Ministry of Water, Irrigation and Electricity

OPERATION & MAINTENANCE MANUAL

Pastoral Areas Water Supply

(Parts A, B, C, D)

Sand and Haffir Dams, Berkas, Rainwater Harvesting

Document 09

Addis Ababa 2018

FOREWORD and ACKNOWLEDGEMENTS

Her Excellency, Mrs Frenesh Mekuria, State Minister of the Ministry of Water, Irrigation and Electricity

Ethiopia has made great achievements during the last 10 years in providing improved water supply service for its rural population. As a result, Ethiopia achieved the Millennium Development Goal (MDG) target in water supply. The target was achieved mainly through the implementation of small community water supplies. Today the number of these small community water supplies is well over 200,000 and serving a population of 50 million rural people. In order to keep these water supplies operational, the National Rural Water Supply (RWS) Operation and Maintenance Management (O&MM) Manual and Strategic Framework was prepared.

The National RWS O&MM Strategic Framework for Ethiopia is an outcome of collective efforts carried out through a consultative process across the nine regional states by the Federal and Regional Governments and Development Partners (DPs).

I wish to acknowledge the invaluable inputs of Ministry of Water, Irrigation and Electricity staff Regional Water Bureaus, Zone and Woreda Water Offices, Community-Led Accelerated WASH Project (COWASH), Water Action, Action Aid, JICA, World Bank, African Development Bank, DFID, UNICEF, Ethiopian Catholic Church Social & Development Coordination Office of Harar, Millennium WASH Alliance, Ethiopian WASH Alliance, all visited rural piped system Water Boards and Water Administration Offices (WAOs), numerous WASHCO members, user communities and several key individuals who gave freely their time, provided data and information and arranged scheme visits. Special thanks go to Demewoz Consultancy Company in the development of this document.

I would like to underscore the technical and financial support and extensive assistance we received from the Government of Finland financed COWASH project in this strategic framework and manual preparation.

I therefore request that all decision-makers, water technical stall at federal, region, zone, woreda, kebele and community levels secure budget for maintenance management and make sure that continuous improved water supply is provided to all Ethiopians. I believe that this manual will make it possible.

Providing rural water services is irreducibly complicated; there is no single solution for sustainability. Sustainable services rely on an interlocking network of different actors and institutions – all of which need to function at least well enough. Sustainable rural water supply means that whole system from regulation through provision of adequately resourced support services is ensured with accountability.

Addis Ababa in March 2018

Frenesh Mekuria
State Minister

Frenesh Mekuria
State Minister
Ministry of Water, Irrigation and Electricity
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TECHNICAL OPERATION AND MAINTENANCE REQUIREMENTS MANUAL FOR PASTORAL AREAS WATER SUPPLY FACILITIES

Pastoral Areas Water Supply

(Parts A, B, C, D)

Sand and Haffir Dams, Berkas, Rainwater Harvesting

PART – A: INTRODUCTION TO PASTORAL AREAS WATER SUPPLY

Document 9

Pastoral Area Water Supply
Sand and Hafir Dams, Berkas, Rainwater Harvesting

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PART – A: INTRODUCTION TO PASTORAL AREAS WATER SUPPLY

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Acronyms

CBMS	Community Based Maintenance System
CBO	Community Based Organization
CMP	Community Managed Project
CSO	Civil Society Organization
DFID	Department for International Development (UK)
DAG	Development Assistance Group
FGD	Focus Group Discussion
GIS	Geographical Information System
GTP	Growth and Transformation Plan
IDA	International Development Agency (WB)
JICA	Japan International Cooperation Agency
ICB	International Competitive Bidding
KDC	Kebele Development Committee
LSP	Local Service Provider
MDG	Millennium Development Goal
M&E	Monitoring & Evaluation
MIS	Management Information System
MoE	Ministry of Education
MFI	Micro Finance Institution
MoWIE	Ministry of Water, Irrigation & Electricity
NCB	National Competitive Bidding
MVS	Multi Village System
NGO	Non-governmental Organization
NWI	National WASH Inventory
O&M	Operation & Maintenance

OWNP	One WASH National Program
PBT	Pressure Break Tank
RPS	Rural Piped System
RWCO	Regional WaSH Coordination Office
RWS	Rural Water Supply
SNV	Netherlands Development Organization
SP	Spare Part
TVETC	Technical Vocational & Educational Training College
UAP	Universal Access Plan
UNICEF	United Nations Children's Fund
WASH	Water Supply Sanitation and Hygiene
WAO	Water Administration Office
WASHCO	Water Supply Sanitation and Hygiene Committee
WDC	Woreda Development Committee
WB	World Bank
WIF	WASH Implementation Framework
WSG	Woreda Support Group
WUG	Water User Group
WWO	Woreda Water Office
WWT	Woreda WASH Team

DEFINITIONS OF TERMS:

Accessibility	Is having a functional and reliable water supply facility without any barriers within a radius of 1500 metres for Rural Water Supply
Access Coverage	Is the percentage of people with access to safe, adequate and reliable water supply within 1500m at 15 l/c/d for rural community
Adequate Water	Is the quantity of water required to meet the minimum demand per capita per day. The standard being 15l/capita/day by 2015 for Rural people
Berkad	Underground reservoir, lined or un-lined, excavated to store surface runoff
Borehole Depth	The term “shallow” in Ethiopia is used to refer to a borehole up to about 60m in depth; “medium” depth refers to 60-150m; “deep” boreholes are drilled up to about 450m
Community	Refers to a group of people living in a designated area who share residential and developmental challenges and benefits. It may also refer to all people sharing such challenges and benefit regardless of geographical and social boundaries
Community Based Management	Is the process of empowering community members to assume the lead role in decision making about the levels of services they require, whilst organizing themselves to plan, implement, operate and maintain their water supply and sanitation facilities.
Community Management	Is a form of community participation in which the community takes the final decision on all aspects of planning, implementation, management, monitoring, evaluation, O&M of the water supply facility
Evaluation	Is the periodic and systematic review and analysis of a practice to determine the relevance, effectiveness, efficiency and impact of programmes/projects compared to the set objectives
Functionality	The term functionality refers to the number or percentage of working/operational rural water supply schemes out of the total number of rural water supply schemes constructed at any given period.
Haffir Dam	Haffir is an Arabic word that express that a type of earth dam serves for people and community water supply. They are ponds dug into natural depressions in arid and semi-arid areas.
Kebele/Tabia	Is the lowest administration unit in the Ethiopian government’s administrational hierarchy
Maintenance	Refers to activities required to sustain the water supply facilities in a proper working condition. It includes preventive maintenance, corrective maintenance and crisis maintenance.
Monitoring	Is the regular and continuous checking of whether plans, activities and situations are being implemented as planned, and includes the provision of feedback to facilitate the taking of corrective measures by relevant stakeholders.
Operation	Operation refers to the routine activities necessary to make the system function
Point Water Supply	In rural water supply context, these are hand dug wells, shallow wells, on-spot springs types of schemes
Preventive Maintenance	Refers to an activity that includes checking the status of hand pump components at regular fixed intervals
Rehabilitation	Is the correction of major defects and the replacement of equipment to enable the facility to function as originally intended.
Reliable Water	Is the supply of water on a continuous basis meeting the minimum demand per capita

Supply	per day
Repair	It is the restoration of a defective component to return the facility to acceptable working condition. The cost of the repair should be borne by the community.
Rural Area	“Areas of population outside urban and peri-urban using point or surface water sources for which the community is responsible for the O&M”. in addition, low population densities characterize rural areas, with small houses isolated from each other.
Rural Piped System	It is a water supply system feeding various villages and small towns by gravity, pumping and a combination system through public taps and yard connections
Sand Dam	is a special type of sub-surface dam built across a seasonal river. It provides a means of increasing water storage capacity by accumulating sand and gravel upstream of the dam, which is raised progressively before each rainy season until it reaches an appropriate height.
Safe water	Is water that is free from harmful quantities of physical, chemical and pathogenic matter and that meets the minimum Ethiopian standards (usually WHO Guidelines)
Seed Money	Is the initial sum of money disbursed to an organization in order to create/start a revolving fund for undertaking a designated programme
Scheme (Water)	The entire facility (concrete works, pipes, pumps) established to extract water from a water source, and distribute it to (close to) people’s homes
Sustainable Supply Chain	Is a system of procuring and supplying spare parts that guarantees a continuous supply of spare parts
Source (Water)	The natural water source only, i.e. spring, groundwater, river, etc
Supply chains	Is the term used for the process that relates all activities involved with the flow and transformation of goods from the raw materials stage through to the end-user, as well as the associated information flows
WASHCO	It is a committee of representatives from a number of Water, sanitation and hygiene Point Committee of the same village. Sometimes WASHCO committee may refer to 2 or more village representatives benefitting from a water and sanitation point.
Woreda	It is the lowest administration unit (next to Kebele), in the Ethiopian government’s administrational hierarchy.

1 INTRODUCTION TO PASTORAL AREAS WATER SUPPLY

1.1 General

Pastoral areas in Ethiopia are found in North east, east and South East of Ethiopia mainly in Afar, Somali, Oromia (Borena) and SNNP regions. Sand dam, Hafir dam and *Berkad's* of water harvesting are well known water supply provision systems in pastoral areas. Thus, this manual is more pronounced to the water supply technological options apply in these areas. Of course, conventional rural water supply technologies accustom in highland areas are also applies in low land areas like in Afar, Oromia and SNNP regions, even in Somali region.

Pastoral production remains the dominant land use in Ethiopia's lowlands, which occur below an elevation of 1500m and constitute between 54% and 61% of the Country's surface area (Coppock, 1994). Pastoralists are defined variously in the literature as those who obtain more than half their income from livestock and livestock products and who characteristically practise mobility to avoid risk, respond to variable climatic conditions and ensure healthy livestock and rangelands.

A further category of agro-pastoralists is defined as those who practise some degree of mobility but obtain less than half their income from livestock, with most of the remainder coming from crop cultivation.

In Afar region, pastoralists make up 90% of the estimated 1.4 million population, with the remainder practising agro-pastoralism. A total of 85% of Somali region's 4.4 million people are pastoralists, (FDRE, 2007; World Bank, 2008), and pastoralists also represent a significant proportion of the population in Oromia and SNNPR's arid lowlands (World Bank, 2008). Agriculture has to date extended to a relatively small area – about 0.3% of the total land area in Afar Region and 5.5% in Somali region (ibid.). However, crop production is becoming more widespread in some areas. For example, in Oromia, where only around 5% of the land is under cultivation (OWWDSE, 2009) the area set aside for crop production in one study area has increased by a factor of 12, from 1.4% in 1986 to 16.3% in the late 1990s (McCarthy et al, 2001).

There are a number of global technology options available for improved rural water supply systems. However, not all can be applied everywhere. In rural of Somali Region, berkad or hafirs (with or without a combination of filtration systems) are a common choice for the supply of drinking water. Hafirs are selected for the simple reason that there are no other water sources like groundwater or surface water sources.

According to the National WASH Inventory, 2013, there were exist 73 Hafir dams, 1,472 Berkad in Somali region.

1.2 Description of Pastoral areas Water Supply Facilities

For centuries, pastoral communities have developed a sophisticated network of water resources – including rivers, rainwater and groundwater-fed permanent sources – and complex customary institutions through which to coordinate development and manage access. This system, including both its physical and its institutional components, critically ensures that the availability and exploitation of water resources does not jeopardise other resources, particularly by avoiding high concentrations of animals, which can threaten the health of the rangeland and livestock itself and lead to conflict.

Afar Region:

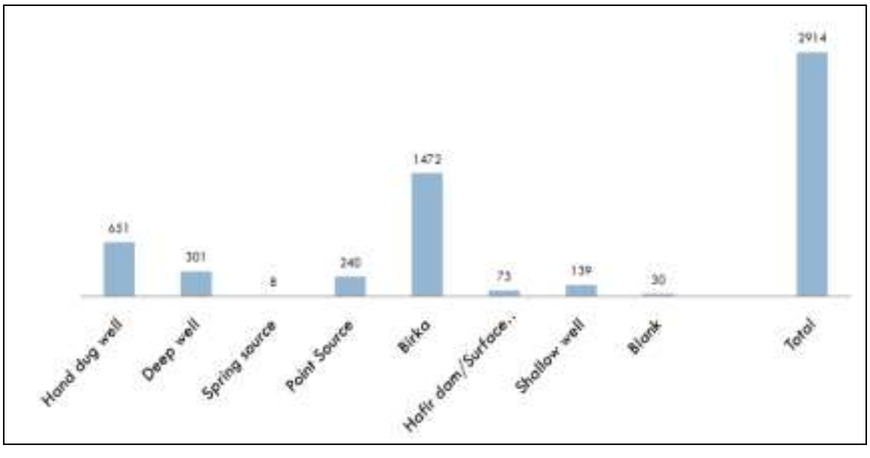
The main sources of water supply in Afar region are Awash and Mille rivers, deep and shallow wells.

Somali Region:

The main water sources for water supply are hand dug well, borehole, followed by Haffir dam and River Intakes. Berkads are traditional water supply system which is constructed by individual household.

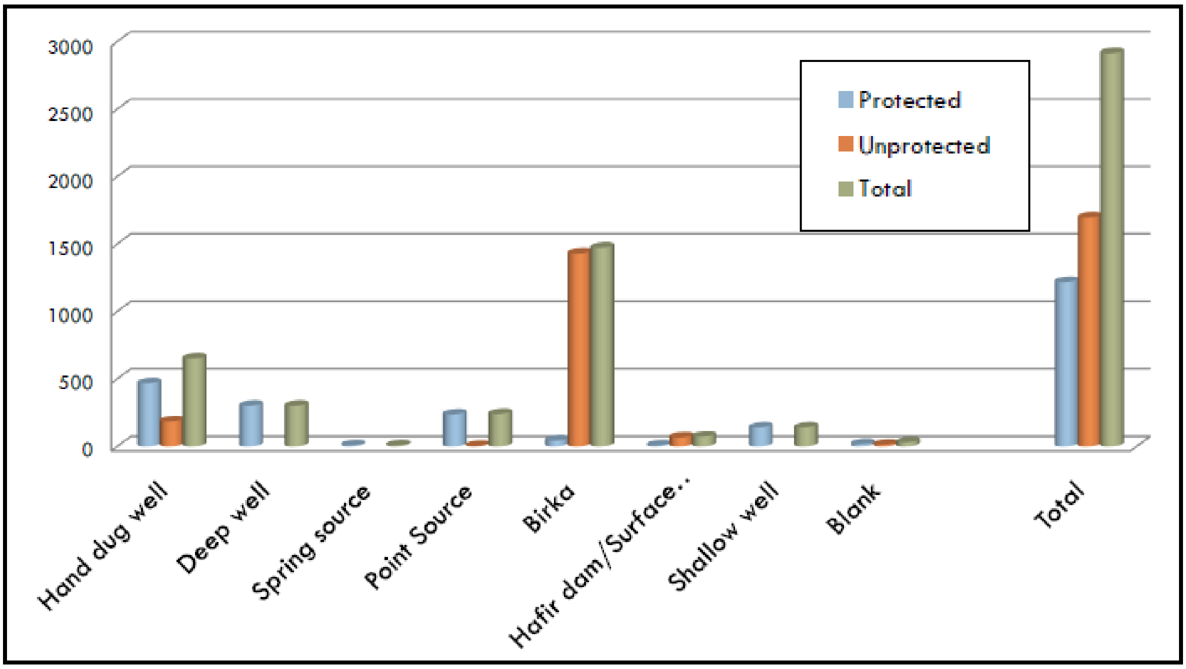
According to the Somali region WASH inventory, there were about 1219 protected water supply schemes and 1,695 unprotected water supply schemes, with a total of 2,914.

