell Donkor
Chief, WASH Section
Water and Environmental Sanitation (WASH) Section
UNICEF SCO, Juba
Southern Sudan
Tel. : +249 126 537693
Email: smdonkor@unicef.org