Figure 1-1: Number of Water Supply Schemes in Somali Region (WASH Inventory, 2014)



Source: MoWIE, May 2014.

Figure 1-2: Number of Water Supply Schemes in Somali Region (WASH Inventory, 2014) by type



Source: MoWIE, May 2014.

During the inventory, only 60% and 73% of the protected and unprotected water supply schemes were functional, respectively.

1.3 Objectives of Operation and Maintenance

The Manual on Operation and Maintenance is intended to serve as a guide to strengthening the technical, operational and managerial capabilities required of the concerned personal to operate and maintain water supply services as per acceptable norms of quantity, quality, sustainability, reliability and cost.

The manual also helps to:-

- Creating know-how of scheme and financial management by water boards and WASHCOs,
- Create understanding of different water supply technologies and their requirements for operation and maintenance,
- Prepare detailed schedule for operation and maintenance activities.
- To give clear procedure and tact of operation and maintenance.

The core objective in ensuring the sustainability of the schemes through proper O&M management of the schemes, so the water supply service can be sustainable if:

- It functions and is being used;
- It is able to deliver an appropriate level of benefits (quality, quantity, convenience, comfort, continuity, affordability, efficiency, reliability, equity, health);
- It continuous over a prolonged period of time (which goes beyond the life-cycle of the equipment);

- Its management is institutionalized (community management, gender perspective, partnership with local authorities, involvement of formal/informal private sector);
- Its operation, maintenance and administrative and replacement costs are covered by itself;
- It can be operated and maintained by the local operators and caretakers with limited external support like technical assistance, training and monitoring.

Hence, in order to make a system sustainable, at least it requires the consideration and the achievement of the above issues, which is a long process.

1.4 Definition of Operation and Maintenance

1.4.1 Operation

Operation refers to the routine activities necessary to make the system function. The proper operation of a scheme results in its optimum use and contributes to a reduction in breakdowns and maintenance needs.

This involves the correct handling of facilities by the user communities for long use of components of the facilities.

1.4.2 Maintenance

Maintenance refers to periodic inspection, replacement or repairs the damaged parts, cleaning of filters etc. Maintenance can be divided into two types: 1) Preventive maintenance (Planned maintenance), 2) Corrective maintenance (breakdown maintenance) and 3) crisis maintenance (unplanned maintenance).

Preventive maintenance refers to systematic pre-scheduled activities or programmes of inspections and maintenance activities aimed at the early detection of defects and implementation of actions to avoid breakdowns or deterioration. Preventive maintenance is 'pre active' since activities are conducted before a defect occurs. Often the cost of preventive maintenance activities is low compared with corrective maintenance or rehabilitation.

Corrective maintenance refers to activities conducted or repairs carried out as a result of breakdowns or noticeable infrastructure deterioration. Corrective maintenance is inherently 'reactive' in that it is carried out after some defect is discerned, often because the system is not operating as intended.

Crisis maintenance: unplanned responses to emergency breakdowns and user complaints to restore a failed supply.

Rehabilitation: entails the correction of major defects and the replacement of equipment to enable the facility to function as originally intended. Rehabilitation becomes necessary when it is no longer technically feasible or economically viable to maintain a facility in good working order. Maintenance will become uneconomic if the long term cost of rehabilitation and subsequent operation is more favorable than continued repair and maintenance.

1.4.3 Consequences of Poor O&M

It was learnt during the assessment part of this project, 0 & M is not given enough attention and instances of poor operation and maintenance practices have in many occasions largely contributed to:

- decreased quality of the produced drinking water,
- many interruptions of supply and reduction in reliability,
- reduction in lifetime of the various facilities which could lead already in the near future to high rehabilitation cost,
- reduction of sustainability,
- water wastage by many leaks,
- lack of consumer's confidence and resistance for water use,
- Reduction of willingness to pay water bills and consequently less income for the water supply service office.

1.4.4 Causes of poor O&M

Causes of insufficient O&M, which may be attributed to different management levels within the organization, as undertaking's top level management and executive staff, are:

☞ Lack of sufficient funds for operation and especially maintenance activities:

- O&M cost is partly subsidized and has to be substantially covered by revenue collection, which is mostly disappointing, because the billing/collection- ratio is 100% and low water rates that are politically stipulated. Lack of service is generally leading to reduced consumer payments.

☞ lack of knowledge how to organize proper maintenance:

- Inappropriate staffing of the Water Administration Office due to a combination of staff limitations (financial reasons), and inflexible employment agreements (political reasons), Transfer officers from other posting is not so easy too.

☞ lack of know-how and skilled personnel

- Inexpert use of facilities has to prevent,
- Frequently not sufficient training facilities for off - and on- the job training are present.

☞ Lack of information exchange between engineers and operators, e.g. regarding the background of given instructions,

☞ lack of basic means and "tools" for performing proper operation and especially preventive maintenance (e.g. 0 & M manuals, standard procedures, logistical support),

☞ lack of available, stored spare parts and long delivery times, lack of tools and equipment,

☞ **Sub-standard quality** of various materials and equipment (e.g. taps, valves, meters, fittings, Gaskets), causing frequently expensive and time consuming repairs and/or replacements. One of the reasons that cheap, inferior parts are used lays in the tendering procedure in which mostly the cheapest contractor is awarded. The use of inferior materials has also a negative effect on the motivation of staff involved.

- Adequate procedures for commissioning of schemes are mostly lacking. Due to initial defectives O&M suffers already from the beginning.

- Sometimes the organization of the water supply undertaking is not well tailored to O&M activities, maybe due to lower priority of O&M within the undertaking. The concept of being "consumer friendly" is often poorly developed and the number of contacts between supplier and client are restricted.

- Responsible officers and operators are not motivated, or are not aware of the importance of O&M, may have other personal interests, or are so occupied with the day to day administrative duties that less time for O&M activities remains.

- The O&M responsibilities and duties are generally not considered to be attractive or give job satisfaction, due to poor salaries and lack of incentives, encouraging and interest of superiors, logistical support or career possibilities.

1.5 Requirements for Sustainable O&M

In these Manuals, CBM shall be widely endorsed as the essential component of a sustainable O&M approach, with the following being in place:

- **Skills**: Capacity building of communities to ensure that they are effective in their participation at the various stages of the RWS programmes. Considerable investment should be made in terms of time and funding to effectively carry out capacity building initiatives.

- **Awareness**: User communities' appreciation of the advantages of reliable and adequate safe water supply. This will see the manifestation of economic and social benefits and improvement in their health status. This is achieved through public campaigns.

- **Availability of spare parts**: The necessary materials and equipment should easily be available for communities to keep the systems operational using the skills imparted during the capacity building process. Sustainable supply chains should be established at the Woreda level for providing necessary spare parts and materials at a reasonable market price.

- **Adequate fundraising by communities**: Community financing towards O&M activities at the community level should be developed and enhanced. This should include accurate cost determination of O&M for different available technologies.

- **Making funds available for O&M**: Identification and facilitation of income generating activities will have to be undertaken by the Government and support agencies. The establishment of loan schemes could be a bridge towards community financial independence in effectively managing their RWS systems.

- **Legal provisions**: Appropriate legal provisions such as statutory instruments, by-laws, regulations and other similar initiatives should be introduced. This will prompt communities to be committed and to establish clear ownership of the facilities. Local Woredas may have to formulate by-laws to enforce these Manuals.

- **Monitoring and evaluation**: There should be effective monitoring of the entire set up of the O&M systems to ensure sustainable O&M is achieved.

- **Mechanism of quality control**: Mechanisms should be developed that will ensure good workmanship of the water supply installations. Poor workmanship is a recipe for failure of efficient and effective O&M systems.

1.6 Classification of Maintenance

1.6.1 Scheduled (Preventive Maintenance)

It may be defined as the care and servicing by individuals involved with maintenance to keep equipment/facilities in satisfactory operational state by providing for systematic inspection, detection, and correction of incipient failures either prior to their occurrence or prior to their development into major failure.

a) Objectives of POM are to:

- enhance capital equipment productive life,
- reduce critical equipment breakdowns,
- allow better planning and scheduling of needed maintenance work,
- minimize production losses due to equipment failures, and
- promote health and safety of maintenance personnel

The most important principle to keep continuous management support is: *"If it is not going to save money, then don't do it!"*

b) Elements of Preventive Operation and Maintenance (POM):

The following are the list of elements of preventive operation and maintenance.

Table 1-1: Elements of Preventive O&M

No	Elements	Description
1	Inspection	Periodically inspecting materials/items to determine their serviceability by comparing their physical, electrical, mechanical, etc., characteristics (as applicable) to expected standards
2	Servicing	Cleaning, lubricating, charging, preservation, etc., of items/materials periodically to prevent the occurrence of incipient failures
3	Calibration	Periodically determining the value of characteristics of an item by comparison to a standard; it consists of the comparison of two instruments, one of which is certified standard with known accuracy, to detect and adjust any discrepancy in the accuracy of the material/parameter being compared to the established standard value
4	Testing	Periodically testing or checking out to determine serviceability and detect electrical/mechanical-related degradation
5	Alignment	Making changes to an item's specified variable elements for the purpose of achieving optimum performance

No	Elements	Description
6	Adjustment	Periodically adjusting specified variable elements of material for the purpose of achieving the optimum system performance
7	Replacement	Periodic replacement of limited-life items or the items experiencing time cycle or wear degradation, to maintain the specified system tolerance

c) Items necessary for effective POM program:

- accurate historical records of equipment,
- manufacturer's recommendations,
- skilled personnel,
- past data from similar equipment,
- service manuals,
- unique identification of all equipment,
- appropriate test instruments and tools,
- management support and user cooperation,
- failure information by problem/cause/action,
- consumables and replaceable components/parts, and
- Clearly written instructions with a checklist to be signed off.

1.6.2 Un-scheduled (Breakdown) Maintenance

Un-scheduled maintenance helps in preventing breakdown of equipment but totally avoiding is impractical. Some failures could not be identified easily but needs fault tracing and correction in other words trouble shooting. Repairing the failed part cannot be a full solution to the problem as long as reasons of failure are not known. Knowing the exact problem will assist in preventing repetitive failures. As in all repairs and maintenance activities, correct procedures must be followed in repairing break downs. These procedures must be followed in repairing break downs. These procedures include testing by instruments, trouble shooting or any other means but the manufacturer maintenance manual is the best reference to follow correct repair procedures.

1.7 Manual Organization

The entire manual of the Pastoral area Water Supply Technologies has one volumes and eight parts.

Among the other series of the manuals, Volumes – III of the Pastoral area Water Supply Technology OPERATION AND MAINTENACE MANUALS covers the following topics:

PART – A	INTRODUCTION TO PASTORAL WATER SUPPLY TECHNOLOGIES
PART – B	SAND/SUBSURFACE DAM
PART – C	HAFIR DAM AND BERKAD
PART – D	ROOFTOP AND ROCK CATCHMENT RAIN WATER HARVESTING
PART – E	SOLAR POWERED PUMPING SYSTEM
PART – F	WINDPOWERED PUMPING SYSTEM
PART – G	COMMUNITY BASED FINANCIAL MANAGEMENT
PART – H	COMMUNITY BASED SCHEME MANAGEMENT

1.8 Who and How will use this Manual?

This Pastoral area Water Supply Technological options OPERATION AND MAINTENANCE MANUAL and the companion volumes and parts in the series can at best serve as a general reference and guide. As they refer to the information, recommendations, and guidelines contained in them, readers are urged to consider them always in relation to their own specific requirements, adapting and applying them within the context of their actual situation.

Even as they refer to this Manual for information, its users are advised to consult with qualified professionals – whether in the private sector, in the Zone or Woreda Water Offices, or in the regulatory and developmental agencies concerned with the water sector – who have had actual experience in the construction, management, operation, maintenance, and servicing of water supply systems– including those other professionals who can help them in the financial, legal and other aspects.

This manual is intended primarily for the Water Boards / WASHCOs, Operators in charge of the operation and maintenance and any other practitioners and technicians. In addition it is also a useful tool for Ministry of Water, irrigation and Energy, Regional Water Bureaus, Zone and Woreda Water Offices, supporting organizations and relevant stakeholders to support, monitor and evaluate the plan and implementation of the O&M functions to achieve its objective stipulated above.

1.9 Dissemination of the Manual

These manuals are developed by the initiative of the Ministry of Water, Irrigation and Energy (MoWIE) with the financial and technical support of the Finland Government through COWASH. Thus, the manuals will be disseminating to all stakeholders involved in pastoral areas as stakeholders.

COWASH will print all the manuals in a good quality and handover to the MoWIE and then the MoWIE will disseminate this manual to the Regional Water Bureaus: The RWBs in turn will distribute to the Zone and Woreda Water Offices. The Zone or Woreda Water Offices will distribute to the respective EWBs and WASHCOs.

Secondly, the MoWIE will disseminate these manuals to the relevant development partners (World Bank, African Development Bank, DFID, UNICEF) and various NGOs like Water Aid, Action Aid, Water Action, Plan International, SNV, International Rescue Committee, REST, ORDA, ODA and other unmentioned relevant stakeholders.

1.10 Revision of the Manual

These manuals tried to cover all the necessary topics Operation and Maintenance Management of scheme components that demanding rural water supply system, however, due to the various technological upgrading, they can me revised and updated. Hence, periodical updating the technical manual is mandatory so as to fit the technical issue overlooked and to suite to the particular nature of the system for the RWS. Hence, the Water Board / WASHCOs in consultation with MoWIE and Regional Water Bureau, shall update its manual so as to suit the operation and maintenance activities and achieve the following three basic measuring gauges:

- Less costly
- Prompt
- Better service or quality

Updating can be made to these manuals due to the following reasons.

- Update the tasks and responsibilities listed in this manual so as to include new installations or exact recommendation of manufacturers.
- Update the maintenance management system as per the realistic path.
- Update the procedures for procurement and store keeping meeting the service scope.
- Update the system components in the manual to suit the prevailing water supply system components.

Pastoral Areas Water Supply

(Parts A, B, C, D)

Sand and Haffir Dams, Berkas, Rainwater Harvesting

PART – B: SAND/SUBSURFACE DAM

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PART – B: SAND/SUBSURFACE DAM

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2. SAND/SUB SURFACE DAM

2.1 General

In arid and semi-arid areas, sand and gravel deposits associated with streams and rivers can provide water for drinking purposes as well as for irrigation. Such watercourses are generally seasonal, but can be perennial. River beds which are dry, but have green vegetation along their banks and beds that they indicate there must be a source of water in the vicinity, below bed level.

Sand dams are amongst the most cost-effective methods of rainwater harvesting known. They have the potential to provide communities living in dryland areas with an improved local water supply for life, even during periods of drought.

Rural people and most well-diggers know by experience that water can only be found at certain places in riverbeds. They can also give a rough estimate on how deep they have to dig to reach the water. Their knowledge is based on the fact that certain species of trees and vegetation must have roots reaching down and into the water-table in order to survive droughts.

This manual on sand dams is a guideline on how it is operated, maintained and managed both by the community and regional water bureau/Zone or Woreda Water offices.

As a matter of fact, if the components of the sand dams are carefully constructed, the maintenance required is a minimum.

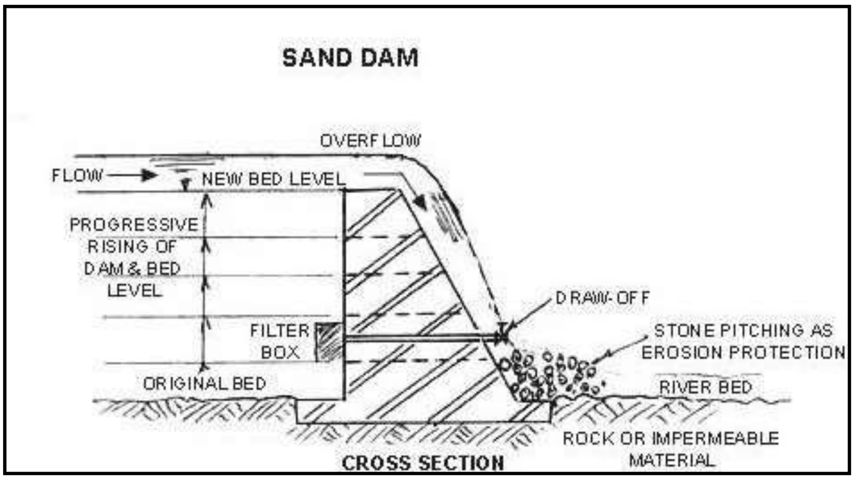
Experiences are shown that sand dam/subsurface dams are constructed in Somali region and Dire Dawa Administration, in most cases by the NGOs.

2.2 What are Sand Dams and Sub Surface Dams?

The terms sand dams and subsurface dams are often used interchangeably for structures built across sand rivers. However, it is useful to make a distinction.

a) Sand Dams

A sand dam is a special type of sub-surface dam built with a reinforced stone masonry wall (or a similarly robust and impermeable weir) across a seasonal riverbed. It provides a means of increasing water storage capacity by accumulating sand and gravel upstream of the dam, which is raised progressively before each rainy season until it reaches an appropriate height.

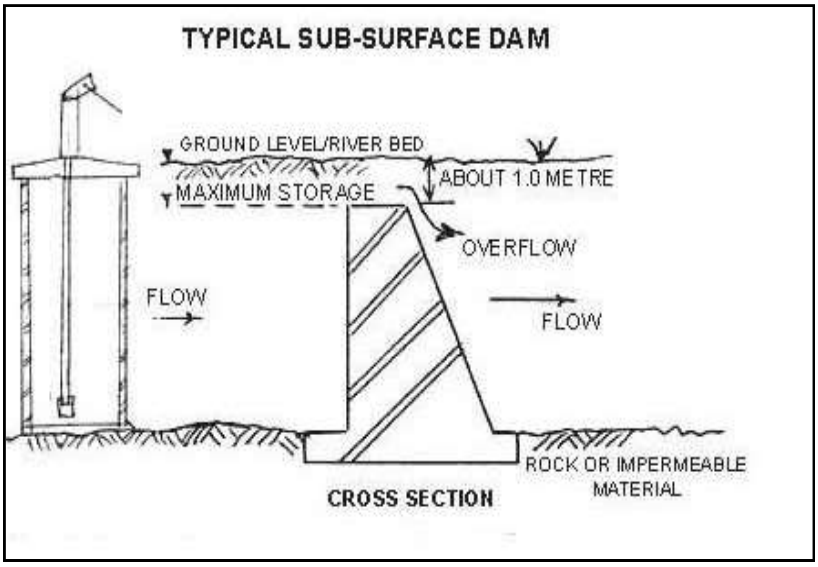


This incremental raising should be to such an extent that it allows finer material such as silts to be washed out of the deposited sand and gravel by the turbulence created at times of overflow. The coarser the sand and gravel collected by the dam, the greater the size of voids and, therefore, the potential storage capacity. Gravels and coarser sands can store up to 35% of their total volume as water.

The final height of the dam is governed by the bank height at its extremities and, in any case, should not be greater than about 5 metres. It should be constructed preferably of concrete or masonry, because its upper surface acts as an overflow weir and has to resist the erosive action of water which is laden with silt and sand in suspension. The above figure is shown a typical cross section of sand dam.

b) Sub-surface dams

Natural sub-surface dams are often the reason for such areas of accumulated water and the resultant greenery. An outcrop of bedrock lying across a river acts as a dam and prevents the downstream flow of the sub-surface water within the sand bed of the river. Seasonal flood flow also saturates the riverbanks.



The improvement of natural sub-surface dams in valleys and rivers beds, and the construction of new ones, is an effective and, usually, an inexpensive means of augmenting water resources. The dam can be constructed of concrete, masonry, block work, stone-filled gabions with waterproof membranes such as plastic sheet or clay layer, or stabilised soil.

2.3 Components

There are four components to consider: the river, the dam, the water reservoir and the method of abstraction.

a) River

Each river is different and therefore the design of a dam has to be appropriate to the situation. The best situation is where the riverbed slopes gently and any dam installed will cause the water to be held up for a considerable distance upstream. Sand dams require high banks or wing walls to prevent flood water cutting round the side. The sand must be plentiful as a dam that fills with too much silt or clay will hold little water. Where a river is large, meandering, and has little slope to the riverbed, dams can be problematic as any obstruction to the flow of water may cause the river to change course, especially if the river banks are low.

b) Dams

Dams have to be constructed on a good foundation and sand dams require a strong apron of rock, masonry or concrete on the downstream side.

c) Water reservoir

The amount of water stored in the dam depends on the quality of sand. Where the sand is coarse, up to 35 per cent of the volume will be available for water storage. During the dry season some of the water will be lost to evaporation but once the water level falls to 50 centimetres below the surface, evaporation virtually ceases.

d) Water abstraction

There are three main ways for water abstraction:

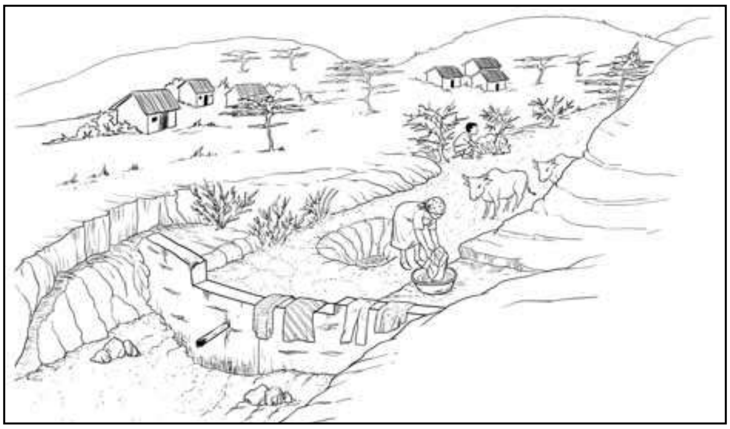
- Digging a hole in the sand and using a scoop made from a gourd to collect the water and pour it into jerrycans
- Constructing a shallow well to the side of the reservoir
- Installing a pipe in the dam wall and drawing off the water below the dam.

2.4 Maintenance and Management

2.4.1 Maintenance of components of the sand dam

2 Dams

Subsurface dams should not require maintenance if they have been well constructed but sand dams may need repairs if there is any damage during periods of major flooding. The most likely damage is from flood waters cutting into the riverbank at the side of the dam wall. Repairs may involve installing wing walls or, if they already exist, strengthening and possibly extending them.



Damage may also occur where the flood waters start weakening the dam on the lower side. Strengthening or extending the apron at the foot of the wall may be needed. When sand dams are under construction it is recommended to leave a gap in the centre of the wall and build it up in stages, adding about 30 centimeters after each flood that has deposited coarse sand. If the wall is built to its maximum height in one operation, there is a risk of silt and clay being deposited.

But when the installation is in stages, the silt and clay should be carried over the wall and the coarse sand will be trapped where it is needed.

3 Water reservoir

The main problem is pollution. Livestock can contaminate the water if they are allowed to wander over the surface. People can contaminate the water if, for example, they bathe, wash laundry, clean motor bikes or cars and let the dirty water back into the reservoir. In one instance a farmer was seen spraying livestock against ticks close to the reservoir. The chemicals could be dangerous for people drawing water for drinking. Urinating or defecating close to the reservoir must be avoided because of the risk of spreading bilharzia (a human disease caused by parasitic worms) or gastroenteritis (infection of the bowel). While some increase in vegetation along the riverbank can be beneficial, it is a mistake to allow plants or bushes to intrude into the dam area as transpiration (loss of water vapor) will reduce the available water. Fencing of the reservoir area is useful in preventing contamination by livestock but this will apply only where a trough for watering animals has been installed.

4 Water abstraction

Water abstraction from a hole dug in the sand is the most common method but there can be problems. Dirty containers will add to the pollution of the water.

A hole has to be dug deeper and deeper as the dry season progresses. The effort of hauling up 20-litre jerrycans from a deep hole can be difficult for children who are often the ones sent to fetch water and there is always a risk of the sand caving in. The hole is also prone to being silted each time there is flow in the riverbed.

Water abstraction from a shallow well installed on the riverbank is a better option as the water at the bottom of the well will have automatically been strained through the sand. However, there is the same need to ensure that the containers used for drawing the water are clean. Wells should preferably be installed above the highest point that floods are likely to reach but if this is not possible, some protection from flood damage will be needed (e.g. raising the well-head platform above high-water levels).

The figure shows shallow well under construction as one of water abstraction from sub surface dam through filter gallery.

Water abstraction through a pipe in the dam wall has certain advantages and disadvantages. Water can be taken from the pipe to a tap stand and a trough for livestock, thereby reducing the risk of pollution. In some situations, there may be a legal requirement to keep a pipe open so that even in dry weather some water is allowed through the dam wall for the benefit of downstream users. In other situations, it may be permitted to put a lockable gate valve or tap on the lower side to prevent wastage of water. But the risk of breakage or theft should be considered and a lockable manhole may have to be constructed. Any pipe installed through the dam wall must have a properly constructed filter on the upstream side or it will soon become blocked.

The maintenance of sand dams and subsurface dams should be the responsibility of a committee representing the local community. Issues on which decisions may be needed include:

- Who has rights to abstract water and what quantity of water is allowed?
- Who is responsible for maintaining a well and the windlass or pump if there is one? Who is responsible for the tap stand if there is one below the dam?
- Can people be allowed to abstract water upstream for vegetable growing?
- If the dam is to be fenced to exclude livestock, who is responsible for this?
- What should be done if sand harvesters come to take the sand for construction purposes?
- What should be done if people are found polluting the water?

One issue that will need more consideration in future is the rights of individuals versus the rights of the community. As individual rights become more firmly established on land that was previously owned by the community, the rights to access and abstract water need to be clearly established.

2.4.2 Warning Signs of Sand Dam Failure

A well designed and constructed dam requires zero or minimal maintenance. The WASHCO along with Zone or Water Offices must regularly inspect the dam for damage, especially after major rains during the first year after construction. The WASHCO along with Zone or Water Offices should be able to identify and implement repairs and preventative maintenance themselves and have the expectation that this is their responsibility. However the supporting implementing organization should remain available to provide advice and support as required.

The warning signs of failure:

- Cracks and leakages through the dam wall and at the base of the dam
- Undercutting of apron
- Erosion around the wings

- Erosion outside the wings
- Erosion of river banks

2.4.3 Monitoring and Preventative Maintenance

2.4.3.1 Sealing Cracks and / or Leaks

A small amount of seepage is to be expected initially. Over time, this seepage will reduce and then stop. If the seepage continues or any visible crack is found, this will need to be repaired. Open the crack, removing any loose mortar, wash and wet it and seal with neat cement for very fine cracks or mortar for slightly wider cracks. For any leakage at the base between the dam and the bedrock or for any large crack (>5mm) a 15cm by 15cm concrete block is created around the crack or leak on both the upstream and downstream side of the dam.

The dam in the picture here is not properly adhered to the bed rock resulting in a steady trickle of water under the dam. In time this leak may grow and undermine the whole dam.

2.4.3.2 Maintenance of Apron and Wings

Any damage to the apron or its foundation must be repaired urgently. The land at the base of the dam wings needs to be protected from erosion. Erosion here can result in an increase in seepage under the wings and ultimately erosion of the wing foundations and failure of the dam. People and animals walking around the dam can cause footpath erosion which in time could result in a gulley. If this is a risk, overland flow must be channelled away from the dam wings and thorns used to prevent people and animals creating further erosion. Any low spots must be back filled with compacted soil or sand bags.

Erosion outside Wings

The dam spillway/s is designed to keep the main flow of the river within the river banks and the peak annual flood (during wet season) within the spillway designed for the MPF. On large rivers, an additional spillway to control the peak lifetime flood may also build. Occasionally, when a flood larger than the PMF is experienced, water will flow over the dam wings. This flow will only occur for a brief period of time and usually will not have enough force to cause significant erosion either at the base of the wings or outside the wings. However it is essential this is regularly monitored especially immediately after particularly heavy rains and / or during the first few years of the dam’s life. If the erosion is not repaired, it will lead to further erosion and potentially failure of the dam.

There are 2 options:

1. If the erosion is minor and the flood which caused the erosion was particularly unusual, sand bags can be used to replace the eroded soil and prevent further erosion.

2. However if the erosion is more significant and occurs more regularly, the dam wings will need to be raised and extended. The outer limits of the wings can be extended using sand bags.

2.4.3.4 Bank erosion and changes in River Course

A clear picture of how the dam will affect how the river flows can only be gained once the dam is full of sediment. During this time, the river banks both upstream and downstream of the dam should be inspected for erosion and grasses planted to protect banks and keep the river flowing in its original course. Some erosion is a natural part of a river's life. However additional erosion resulting from the dam must be managed. If the erosion cannot be managed by planting vegetation, the river's flow must be managed by (1) extending and / or raising the wings or (2) altering the positioning of spillway(s) to control the position of the main flow of the river.

2.4.3.5 Managing gulley erosion

As explained above, gulley's above the dam must be reclaimed prior to the dam construction. However, these measures need to be monitored and if necessary reinforced. As gulley's are filled in, more check dams should be built and Sisal plants planted to continue the process and terraces should be inspected and if necessary maintained.

2.4.3.6 Cleaning of the Outlet

It is very important that the outlet isn't blocked with silt of other fine textured material. Therefore during construction it is always important to have a good access to the outlet construction. Blocking of the outlet can be prevented by the designing criteria. Also cleaning of the riverbed after a flood, can prevent silt from blocking the outlet.

2.4.3.7 Removing silt from the top of riverbed of the reservoir

The riverbed of the reservoir has to be cleaned: rocks, branches, leaves, dead animals, animal dropping and fine textured material can reduce the capacity of the dam, lead to blocking of the reservoir and outlet or cause, causes damage to the dam structure and lead to contamination of the water within the reservoir. Debris like rocks, branches, leaves and sediment are usually deposited after a flood event, so the time of inspecting is well known. But dead animals, animal dropping and other debris can be deposited any time. It is wise to have a strict schedule for inspection of the dam and its surroundings.

2.4.4 Trouble Shooting

The following are the potential unexpected problems, what might be the causes and the solutions:

Table 2-1: Trouble shooting for sand dam/sub surface dam

No.	Problem	Probable cause	Possible solution
1	Water in sand dam but nothing in the well	▪ No connection between sand dam and shallow well. ▪ Blockage of filter drain to shallow well	Excavation and repair of filter drain
2	No water in the sand dam	▪ Lack of inflow ▪ Seepage under or around the wall of the sand dam ▪ Faulty leaking draw off pipe	Check for seepage path and take measures to prevent seepage by sealing flow path with clay or waterproof plaster on upstream face of wall. Fix leaky draw off pipe
3	No water in the sand dam	Dam full of silt not sand. Dam may be incorrectly sited in a water course with insufficient sandy material or wall raised too quickly during construction which can result in a top layer of silt which prevents water seeping into the lower sandy material	Remove silt if the water course has sufficient sandy material
4	Wall at risk from erosion undermining the wall	▪ Turbulent and erosive water spilling over the wall. ▪ Lack of sufficient protection for toe of wall	Place grouted riprap to create protective apron on downstream toe of wall
5	Polluted water	Livestock or human activities polluting surface area of dam resulting in contamination of the water.	Control access through establishing clear rules of access and behavior and monitoring compliance to the rules
6	No sand	Sand harvested for construction purposes	Control access through establishing clear rules of access and regulate quantity of sand harvested from the sand dam.

2.4.5 Tools, Spare parts and Technical Assistance

a) Tools

- Shovels, pick axes, wheel barrows for moving silt and undertaking repair of wall

b) Spares – include:

- Valves for outlet
- Taps and tap washers

Supply Chain – O & M materials can be purchased at a well provisioned hardware store.

c) Technical Assistance

Technical assistance should be sought if the sand dam signs of excessive erosion at the edge or downstream toe of the wall. If the sand dam is actually full of silt, technical assistance may be required to determine the best course of action. If there is no water in the shallow well, technical assistance to determine best course of action may be required.

The technical assistance is expected from the Regional Water Bureau, Zone or Woreda Water Offices or implemented agency like the NGOs that depending the magnitude of maintenance needed.

2.4.6 Sand dam management

Management of the sand dam is done to ensure that the sand dam meets the needs of the community and is sustainable. The purpose is to ensure that the sand dam is robust and well maintained and the benefits to the community are maximized.

2.4.6.1 Controlling large scale abstraction of sand

Small scale sand abstraction for construction is not a problem. However, large scale removal of sand reduces the sand dam aquifer and increases bank erosion and must be controlled. Large scale abstraction is most common at sites close to large towns and cities.

2.4.6.2 Controlling large scale water abstraction and water scarcity

A common concern of community groups is that the water in a sand dam will be exhausted by bulk abstraction. The group must monitor water usage and levels and where necessary use legal and physical means to control water abstraction. Although anyone is permitted to take water from scoop holes, the group will often control water abstraction at times of scarcity from wells, tanks and pipes by locking / controlling access to the taps, pumps and access covers and restricting the use of petrol powered pumps for taking water in bulk from scoop holes. The need to physically control abstraction often influences their choice of abstraction technology.

2.4.6.3 Management and maintenance of abstraction technologies

Where the dam is registered and owned by a certain WASHCO/Community, the group is responsible for monitoring and managing the water abstraction points. This includes monitoring:

- Water levels in scoop holes, off-take wells and tanks and maximum abstraction rates.
- Water usage including any bulk abstraction for irrigation and use by animals.
- Simple water quality indicators such as any change turbidity (the cloudiness of the water), salinity, taste, colour and odour. In addition, it is desirable to monitor bacteriological quality. However this is not always possible and usually requires external support from either the implementing NGO or a water testing facility. The Woreda Water offices can often advice on the water testing.
- Incidence of water borne illness amongst users.
- Any damage to pipes, tanks, well heads, pumps or taps.
- Water charges (if applicable) and expenditure on maintenance and repair.

As part of the construction and installation process members of the WASHCOs should be trained on carrying out maintenance and repairs such as pump priming and replacement of pump valves and taps. Any difference between the water level in a neighboring scoop hole and the water level in an off-take well or tank indicates that the infiltration gallery has insufficient capacity and / or become clogged with fine sediments and the gallery will require expansion and / or overhaul.

2.4.6.4 Monitoring and managing livestock usage

Communities fence scoop holes that are used for people and to keep livestock out. Groups often construct a cattle watering trough below the dam to further this separation of people and animals. Because water can be accessed from multiple scoop holes along a sand river, the risk of environmental degradation is less concentrated in one location. However, a reliable water source in dry area will attract people and animals from a wide area and the group will need to monitor and manage livestock usage through negotiation, charges and the use of customary law.

2.4.6.5 Managing payment and maintenance systems

As part of its responsibility for managing the dam and any abstraction system, the WASHCO must put in place a system for funding any maintenance and repair work. Two major advantages of sand dams are: (1) they have little or no maintenance and operation costs and (2) through livestock watering, vegetable and tree nurseries and block making, they significantly improve incomes.

As a consequence, users are willing and able to pay the costs of repair and maintenance. Because the cost is often small, unpredictable and one-off, users will agree to contribute as required rather than through regular payments. When the costs of operation and maintenance are on-going and predictable, the WASHCO will introduce water charges to raise the necessary income. When WASHCO members come together to irrigate land, they will agree a system to pay for the pump and its operation and maintenance.

If a sand dam is to be used as a bulk water supply for a piped network of taps and water points, the whole abstraction, pumping, storage and distribution system will require a planned maintenance and management plan. Such a plan will describe:

- The on-going operation of the pump and water points including metering and recording all flows at the pump, private connections and public taps.

- The routine maintenance of the powered pump.
- The repair of and scheduled replacement pipes, tanks and taps including (where required) the engagement of external support from Woreda Water Offices/ NGOs will be able to advice on maintenance schedules and typical design lives.
- An annual budget for income and expenditure including the staffing of water points and reserves for major repairs and the governance and management of the system.
- Decisions over payment and maintenance systems and how the dam water will be used must be made prior to any decision to build a dam.

Annexes

Annex A: References

Sand Dams: a Practical Guide, by Simon Maddrell and Ian Neal, Excellent Development Ltd, 2012

Manual on Sand Dams in Ethiopia, Ethiopian Rainwater Harvesting Association and Rainwater Harvesting Implementation Network,

Pastoral Areas Water Supply

(Parts A, B, C, D)

Sand and Haffir Dams, Berkas, Rainwater Harvesting

PART – C: HAFFIR DAM AND BERKAD

<u>Document 9</u>

PART – C: HAFFIR DAM AND BERKAD

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3. HAFFIR DAM AND BERKAD

3.1 General

Pastoral areas in Ethiopia are found in Afar, Somali, Oromia (Borena) and SNNP regions. Haffir dams and *Berkads* of water harvesting are well known in Somali region, to some extent in Borena area. Thus, this manual is more pronounced to the Somali region.

There are a number of global technology options available for improved rural water supply systems. However, not all can be applied everywhere. In rural of Somali Region, Haffirs (with or without a combination of filtration systems) are a common choice for the supply of drinking water. Haffirs are selected for the simple reason that there are no other water sources like groundwater or surface water sources The Sudan with over 1,500 Haffirs nationwide, is one of the few countries using this unique water harvesting systems for arid zone areas.

In Southern Sudan, Haffirs provide water to livestock, agriculture, humans and to some extent wildlife. This manual focus on the application of technology in the operation and maintenance of an improved Haffir (Haffir with a treatment system) intended to serve as sources of drinking water for the human population.

Haffir dam and Berkads are synonymous that both are catchments of the surface run-off for water supply of human consumption and livestock's. They are constructed from earth and concrete as traditional collection and storing of water. An improved of both systems is equipped water treatment facilities in order to produce potable water.

According to the National WASH Inventory, 2013, there were 73 Haffir dams, 1,472 Berkads in Somali region.

3.2 Purpose of this Manual

The purpose of this O&M manual is to provide a guide to communities, WASHCOs, technicians, caretakers, regional water bureaus/ zone and woreda water offices and others who are considering developing a water source for agricultural, livestock watering or domestic purposes.

3.3 What is Haffir Dam?

Haffir is an Arabic word that express that a type of earth dam serves for people and community water supply.

Haffirs are ponds dug into natural depressions in arid and semi-arid areas. Soil removed from the Haffirs can be used to form banks surrounding the reservoir to increase its volume. Haffirs typically range in size from 500 to 10,000 cubic meters and provide water for both livestock and domestic purposes. In the past most Haffirs were dug by hand, but today heavy machinery is used when building larger Haffirs.

An 'improved Haffir' is one with a water treatment system that can provide drinking water primarily for human consumption. A Haffir without a water treatment system that is used for purposes other than drinking may not be classified as 'improved Haffir'

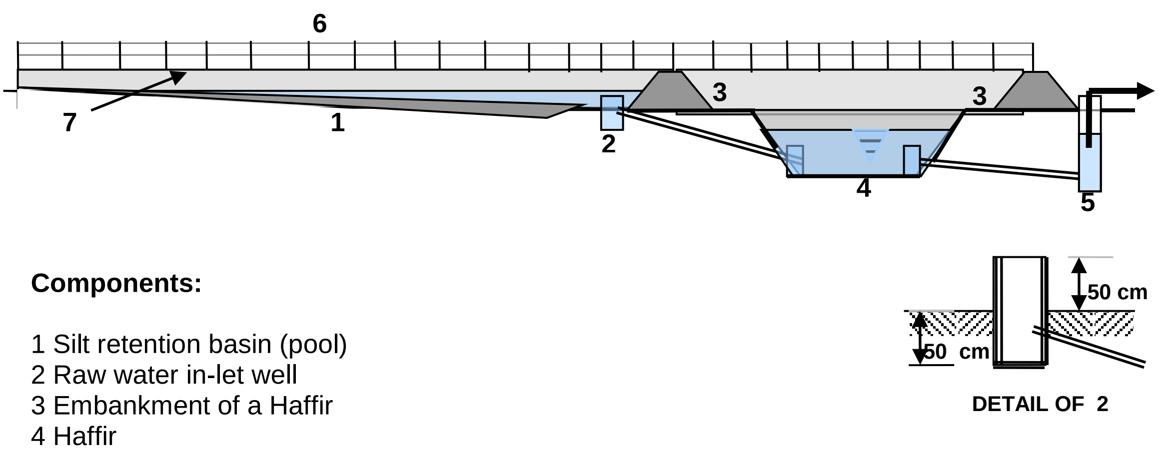
- Haffirs are rectangular or semi-circular impoundments that store water to be used by both human and livestock population during the dry season.

- Haffir size varied from 15,000m^3 to 100,000m^3.

Haffirs should be fenced and protected. Fencing should include the silt retention area in order the community be able to manage the whole available water source and to minimize pollution and hygiene hazards during storage and abstraction.

Figure 3-1: Picture shows a typical Haffir Dam

Figure 3-2: Longitudinal section and arrangement of components of a Haffir



Components:

1 Silt retention basin (pool)
2 Raw water in-let well
3 Embankment of a Haffir
4 Haffir
5 Raw water abstraction well (or intake for the treatment system)
6 Fences
7 Flow diversion embankments

3.4 What is Berkad?

A *Berkad* is a catchment for surface run-off. In its most primitive form, this is simply an excavation in poorly permeable soil to a few meters depth. Surface run-off during rainfall is directed to the excavation. As run-off collects in the pool, clayey and silt sediments settle, eventually forming a seal at the base of the *Berkad*.

Modern *Berkads* are constructed with concrete and consist of a catch-pool before the main pool to act as a sediment trap. The majority of concrete *Berkads* are privately owned and used not only for domestic water supply, but also for livestock and agricultural activities.

The most typical concrete *Berkads* are rectangular, approximately 20m long, 8m wide and 4m deep.

They may be fenced or covered by thorny scrub to deter wild animals prevent them falling into the pool. During rainy periods, most *Berkads* fill in a matter of hours, depending on rainfall intensity. The water does not however last long in the dry period due to the small size of the *Berkad* and the large number of users. When *Berkads* dry, refilling is usually done from the nearest permanent sources via tankers. Water is fetched from *Berkads* using a bucket-on-a-rope system. Contamination from animal excreta and other foreign particles is high, since the top is open. Animals or even people also risk falling into the open *Berkads*.

Berkads are ground tanks that are excavated and lined with concrete blocks or ferro-cement in the semi desert regions. Rainwater is diverted into the Berkads by soil or stone bunds sloping upwards from Berkads on hillsides.

Silt traps, as seen in the photo, are made as small Berkads before water flows into the water reservoir. Strangely, the standard design of most Berkads is rectangular with vertical walls that crack due to external pressure of the soil when the Berkads dry up. The much stronger circular and oval-shaped design was only observed in a few places.

3.5 Components of Haffir Dam and Berkad

Haffir and Berkad are synonymous unless they are differentiating by size and appurtenant structures. In Somali region the dam is known by the name “Berkad”, while in North and South Sudan by “Haffir”. It can be differentiated as traditional and improved. It is called improved if the system associated with treatment facility like slow sand filter.

See the main components of the Haffir dam on figure 3.1 above, for Berkads the following are the main components:

1. Silt retention basin (pool) made with concrete or masonry
2. Raw water inlet well made with concrete or masonry
3. Berkad: rectangular or circular structure made with masonry or concrete,
4. Most Berkads are traditional with no treatment facility,
5. Fence
6. Outlet lined channel of excess water

3.6 Managing Haffir Dam and Berkad

The maintenance and sustainability of Haffir dam requires the involvement of skilled personnel. It is recommended that a joint community/Zone or Woreda Water Office management system is applied for a transitional period, during which management remains the responsibility of the community, whilst ZWO/WWO takes charge of monitoring and the technical aspect of maintenance. To ensure a strong and capable community management system, capacity needs of the community members should be identified and strengthened during the transitional period.

The size and makeup of the management committee (ensuring gender balance) will depend on location and the revenue generating capacity of the facility. The minimum number on a committee should not however, be less than 5 as specified elsewhere in the other part of the manual.

A community-based management system that is enforced by viable tariff and strong legislations are recommended. A substantial part of the revenue should be allocated to maintain and improve the facilities.

Extensive training of communities and local authorities together with awareness campaigns on the danger of guinea worm is necessary to ensure that Haffir water is only used for by humans when it is treated.

3.7 Operation and Maintenance of Haffir Dam

- Every inlet and outlet well should be cleared from silt and debris before the rainy season. When necessary, depending on the volume of material deposited in, the silt retention basin should be cleared and removed outside of the drainage area.

- After every rainy season, an inspection of the components of the improved Haffir is a good practice. This information should be recorded, and recommendations for the next maintenance schedule included in the report.

- A Haffir dam is considered improved when the water abstracted from the dam is treated appropriately to obtain the required quality. Abstracted water is conveyed to the treatment facilities either by gravity or pumping. If abstraction is by gravity, regular cleaning of the inlet is required: this may be more frequent during the flooding season and when necessary during the dry season. If water is abstracted by pumping, the manufacturer's guidelines on operation and maintenance should be followed or the operation and maintenance of other parts of this manual should be referred.

- Haffir dams should be inspected periodically, prior to the season and after every heavy rain, to determine if there is a need for repairs. Check the dam for any seepage or cracks. If there is seepage on the embankment body, consult an engineer immediately for advice on correcting the problem promptly to prevent the condition from getting worse.

- Maintenance work, begins after completion of the construction, and includes removal of trees, bushes and grasses from the reservoir. Debris including floating trees can create problem at the dam. Organic material that does not decay can create an undesirable odour in water. Before filling the dam with water, soil cracking that caused by desiccation must be closed up. The dam will be threatened by sliding if such actions were not taken.

- Erosion caused by rain or wave action in the reservoir must be controlled. Where it is possible and appropriate, plant grass (not trees) as a protective measure against erosion on the outer face

- Dams may lose their storage capacity due to siltation. Soil and water conservation activities of the catchment area, like planting trees, terracing, check dams, prevention of overgrazing, etc, should be part of the O&M activity in order to minimize the rate of siltation and deposition of sediment material in the reservoir.

3.7.1 Fence the reservoir

Where feasible it is often appropriate to fence off reservoirs to keep livestock out. This helps to maintain better quality water and avoids the problem of cattle getting stuck in the mud. So, fence should be regularly inspected whether broken or not. If broken, it must be immediately repaired by the caretaker.

3.7.2 Control pollution/contamination

To prevent contamination of Haffir dam reservoirs by people bathing, washing clothes, and watering livestock directly in the reservoirs, build washing stands and bathing facilities on outer side of a dam wall next to the draw-off point. The waste water from washing stands, bathing facilities and draw-off points can be diverted to irrigate a small vegetable garden. Where the slope is sufficient, a watering trough for livestock can be included.

3.7.3 De-silting of the reservoir

Rainwater transports topsoil and other light surface particles from a catchment to a dam reservoir where some of it settles to the floor of the reservoir as a layer of silt. A layer of silt that is only a few centimeters thick is good because it reduces seepage, but thicker layers of silt decrease the water storage capacity reducing the period during which water can be drawn from a dam reservoir. Catchments without soil conservation and ponds or dams without silt traps may result in dam reservoirs that cannot store any water after only ten years.

De-silting can be done using any of the techniques suitable for construction (manual, draught animal traction or mechanical).

De-silting should be done regularly, preferably once a year in areas where heavy siltation occurs. The depth of silt deposited (and hence the quantity to be removed) can be measured easily if a marked post is installed in the reservoir floor at the time of construction. De-silting should be carefully supervised to ensure that the very bottom layer of silt, which helps seal the reservoir, is not removed.

3.7.4 Operation of the Raw Pumps

3.7.4.1 Important Points for Operation

The following Important points shall be observed while operating the pumps:

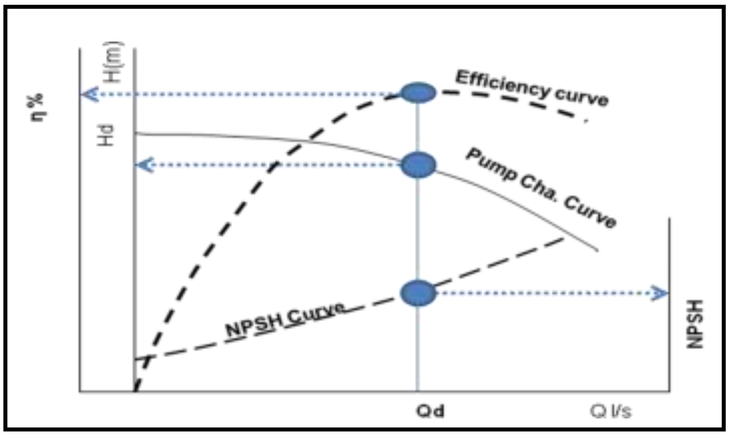
a) Dry running of the pumps should be avoided,

b) Centrifugal pumps have to be primed before starting,

c) Pumps should be operated only within the recommended range on the head-discharge characteristics of the pump,

- If pump is operated at point away from duty point, the pump efficiency normally reduces.
- Operation near the shut off should be avoided, as the operation near the shut off causes substantial recirculation within the pump, resulting in overheating of water in the casing and consequently, in overheating of the pump.

d) Voltage during operation of pump-motor set should be within + 10% of rated voltage. Similarly current should be below the rated current as per name plate on the motor.



e) Whether the delivery valve should be opened or closed at the time of starting should be decided by examining shape of the power-discharge characteristic of the pump. Pump of low and medium specific speeds draw lesser power at shut off head and power required increases from shut off to normal operating point. Hence in order to reduce starting load on motor, a pump of low or medium specific speed is started against closed delivery valve.

Normally the pumps used in water supply schemes are of low and medium specific speeds. Hence, such pumps need to be started against closed delivery valve.

The pumps of high specific speed draw more power at shut off. Such pumps should be started with the delivery valve open.

f) The delivery valve should be operated gradually to avoid sudden change in flow velocity which can cause water hammer pressures.

It is also necessary to control opening of delivery valve during pipeline - filling period so that the head on the pump is within its operating range to avoid operation on low head and consequent overloading. This is particularly important during charging of the pumping main initially or after shutdown. As head increases the valve shall be gradually opened.

g) When the pumps are to be **operated in parallel**, the pumps should be started and stopped with a time lag between two pumps to restrict change of flow velocity to minimum and to restrict the dip in voltage in incoming feeder. The time lag should be adequate to allow to stabilize the head on the pump, as indicated by a pressure gauge.

h) When the pumps are to be **operated in series**, they should be started and stopped sequentially, but with minimum time lag. Any pump, next in sequence should be started immediately after the delivery valve of the previous pump is even partly opened.

Due care should be taken to keep the air vent of the pump next in sequence open, before starting that pump.

i) The stuffing box should let a drip of leakage to ensure that no air is passing into the pump and that the packing is getting adequate water for cooling and lubrication. When the stuffing box is grease sealed, adequate refill of the grease should be maintained.

j) The running of the duty pumps and the standby should be scheduled so that no pump remains idle for long period and all pumps are in ready-to run condition. Similarly unequal running should be ensured so that all pumps do not wear equally and become due for overhaul simultaneously.

k) If any undue vibration or noise is noticed, the pump should be stopped immediately and cause for vibration or noise be checked and rectified.

l) Bypass valves of all reflux valve, sluice valve and butterfly valve shall be kept in closed position during normal operation of the pumps.

Frequent starting and stopping should be avoided as each start causes overloading of motor, starter, contactor and contacts. Though overloading lasts for a few seconds, it reduces life of the equipment.

3.7.4.2 Undesirable Operations

Following undesirable operations should be avoided:

1. Operation at Higher Head

The pump should never be operated at head higher than maximum recommended. Such operation results in:

- Excessive recirculation in the pump,
- Overheating of the water and the pump,

- The radial reaction on the pump shaft increases causing excessive unbalanced forces on the shaft which may cause failure of the pump shaft.

As a useful guide, appropriate marking on pressure gauge be made. Such operation is also inefficient as efficiency at higher head is normally low.

2. Operation at Lower Head

If pump is operated at lower head than recommended minimum head:

- Radial reaction on the pump shaft increases causing excessive unbalanced forces on shaft which may cause failure of the pump shaft.

As useful guide, appropriate markings on both pressure gauge and ammeter are made.

Such operation is also inefficient as efficiency at lower head is normally low.

3. Operation on Higher Suction Lift

If pump is operated on higher suction lift than permissible value:

Pressure at the eye of impeller and suction side falls below the vapor pressure, it results in flashing of water into vapor.

These vapor bubbles during passage collapse resulting in:

- Cavitations in the pump,
- Pitting on suction side of impeller and
- Casing and excessive vibrations,
- In addition to mechanical damage due to pitting, discharge of the pump also reduces drastically.

4. Throttled operation

At times if motor is continuously overloaded, the delivery valve is throttled to increase head on the pump and reduce power drawn from motor. Such operation results in inefficient running as energy is wasted in throttling. In such cases, it is preferable to reduce diameter of impeller which will reduce power drawn from motor.

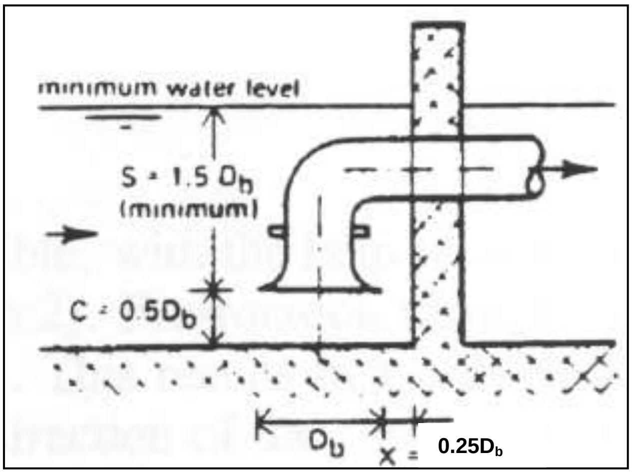
5. Operation with Strainer/Foot Valve Clogged

If the strainer or foot valve is clogged, the friction loss in strainer increases to high magnitude which may result in pressure at the eye of the impeller falling below water vapor pressure, causing cavitations and pitting similar to operation on higher suction lift.

The strainers and foot valves should be periodically cleaned particularly during rainy season.

6. Operation of the Pump with Low Submergence

Minimum submergence above the bell mouth or foot valve is necessary so as to prevent air entry into the suction of the pump which gives rise to vortex phenomenon causing excessive vibration, overloading of bearings, reduction in discharge and efficiency. As a useful guide the lowest permissible water level is marked on water level indicator.



Thus, the submergence depth shall be 1.5 X the diameter of the bell mouth. The operator should always check this requirement by looking the water level indicator.

7. Operation with Occurrence of Vortices

If vibration continues even after taking all precautions, vortex may be the cause. All parameters necessary for vortex-free operation should be checked.

3.7.4.3 Checks before Starting

Box 1: Things to be checked when staring the pump operation

Following points should be checked before starting the pump.

- Power is available in all 3 phases,
- Trip circuit for relays is in healthy state
- Check voltage in all 3 phases,
- The voltage in all phases should be almost same and within + 10% of rated voltage, as per permissible voltage variation,
- Check functioning of lubrication system specifically for oil lubricated and clear water lubricated VT pumps and oil lubricated bearings,

- Check stuffing box to ensure that it is packed properly,
- Check and ensure that the pump is free to rotate,
- Check over current setting if the pump is not operated for a week or longer period,
- Before starting it shall be ensured that the water level in the sump/intake is above low water level and inflow from the source or preceding pumping station is adequate.

3.7.4.4 Starting and Operation of Pumps

Procedures for starting and operation of different types of pumps are described below:

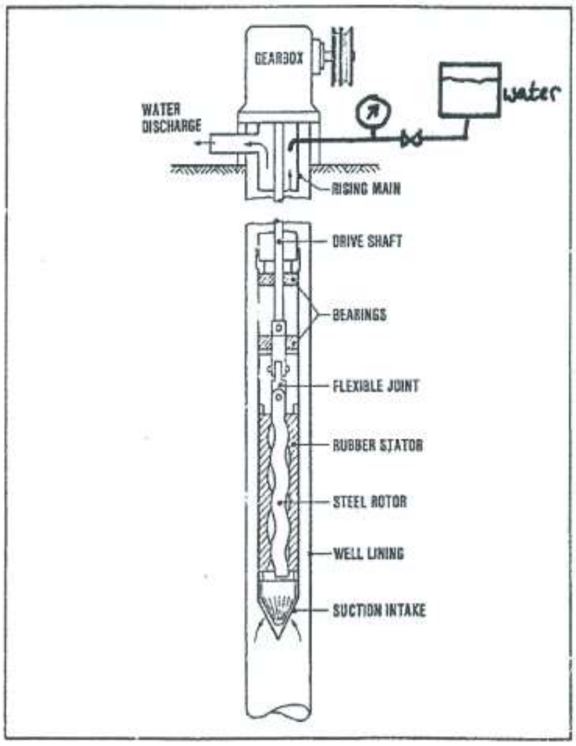
a. Centrifugal Pump (low and medium specific speed)

i) To start a centrifugal pump, the suction pipes and the pump should be fully primed irrespective of the fact whether the pump is with positive (flooded) suction or suction lift.

The centrifugal pump with positive suction can be primed by opening valve on suction side and letting out air from the casing by opening air vent.

Centrifugal pump on suction lift necessitates close attention to prime the pump fully.

To achieve this, the suction pipe and the pump casing must be filled with water and entire air in suction piping and the pump must be removed. If vacuum pump is provided, the pump can be primed by operating vacuum pump till steady stream of water is let out from delivery of vacuum pump. In absence of vacuum pump, priming can be done by pouring water in casing and evacuating air through air vent or by admitting water from pumping main by opening bypass of reflux valve and delivery valve. Check all joints in the suction pipe and fittings.



ii) Close the delivery valve and then loosen slightly.

iii) Switch on the motor, check that direction of rotation is correct. If the pump does not rotate, it should be switched off immediately.

iv) Check vacuum gauge, if the pump operates on suction lift. If the pointer on gauge gradually rises and becomes steady the priming is proper.

v) Pressure gauge should be observed after starting the pump. If the pump is working correctly, the delivery pressure gauge should rise steadily to shut off head.

vi) When the motor attains steady speed and pressure gauge becomes steady, the delivery valve should be gradually opened in steps to ensure that the head does not drop below recommended limit. (In the absence of recommendations, the limit shall be about 85% of duty head for centrifugal pump).

vii) Check that ammeter reading is less than rated motor current.

viii) Check for undue vibration and noise.

ix) When in operation for about 10-15 minutes, check the bearing temperature, stuffing box packing, and leakage through mechanical seal and observe vibrations, if any.

x) Voltage should be checked every half an hour and should be within limit.

b. Vertical Turbine Pump (of low and medium specific speed)

i) Close delivery valve, and then loosen slightly.

ii) If pump is oil-lubricated, check the oil in the oil tank and open the cock to ensure that oil is flowing at the rate of 2-4 drops per minute.

If the pump is self water-lubricated and length of column assembly is long (15 m or above), external water shall be admitted to wet and lubricate the line shaft bearings before starting the pump.

If the pump is external clear water lubricated, the clear water lubricating pump should be started before starting main pump.

iii) Open the air vent in discharge/delivery pipe.

iv) Switch on the motor and check correctness of direction of rotation. If the pump does not rotate, it should be switched off immediately.

v) Check that oil is flowing into the pump through the sight glass tube. The number of drops/min. should be as per manufacturer's recommendations (normally 2-4 drops/minute).

For clear water lubricated pump, check that lubricating clear water is passing into the column assembly.

vi) Check pressure gauge reading to ensure that pump has built up the required shut off head.

vii) When the motor attains steady speed and pressure gauge becomes steady, the delivery valve should be gradually opened in steps to ensure that the head does not drop below recommended limit. (In absence of recommendation, the limit shall about 75% of duty head for VT & submersible pump).

viii) If steady water stream is let out through air vent, close the air vent.

ix) Check that ammeter reading is less than rated motor current.

x) Check for undue vibration and noise.

xi) When in operation for about 10-15 minutes, check bearing temperature, stuffing box packing and observe vibration if any.

xii) Voltage should be checked every half an hour and should be within limit.

c. Submersible Pumps

Starting of a submersible pump is similar to vertical turbine pump except that steps- ii, v, and xi are not applicable and since motor is not visible, correctness of direction of rotation is judged from pressure gauge reading which should indicate correct shut off head.

d. Jet Pump

The procedure for starting jet pumps is similar to centrifugal pump except that priming by vacuum pump is not possible. Priming needs to be done by filling the pump casing and suction line from external source or by pouring water.

e. Vacuum Pump

The procedure for starting vacuum pump is similar to centrifugal pump except that priming is not necessary and valves on both suction & delivery side of vacuum pump should be fully open.

f. Reciprocating Pump

The steps stipulated for centrifugal pump are equally applicable for reciprocating pump. However exceptions as follows are applicable.

- The pump should be started against partially open delivery valve.

The pump should never be started or operated against closed delivery valve.

3.7.4.5 Stopping the Pump

Steps to be followed for stopping a pump of low and medium specific speed are as follows:

Box 2: Things to be checked when stopping the pump operation

i) Close the delivery valve gradually (sudden or fast closing should not be resorted to, which can give rise to water hammer pressures).

ii) Switch off the motor.

iii) Open the air vent in case of V.T. and submersible pump.

iv) Stop lubricating oil or clear water supply in case of oil lubricated or clear water lubricated VT pump as applicable.

3.7.4.6 Stopping after Power Failure/Tripping

If power supply to the pumping station fails or trips, actions stated below should be immediately taken to ensure that the pumps do not restart automatically on resumption of power supply. Though no-volt release or under volt relay is provided in starter and breaker, possibility of its malfunctioning and failure to open the circuit cannot be ruled out.

In such eventuality, if the pumps start automatically on resumption of power supply, there will be sudden increase in flow velocity in the pumping main causing sudden rise in pressure due to water hammer which may prove disastrous to the pumping main.

Secondly, due to sudden acceleration of flow in the pumping main from no-flow situation, acceleration head will be very high and the pumps shall operate near shut off region during acceleration period which may last for few minutes for long pumping main and cause overheating of the pump. Restarting of all pumps simultaneously shall also cause overloading of electrical system.

Hence, precautions are necessary to prevent auto-restarting on resumption on power. Following procedure should be followed.

i) Close all delivery valves on delivery piping of pumps if necessary, manually as actuators cannot be operated due to non-availability of power.

ii) Check and ensure that all breakers and starters are in open condition i.e. **off**-position.

iii) All switches and breakers shall be operated to open i.e. **off-**position.

iv) Open air vent in case of V.T. or submersible pump and close lubricating oil or clear water supply in case of oil lubricated or clear water lubricated V.T. pump.

Information about power failure should be given to all concerned, particularly to upstream pumping station to stop pumping so as to prevent overflow.

3.7.5 Maintenance of the Raw Pumps

3.7.5.1 Daily Observations and Maintenance

a) Daily Maintenance

- Clean the pump, motor and other accessories,
- Check coupling bushes/rubber spider,
- Check stuffing box, gland etc.

b) Routine observations of irregularities

The pump operator should be watchful and should take appropriate action on any irregularity noticed in the operation of the pumps. Particular attention should be paid to following irregularities:

1. Changes in sound of running pump and motor,
2. Abrupt changes in bearing temperature,
3. Oil leakage from bearings,
4. Leakage from stuffing box or mechanical seal,
5. Changes in voltage,
6. Changes in current,
7. Changes in vacuum gauge and pressure gauge readings,
8. Sparks or leakage current in motor, starter, switch-gears, cable etc,

9. Overheating of motor, starter, switch gear, cable etc.

c) Record of operations and observations

A log book should be maintained to record the hourly observations, which should cover the following items:

1. Timings when the pumps are started, operated and stopped during 24 hours,
2. Voltage in all three phases,
3. Current drawn by each pump-motor set and total current drawn at the installation,
4. Frequency (50Hz),
5. Readings of vacuum and pressure gauges,
6. Motor winding temperature,
7. Bearing temperature for pump and motor,
8. Water level in intake/sump,
9. Flow meter reading,
10. Daily PF over 24 hours duration,
11. Any specific problem or event in the pumping installation or pumping system e.g. burst in pipeline, tripping or fault, power failure.

3.7.5.2 Monthly Maintenance

1. Check free movement of the gland of the stuffing box; check gland packing and replace if necessary,
2. Clean and apply oil to the gland bolts,
3. Inspect the mechanical seal for wear and replacement if necessary,
4. Check condition of bearing oil and replace or top up if necessary.

3.7.5.3 Quarterly Maintenance

1. Check alignment of the pump and the drive. The pump and motor shall be decoupled while correcting alignment, and both pump and motor shafts shall be pushed to either side to eliminate effect of end play in bearings,
2. Clean oil lubricated bearings and replenish with fresh oil. If bearings are grease lubricated, the condition of the grease should be checked and replaced/replenished to the correct quantity. An anti-friction bearing should have its housing so packed with grease that the void space in the bearing housing should be between one third and half. A fully packed housing will overheat the bearing and will result in reduction of life of the bearing,

3. Tighten the foundation bolts and holding down bolts of pump and motor mounting on base plate or frame,

4. Check vibration level with instruments if available; otherwise by observation,

5. Clean flow indicator, other instruments and appurtenances in the pump house.

3.7.5.4 Annual Inspections and Maintenance

A very thorough, critical inspection and maintenance should be performed once in a year. Following items should be specifically attended:

1. Clean and flush bearings with kerosene and examine for flaws developed, if any, e.g. corrosion, wear and scratches. Check end play. Immediately after cleaning, the bearings should be coated with oil or grease to prevent ingress of dirt or moisture.

2. Clean bearing housing and examine for flaws, e.g. wear, grooving etc. Change oil or grease in bearing housing.

3. Examine shaft sleeves for wear or scour and necessary rectification. If shaft sleeves are not used, shaft at gland packing should be examined for wear.

4. Check stuffing box, glands, lantern ring, mechanical seal and rectify if necessary.

5. Check clearances in wearing ring.

   Clearances at the wearing rings should be within the limits recommended by the manufacturer. Excessive clearance reduces discharge and efficiency of the pump. If the wear is only on one side, it is indicative of misalignment. The misalignment should be set right, and the causes of misalignment should be investigated.

6. Check impeller hubs and vane tips for any pitting or erosion,

7. Check interior of volute, casing and diffuser for pitting, erosion, and rough surface,

8. All vital instruments i.e. pressure gauge, vacuum gauge, ammeter, voltmeter, wattmeters, frequency meter, tachometer, flowmeter etc. shall be calibrated,

9. Conduct performance test of the pump for discharge, head and efficiency,

10. Measures for preventing ingress of flood water shall be examined. Ingress of flood water in sump, well, borehole shall be strictly prevented. Seal cap shall be provided above borehole.

11. Check vibration level.

3.7.5.5 Overhaul of Pump

It is difficult to specify the periodicity or interval for overhaul in the form of period of service in months/years or operation hours, as deterioration of pump depends on nature of service, type of installation i.e. wet pit or dry pit, quality of water handled, quality of material of construction, maintenance, experience with particular make & type of pump etc.

However generally, following operational hours may be taken as broad guidelines for overhauling.

- Submersible pump – 5,000 – 6,000 hours
- Vertical turbine pump – 12,000 hours
- Centrifugal pump – 15,000 hours

3.7.5.6 History Sheet

History sheet of all pumps shall be maintained. The history sheet shall contain all important particulars, records of all maintenance, repairs, inspections and tests etc.

It shall generally include the following:

1. Details of the pump, rating, model, characteristic curves, performance test report etc,
2. Addresses of manufacturer & dealer with phone & fax number and e-mail addresses,
3. Date of installation and commissioning,
4. Brief details and observations of monthly, quarterly and annual maintenance and inspections,
5. Details of breakdown, repairs with fault diagnosis, replacement of major components i.e. impeller, shaft, bearings, wearing rings,
6. Results of annual performance test including discharge and efficiency,
7. Yearly operation hours of the pumps,
8. Brief findings of energy audit.

3.7.6 Maintenance Schedule for Motors

3.7.6.1 Daily Maintenance

The following activities presented in Box-3 below shall be carried out as a daily maintenance of pumping motor:

Box 3: Daily Maintenance Tasks for Motor

1. Clean external surface of motor,
2. Examine earth connections and motor leads,
3. Check temperature of motor and check whether overheated. The permissible maximum temperature is above the level which can be comfortably felt by hand. Hence temperature observation should be taken with RTD or thermometer. (Note: In order to avoid opening up motors, a good practice is to observe the stator temperature under normal working conditions. Any increase not accounted for, by seasonal increase in ambient temperature, should be suspected).
4. In case of oil ring lubricated bearing:
   - ☞ Examine bearings to check whether oil rings are working,
   - ☞ Note bearing temperature,
   - ☞ Add oil if necessary.
5. Check for any abnormal bearing noise,

3.7.6.2 Monthly Maintenance

Box 4: Monthly Maintenance Tasks for Motor

1. Check belt tension. In case where this is excessive it should immediately be reduced,
2. Blow dust from the motor,
3. Examine oil in oil lubricated bearing for contamination by dust, grit, etc. (this can be judged from the colour of the oil),
4. Check functioning and connections of anti-condensation heater (space heater).
5. Check insulation resistance by mongering

3.7.6.3 Quarterly Maintenance

Box 5: Quarterly Maintenance Tasks for Motor

1. Clean oil lubricated bearings and replenishes fresh oil. If bearings are grease lubricated, the condition of the grease should be checked and replaced/replenished to correct quantity.

   An anti-friction bearing should have its housing so packed with grease that the void space in the bearing housing should be between one third and half. A fully packed housing will overheat the bearing and will result in reduction of life of the bearing.
2. Wipe brush holders and check contact faces of brushes of slip-ring motors. If contact face is not smooth or is irregular, file it for proper and full contact over slip rings.
3. Check insulation resistance of the motor.
4. Check tightness of cable gland, lug and connecting bolts.
5. Check and tighten foundation bolts and holding down bolts between motor and frame.
6. Check vibration level with instrument if available; otherwise by observation.

3.7.6.4 Half Yearly Maintenance

Box 6: Haft Yearly Maintenance Tasks for Motor

1. Clean winding of motor, bake and varnish if necessary.
2. In case of slip ring motors, check slip-rings for grooving or unusual wear, and polish

3.7.6.5 Annual Inspections and Maintenance

Box 7: Annual Inspection and Maintenance Tasks for Motor

1. Clean and flush bearings with kerosene and examine for flaws developed, if any, e.g. wear and scratches. Check end-play. Immediately after cleaning, the bearings should be coated with oil or grease to prevent ingress of dirt or moisture,
2. Clean bearing housing and examine for flaws, e.g. wear, grooving etc. Change oil or grease in bearing housing.
3. Blow out dust from windings of motors thoroughly with clean dry air. Make sure that the pressure is not so high as to damage the insulation.
4. Clean and varnish dirty and oily windings. Re-varnish motors subjected to severe operating and environmental conditions e.g., operation in dust-laden environment, polluted atmosphere etc.
5. Check condition of stator, stamping, insulation, terminal box, fan etc.
6. Check insulation resistance to earth and between phases of motors windings, control gear and wiring.
7. Check air gaps.
8. Check resistance of earth connections.

3.7.6.6 Maintenance Schedule for Valves at Pumping Station

The following five types of valves in pumping installation exist, these are:

1. Foot valve,
2. Sluice valve,
3. Knife gate valve,
4. Non-Return (Reflux) valve, and
5. Butterfly valve.

Maintenance of valves at pumping station is presented in Table 3.1.

Table 3-1: Maintenance of Valves at Pumping Stations

Type of Valves	Maintenance Tasks
Foot Valve	☞ Clean foot valve once in 1-3 months depending on ingress of floating matters, ☞ Clean flap of the foot valve once in 2 months to ensure leak proof operation, ☞ Inspect the valve thoroughly once in a year. Check for leakage through foot valve after priming and observing level in volute casing.
Sluice and Knife Gate Valves	☞ Check gland packing of the valve at least once in a month. It should be ensured that pickings' inside the stuffing box are in good trim and impregnated with grease. ☞ It may be necessary to change the packing as often as necessary to ensure that the leakage is within limit. ☞ Grease should be applied to reduction gears and grease lubricated thrust bearing once in three months. ☞ Check tight closure of the valve once in 3 months. ☞ A valve normally kept open or closed should be operated once every three months to full travel of gate and any jamming developed due to long disuse shall be freed. ☞ Inspect the valve thoroughly for flaws in guide channel, guide lugs, spindle, spindle nut, stuffing box etc. once in a year. ☞ Important **DON'T** for valve is that it should never be operated with oversize hand wheel or cap or spanner as this practice may result in rounding of square top and hand wheel or cap or spanner may eventually slip. ☞ An important **DON'T** for valve is that it should never be operated under throttled i.e. partially open condition, since such operation may result in undue chatter, wear and failure of valve spindle.
Non-Return (Reflux) Valve	☞ Check proper operation of hinged door and tight closure under no-flow condition once in 3 months. ☞ The valve shall be thoroughly inspected annually. Particular attention should be paid to hinges and pins and soundness of hinged door. ☞ Condition of dampening arrangement should be thoroughly examined once in year and necessary maintenance and rectification as per manufactures' instructions shall be carried out. ☞ In case of dampening arrangement, check for oil leakage and replace oil once in a year.
Butterfly Valve	☞ Check seal ring and tight shut-off once in 3 months. ☞ Lubricate gearing arrangement and bearing once in 3 months.

Type of Valves	Maintenance Tasks
	☞ Inspect the valve thoroughly including complete operations once in a year. ☞ Change oil or grease in gearing arrangement once in a year.
General	☞ Operate bypass valve wherever provided once in 3 months. ☞ Flange adapter/dismantling joint provided with valve shall be loosened and retightened once in 6 months to avoid sticking.

3.7.6.7 History Sheet

Similar to history sheet of pump, history sheet of motor should be maintained. The history sheet should contain all important particulars, records of periodical maintenance, repairs, inspections and tests.

It shall generally include the following:

1. Details of motor, rating, model, class of duty, class of insulation, efficiency curve, type test result and type test certificate etc.
2. Date of installation and commissioning.
3. Addresses of manufacturer & dealer with phone & fax number and e-mail addresses.
4. Brief details of monthly, quarterly, half yearly and annual maintenance and observations of inspections about insulation level, air gap etc.
5. Details of breakdown, repairs with fault diagnosis.
6. Running hours at the time of major repairs.

3.8 Slow Sand Filtration (SSF)

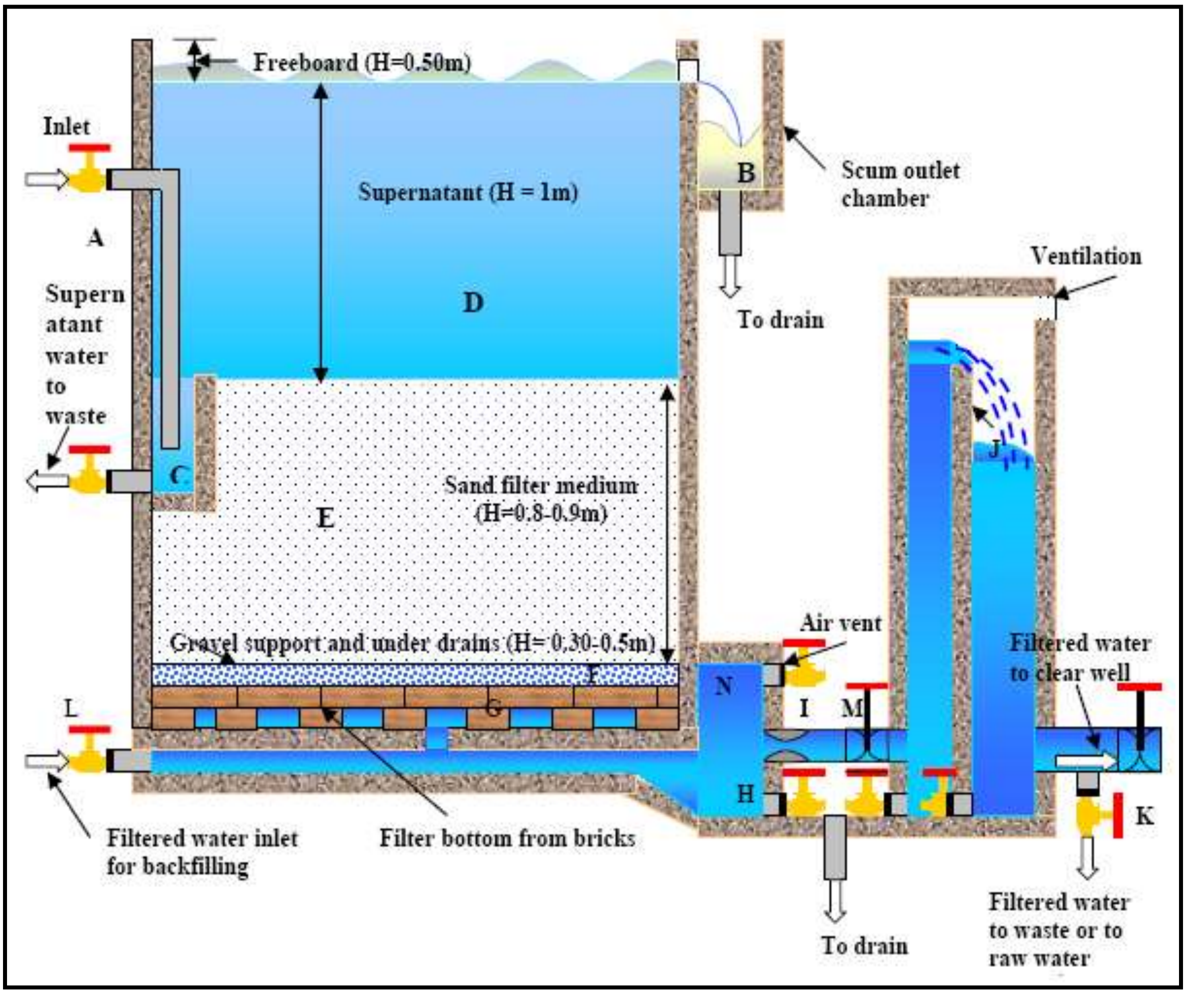
Slow sand filters should function on a continuous basis for two major reasons: to build confidence among the users on the availability of quality water; and to use efficiently the bacteria that has been coped in the 'schmutzdecke' (filth cover) of the filter media.


How turbid water looks like

The bacteria developed in the "schmutzdecke" requires uninterrupted flow in the filters

Slow sand filters are therefore recommended where the water source is available all the year round. A water source that provides water for only a few months after the rainy season, like some Haffirs (Figure 3), should be avoided. If there is no other option of water treatment system, the number of Haffirs should be increased to ensure that the supply lasts all year round.

Figure 3-3: Typical Section of Rectangular SSF Unit



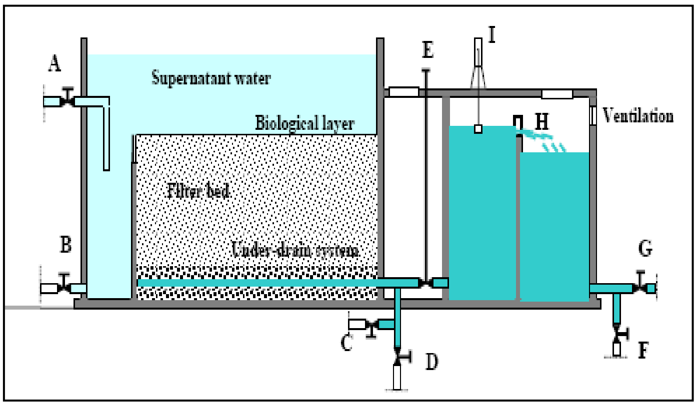
3.8.1 Process

3.8.1.1 Intake

The intake should be checked regularly for clogging by coarse materials or debris (wood, fabric or plastic) by the operator. Supervision should be on daily basis during the flooding seasons. In addition the raw water should be checked for physical, chemical and bacteriological properties, daily during the flooding season and weekly/monthly at other times. The water quality test should be conducted either by the Zone or Woreda Water Offices.

3.8.1.2 Sedimentation tank

Regular maintenance of the sedimentation tank is limited to the removal of accumulated sludge at the floor of the tank. This can be done by opening the drain valve provided at the lowest point of the tank. If the turbidity reduction of the sedimentation tank is less than 50 per cent, the tank should be drained and cleaned. The drain valve should be kept greased and functional and the floor of the tank should be cleaned regularly.



3.8.1.3 Roughing pre-filter

The turbidity of water leaving the roughing pre-filter should be less than 10NTU. If turbidity is above this value the filter may need cleaning or the flow rate needs to be decreased. The flow rate can be controlled with a V-notch and a weir at the inlet. For horizontal flow roughing pre-filter, flow rates should be in the ran ge of 0.4 to 1.0 meter per hour. A log of flow rates should be maintained.

The roughing pre-filter should be cleaned regularly. In order to allow hydraulic cleaning of the filters, the gravel pre-filters should have sloping floors and a channel leading to rapid opening wash-out gates. Steps to be followed for cleaning: a) Close the outlet valve and allow the filter to fill with water. b) Open the wash-out gates, causing the filter to drain rapidly which will carry much of the sediment with the wash-out water, and, c) Close the wash out gates and allow the gravel pre-filters to fill again

3.8.1.4 Slow Sand Filter Units

See Figure 3-1 above for the SSF units. Clogging of the filter bed will cause the supernatant water (D) to rise and this requires the filter bed to be cleaned. For cleaning, it is necessary to remove the supernatant water so that the bed surface is exposed.

Supernatant water can be emptied by opening the high drain valve of the drainage trough. The supernatant water may be discharged to waste if water is plentiful or returned to the raw water reservoir for treatment through other filters. As successive cleanings reduce the height of the filter bed, the sill of the drainage trough must be adjusted to the new surface after each cleaning.

3.8.1.5 Bed drainage

After the supernatant water is drained, it is necessary, before cleaning, to lower the level within the bed by a further 10cm or more so that the schmutzdecke and the top layer is relatively dry and easy to handle. Re-sanding, replacement of active charcoal layer, or repairs to the under-drainage system need complete drainage of the bed using the drainage valve (H).

3.8.1.6 Diversion of filtered water

During the ripening period of a new or recently cleaned filter, it is necessary to divert the effluent to waste or return it to the raw water reservoir, until the bacterial action of the bed has become established and the effluent quality is satisfactory. Valve K serves this purpose in Figure 3-1.

3.8.1.7 Backfilling

After the cleaning of a filter-bed (as well as during its initial filling) filtered water is introduced from the bottom to drive out air bubbles from the filter medium as the water level inside the sand rises. The filtered water is obtained from the clear well or from the outlet side of another filter and is admitted through valve L (see Figure 3-1).

3.8.1.8 Flow and Filter Controls

Maintenance of a constant flow through the bed is important for filter efficiency. Flow control can be practiced at the inlet or outlet.

Description of Controlling System of SSF:

A : Raw water inlet valve
a : Valve for raw water inlet and regulation of filtration rate
B, b ; Valve for drainage of supernatant water layer,
C,c : Valve for backfilling the filter bed with clean water,
D,d : valve for drainage of filter bed and outlet chamber,
E : Valve for regulation of the filtration rate,
F, e ; Valve for delivery of treated water to waste,
G, f : Valve for delivery of treated water to the clear water reservoir,
G ; Inlet weir
H ; Outlet weir
I, h ; Calibrated flow indicator

When the flow is controlled at the outlet, an outlet valve must be adjusted frequently, often daily, or output will fall. This ensures the maximum retention of water even at the beginning of a filter run. This method maximizes treatment efficiency but increases operator involvement. Inlet flow control can be accomplished by a gate valve plus V-notch weir. As the resistance of the filter bed increases, the water level rises. When it reaches the overflow pipe the bed should be cleaned. Inlet flow control requires less operator involvement but decreases filter efficiency slightly.

Slow sand filters are very easy to maintain. If the bed becomes clogged the top layer of sand is removed. To do this, the water in the bed is drained to 30.to 40cm below the top of the bed and the top layer (1-2cm) scrapped off. Once this is done, filtered water (from clear water well or other filter unit) is allowed in by opening valve L from the under-drains to cover the sand layer E. During this process valves H and M should be closed. As this filtered water flows through the bed, raw water may be reintroduced.

In case air is trapped in chamber N, it has to be released by opening the air vent valve I. After all air is released, valve I should be closed.

It takes 1-2 days to get the bed re-functional. It is recommended that re-filter the first lot of water that exited the filter after cleaning. The sand which was removed should be washed immediately to prevent it putrefying and then stored for re-use.

When the depth of sand in the slow sand filter bed has reached the minimum level of 0.7m, after years of service, the bed must be re-sanded. An additional 0.3m of sand should be removed before fresh sand is added. Once the new sand is installed, the old sand can be placed above that to promote the growth of bacteria.

3.8.2 Operation and Maintenance of SSF

The following operation/maintenance tasks are recommended for slow sand filters.

3.8.2.1 Checklist for Operation

For proper operation of slow sand filters, various activities are required at various times. One or more persons might be responsible for the activities. People that take part in the activities could be pump operator, trained technician, daily labor etc depending on the type and agreed upon management and operation modalities of the treatment system. Therefore, the person(s) responsible for each level of activities should perform and document that:

Box 8: On Daily Basis

1. Check the raw water intake (some intakes may need checking less frequently)
2. Check and adjust the rate of filtration
3. Check water level in the filter
4. Check water level in the clear water well
5. Sample and check water quality
6. Check pumping system, if pump is used
7. Check for residual chlorine, if chlorination is applied
8. Enter observations in the logbook of the plant

Box 9: On Weekly Basis

1. Check and grease any pumps and moving parts
2. Check the stock of fuel; order more if necessary
3. Check the distribution network and taps; repair if necessary
4. Clean the site of the plant

Box 10: On Monthly Basis

1. Scrape the filter beds if necessary
2. Wash the scrapings; store the retained sand

Box 11: On Yearly Basis

1. Clean the clear water well
2. Disinfect the clear water well
3. Check that the filter and clear water well are watertight

Box 12: Every two Years

1. Re-sand the filter unit

3.8.3 Capacity Building

The availability of trained technical personnel within the community is important for the O&M of the system. Hence, training of such technical people and provision of continuous support is very critical for sustainability. Various modules of training plans should be developed based on need. Some of these are listed below:

- At community level, the provision of turbidity measurement kits and strengthening the reporting capacity on the situation of the water supply system,
- At regional/Zone or Woreda level enhancing operation & maintenance management activities, monitoring and technical backup as well as on water quality monitoring including the provision of mobile water quality testing kits,
- At federal level a refresher workshop on slow sand filter design, construction and operation and management for all stakeholders.

The management, operation and maintenance of slow sand filters require skilled personnel. Skilled, trained people who understand how slow sand filters function should be assigned at Regional water bureaus/Zone and Woreda Water Office as well as at each location of a slow sand filter.

3.8.4 Control of Algal Growth

Excessive algal growth may cause trouble in the operation of open filters. Pre-treatment by micro strainers is one method of removing the algae contained in the raw water.

3.8.5 Dissolved Oxygen

If the dissolved oxygen content of the raw water drops below the potential oxygen demand, anaerobic conditions may develop within the bed. To some extent a reasonable growth of algae in the supernatant reservoir oxygenates the supernatant water. Where the composition of raw water or climate does not favour the growth of algae, or where chemical dosing or some other device has been used to remove or exclude them, it may be necessary to use other expedients to increase the dissolved oxygen content, such as aeration of the incoming raw water.

Ventilators are provided as an integral part of the filter bed. It should be ensured that these function properly.

3.8.6 Water Quality

Samples of raw and treated water will be taken at regular intervals for analysis. In case of small plants with no laboratory facilities, an attempt should be made to conduct sampling on regular basis. Field testing equipment may be used to measure water quality. For more details please refer to Water Quality Monitoring and Surveillance part of the manual.

3.8.7 Record Keeping

The following are the basic records that must be maintained:

1. The date of each cleaning (commencement)
2. The date and hour of return to full service (end of re-ripening period)
3. Raw and filtered water levels (measured each day at the same hour) and daily loss of head.
4. The filtration rate, the hourly variations, if any.
5. The quality of raw water in physical terms (turbidity, colour) and bacteriological terms (total bacterial count, E.Coli.) determined by samples taken each day at the same hour.
6. The same quality factors of the filtered water.
7. Any incidents occurring e.g. plankton development, rising Schmutzdecke, and unusual weather conditions.

3.9 Clear Water Well (CWW)

3.9.1 Operation and Maintenance

a) Concrete CWW

- Drain and clean well by draining the stored water into the distribution system, until about 10 cm remains. Use this water to clean and scrub tank floors and walls. Remove all water, sediments and loose materials.
- Check for cracks in concrete reservoirs and repair.
- Check manhole cover (sufficiently tight fitting).

- Check interior piping for corrosion; clean and repaint.
- Disinfect tank after thoroughly rinsing the interior of the reservoir by adding a chlorine solution to the water at a sufficient rate to provide a chlorine solution of 2 mg / liter when the tank is full. Keep the chlorinated water in the tank for 24 hours before putting the storage reservoir back into service. The disinfected water is suitable for domestic consumption.

b) Steel Tanks

- Check general condition for loose scale, leaking seams and rivets; repaint if necessary.
- Inspect ladder, roof, and structure forms, base and stand tower foundation.
- Inspect condition of paint work - empty tank, examine interior paint. If heavy corrosion exists, arrange for withdrawing the tank from service to permit repainting. Carry out proper cleaning and repainting by suitable paint for drinking water. After painting, carry out the disinfection for concrete reservoirs as mentioned above.

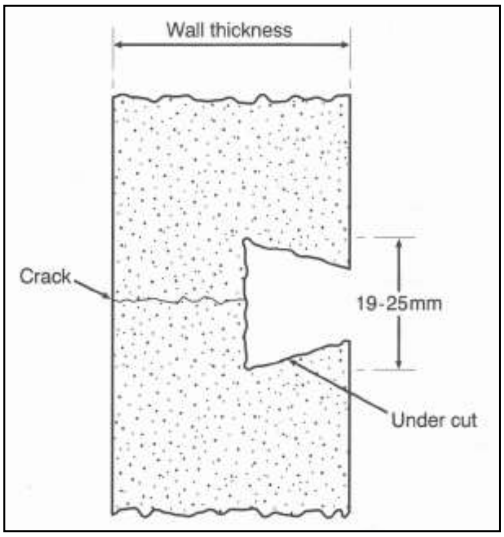
4.1.1.1 Crack Maintenance

a) Repairs Using Cement Mortar

Cracks in concrete well walls should be repaired from the inside; if at all possible, by chiselling a cut in the cracked area and filling with a stiff cement mortar (1:3 mixes by volume). Keep the repair wet for at least 24 hours before putting the tank back into operation. Remember to disinfect the tank if necessary.

If it is not possible to reach the inside of the tank easily, try undercutting (dovetailing) from the outside as follows:

- Drain to below the crack line.
- Using a cold chisel, make a cut on the reservoir cracked/leak with the following dimensions: Width 19-25 mm and depth 19-25 mm
- Clean and wet the cut before applying a stiff mortar (1:3 mixes).
- Clean and wet the holes cut in the reservoir and apply the cement mortar paste.
- Keep the mortar wet for at least 24 hours before putting the tank back into operation.
- Disinfect the tank;
- Rinse the tank with clean water;
- Put the repaired tank back into operation.



b) Repairs Using Proprietary Fast-Setting Cements

There are a number of proprietary fast-setting hydraulic cements specially formulated to quickly stop leaks and the seepage of moisture through holes or cracks in concrete or masonry walls.

Some brands are “Quickrete”, “Parson Quick

Plug", and "Dry Lok Fast Plug." These are generally based on Portland cement, but have ingredients that make the compound expand as it sets. Most of these proprietary blends are supplied as a dry powder to be mixed with clean water, and set within 3 to 15 minutes depending on the brand.

These formulations are durable and can be expected to last for the life of the concrete structure being repaired. They do not contain toxic elements, are highly impervious to water, and thus are suitable for use with potable water systems.

Application Procedure:

1. Open up the crack or hole by making a cut along the damaged area using a cold chisel. This will make it possible for the compound to form a plug. As the compound sets, it expands to complete the seal;
2. Before applying the compound, brush away all loose particles;
3. Mix the compound in accordance with the manufacturer's directions, which usually results in a paste of sticky consistency. The compound is hydraulic cement that begins to bind once it comes into contact with water. Once the water is mixed in, the paste must be used within minutes;
4. Apply the paste and force it into the crack. Start from any edge;
5. When sealing leaks beneath the water level in an un-drained reservoir, use a trowel or your hand with a glove. Hold the mixture in place for 3 to minutes or until no water passes through the leak;
6. Keep the repaired leak damp for 15 or more minutes (see directions).

c) Repairs Using Epoxy

Epoxy is an adhesive sealant available commercially in plastic packs of 15 grams or more. It consists of two components: A (Resin) and B (Hardener). Epoxy is generally used in repairing small leaks. Repairing a reservoir using this compound requires the following steps:

1. Drain the reservoir;
2. Dry and clean the surface to be repaired. In the case of steel tanks, roughen the surface to ensure good adhesion. In the case of concrete surfaces, clean out all loose particles;
3. Squeeze equal amounts of component A (Resin) and B (Hardener) on a suitable palette, and mix thoroughly;
4. Apply the mixture immediately to the leak;
5. Allow 2 to 4 hours for the epoxy to set. (Check instructions on the package if more or less setting time is needed);
6. Put the reservoir back to operation.

d) Repairs on Steel Tanks Using Electric or Acetylene Welding

1. Drain the reservoir;
2. Dry the surface to be repaired;

3. Weld the hole or break directly if small. If the leak is large, cut a metal plate with size lightly greater than the hole and then weld it in place;
4. Clean and smoothen the welded surface;
5. Paint the repaired area;
6. Disinfect the reservoir;
7. Put the reservoir back into operation.

4.1.1.2 Cleaning of CWW

The quality of water coming from the CWW must be maintained within the standards for potable water. To ensure the quality of the water supply, the service reservoir must be cleaned and disinfected periodically. Failure to apply this routine will result in the accumulation of solids and proliferation of bacteria in the tank, making the water unsafe for drinking.

Cleaning is usually done once a year, but it always must be done whenever the water in the reservoir contains an appreciable amount of dirt.

Routine inspection is the best way to determine when a tank requires maintenance and cleaning. A visual inspection can be made from the roof manhole with water level lowered to about half full or less. Alternatively a detailed inspection can be made after draining the tank and then cleaning or washing. Best time of the year to take up cleaning of SRs is during the period of lowest water consumption that is during rainy season (June-September).

The following activities are normally involved in cleaning of service reservoir/tank:

- Make alternate arrangement for water supply to consumers served by the CWW,
- Close the inlet line before commencing cleaning of CWW,
- Draw the water from the CWW till 20-30cm water is left in the CWW.
- Close the outlet valve so that no water will be used while the tank is being cleaned.
- Collect sample of water and silt/mud accumulated in the Tank and get the biological analysis and for presence of snails and worms. If snails and worms are found find the source and eliminate it.
- Drain and dispose off the remaining water and silt.
- Wash the interior of tank walls and floor with water hose and brushes.
- Inspect the interior of walls and ceiling of tank for signs of peeling off or deterioration.
- Apply disinfectant (Supernatant of Bleaching powder) to the walls and floor before start of filling the tank/CWW.
- Frequency of cleaning of CWW depends on the extent of silting, development of bio films and results from water quality monitoring.

4.1.1.3 Maintenance of Reservoir Appurtenances

a) Monthly Maintenance Tasks

- Lubricate float control pulleys.

- Inspect float for leaks.
- Check level indicator for free operation.
- Sweep roof, catwalks and ladder landings.

b) Manholes

Manholes should always be covered and locked to keep out foreign materials that could contaminate the water supply and also to prevent accidents.

c) Overflow Pipe and Air Vents

1. Covered reservoirs or tanks should be vented to allow the passage of air to and from the reservoir as the water level changes. Use fine screens on the vents to prevent the entrance of animals and insects, and keep the screens in good repair.
2. Keep access manhole covers in place to prevent accidents and contamination.
3. Slope the ground away from the reservoir in all directions to prevent surface water from flowing towards it.
4. Leaks in the cover or walls that allow surface water or shallow groundwater to seep in are dangerous. Repair leaks at once.

4.1.1.4 Records at CWW

1. Records to be kept on the operation

- Water levels in the CWWs (for all compartments) at hourly intervals.
- Time and relevant operation of control valves with time of opening and closure or throttling position of the valves.
- Hourly flow meter readings both on the inlets and outlets.
- Hourly residual chlorine readings of inflow water and outflow water.
- The man-hours spent on routine operations at the CWW in previous year and the cost thereof.

2. Maintenance Record

Maintain record on each of the following maintenance/repair works along with the cost of materials and labour.

- When the gland ropes of the valves at the SR were changed,
- When the spares of the valves were changed,
- When the manhole covers were changed/replaced,
- When the water level indicator was repaired or replaced,
- When the reservoir was last cleaned,
- When the out-fall drain for scour and overflow was last cleaned,
- When the ladder was changed,
- When the structure of the reservoir was last repaired to attend to structural defects or arrest leakage,
- When the reservoir was last painted,

- When the piping at the reservoir was last painted,
- Total cost of repairs and replacements at the SR in previous year along with breakup of material cost and labour cost with amount spent on outside agencies for repairs and replacements.

4.1.1.5 Reports at CWW

With the accumulation of all essential data a report can be prepared evaluating the O&M of the facility. The report can identify the deficiencies in the CWW and its appurtenances andthen plan future repairs to the structure or valves and other equipment or for replacement of defective valves or other equipment or additions to the storage capacity where the existing capacity is inadequate.

3.10 Pump/generator house

If the Haffir dam/Berkads are associated with pumping system and treatment facilities, the operation and maintenance aspect of pump and generator house should be the same as the manual provided under Volume-I, Part- C of Electro-mechanical O&M management. Any user of this manual can refer that manual which is one of the integral parts of the entire package of this part of the manual.

3.11 Berkad

3.11.1 Operation and Maintenance of Berkad

Operation and maintenance of Berkad is similar to Haffir dam.

3.11.1.1 De-silting of Berkad

See section 3.7.3 above for detailed de-silting of the silt trap.

3.11.1.2 Crack maintenance

Cracks in masonry walls

Generally cracks in masonry walls get localized at weak sections such as door and window openings, stair case wall etc. In external walls of a building generally shrinkage cracks run down wards from window sill to plinth level. On the upper story they run from window sill to the lintel level of a lower story.

Remedial measures

Shrinkage cracks in masonry could be minimized by adopting following measures:

a) Avoiding the use of rich cement mortar of 1:3 in the masonry. Preferably weak mix of 1:6 should be used,

b) Plaster work should not be carried out till masonry has properly dried out after curing and has under gone most of its initial shrinkage.

Masonry work should be done with weak composite cement lime and sand mortars of 1:1:6, 1:2:9 or 1:3:12 proportion. These mixes being weak will have lesser tendency to crack due to shrinkage in individual masonry unit. The shrinkage to a great extent will get accommodated in the mortar itself.

Remedies for cracks in plastering and rendering

To prevent the surface cracks at the junction between column/beam and wall, 150 mm wide chicken

Wire mesh should be fixed with u-shaped nails at 150 mm centre to centre at the junction before the start of the plaster. The plastering of wall and column/beam in the vertical plane should be carried out in one go.

The shrinkage cracks usually are thin and should not be treated till the renewal of finishing coat of paint is applied. The surface is rubbed well with emery paper no. 60 or 80 and then two coats of paint are applied to fill the shrinkage cracks.

Typical Repairs of Concrete Structures

Beams, columns and slabs are the most important components of the concrete structures. Due to the large number of cracks or damages observed in these components of the structure, the repair and rehabilitation of such members assumes greater importance. Techniques of repairs of these components have been discussed in the following sections:

Repair of concrete floor and slab system

For change of occupancy i.e. use of the structure to increase life span of concrete slab system, generally their repair or renovation and up gradation is needed. Provision of services below the floor surface may also require the replacements of floor surface. These may require complete structural up gradation or the repair of visual damages only or provision of a thin surface topping to the existing concrete to produce a wearing surface having a good resistance to abrasion and wear.

Before carrying out the repair of concrete floor and slabs, the causes of damage must be investigated and specifications of repair are drawn keeping in view the future use of the floor. The floor should be surveyed for the defects and the existing levels of the floor should be recorded with respect tc a known datum. The existing services in the floors should also be plotted and tested for their satisfactory condition.

In many cases only the bonding coat may be sufficient, while in other cases the topping over the whole area may be required. Before carrying out the repair operation, the damaged area and the joints should be repaired, otherwise these defects may reflect up through the new topping.

Under certain circumstances, the slabs in concrete structures may deteriorate in selective locations exposing the reinforcement. Scaling may occur due to an inadequate internal air void system in the concrete. Considerable scaling may also occur in the presence of moisture and also due to freezing and thawing in cold regions. The surface de-lamination of concrete in the slab may also occur due to the corrosion of reinforcement. The de-lamination of concrete above and around the reinforcement indicates deterioration which is dangerous for the long term structural integrity. To reduce the further corrosion of the embedded reinforcement, repair should be done to prevent the moisture infiltration into the concrete.

For a large extensively damaged slab system, the use of a thin over lay of methyl methacrylate polymer concrete has been found very useful, as usually polymer concrete does not absorb moisture.

Preparation of surface

Each repair area should be marked by a saw cut 3 mm wide and 6 mm deep groove around its Perimeter up to at least 100 mm outside of the damaged area. The entire area in between this boundary should be scarified by a suitable machine or by hand to remove the concrete up to a level below the damage to get a sound and clean concrete suitable for repair. After the scarification of the damaged area, the delaminated surface should be located by using a small chipping gun.

The reinforcement in the de-lamination area should be exposed and chipping continued till all concrete within 12 mm of the entire exposed portion of reinforcing bars in removed. To ensure that all delaminated unsound concrete has been removed, the prepared surface should be resounded again. To remove all corrosion byproducts from the reinforcement, it should be sand blasted. Finally, the entire repair area should be blown off with the compressed air to remove any loose corrosion particles, concrete, blasting sand and dust etc.

In case of cement sand mortar repair, the prepared surface of reinforcement is coated with a cement paste layer. This cement paste layer will provide additional protection to the reinforcement. After the coated surface has dried, the area to be repaired is kept thoroughly wet for 24 hours, if possible. Before filling the cementitious material consisting of 1:3 cement sand mortar of suitable workability by hand, all water from the surface should be wiped off. For small repair works, the proprietary materials may be used, which are carefully batched and quality properly controlled. Due to higher workability of the repair mixes, they should be only hand tempted.

For other cement sand mixes vibrating hammer with square bottom plate are often used, but for a large area, a short beam fitted with form vibrator may be used for compaction. The repairs finished off by hand trowel. It should be allowed to cure for 7 days by covering it with polythene sheets.

For high quality local repairs dry cementitious mortar materials along with a polymer as styrene butadiene, rubber latex etc can be used.

Procedure

The exposed surface of concrete and reinforcement are coated with a primer compatible with the repair system. The primer can be applied by rolling it on the surface with a paint roller and allowed to harden. The primer coat on the reinforcement provides it an additional protection against corrosion. After the primed surface has hardened adequately, it becomes impervious to moisture and could remain protected from environmental effects.

In case of deep sections, an initial bedding layer of polymer concrete is placed around the exposed reinforcement to ensure that the exposed reinforcement is fully surrounded by the polymer concrete. In deeply removed areas the polymer concrete is spaded beneath the reinforcement to remove the air pockets. After this, the chipped areas are back filled with sand loaded polymer concrete. Over the exposed reinforcement a thin coat of neat polymer concrete followed by a 6 mm layer of polymer concrete is applied.

Before applying the second layer of polymer concrete to build up the cover thickness in the area over the reinforcement, the first applied material should be allowed to be hardened. To provide a minimum thickness of 6 mm polymer concrete over the entire repaired area, a final layer of polymer concrete is applied. Over the exposed reinforcement a minimum 12 mm polymer cover is desirable.

After hardening the final layer of polymer concrete, the joint between the repair material and the repaired concrete should be sealed with the same primer as placed on original prepared surface.

In deeper patches, to control the shrinkage, the material should be applied in layers. At higher temperatures above 21°C the rapid evaporation of polymer liquid reduces the working time available before the material gains the initial set. Thus placing, screening and trawling must be done quickly. In such situations working at night or early in the morning gives better control for reducing ambient temperature.

Overlays and surface treatments

For active or dormant cracks in structural and pavement slabs, both can be repaired by laying bonded topping or overlay. Mostly cracks developed due to variation in loading, moisture and temperature are subjected to movement. These cracks will reflect through any bonded overlays and the crack repair will be in effective. However, drying shrinkage cracks can be repaired effectively by the use of overlays.

For such repairs polymers such as latexes of styrene, butadiene acrylic, non re-emulsifiable polyvinyl acetate and certain water compatible epoxy resin system can be used. The minimum quantity of resin solids should be 15% by mass of the Portland cement.

Procedure

Before applying a topping or overlay, the old floor slab should be shot blasted to make it rough to develop good bond between the old surface and the topping. After shot blasting, the surface should be well cleaned and saturated with clear water. The localized depressions or damages should be repaired before applying cementitious topping. Usually two types of toppings may be used, namely bonded or un-bonded toppings. The thickness of the topping is governed by the strength and thickness of the old floor slab.

Bonded toppings

These toppings require bonding aids, such as resins, polymers and cementitious grout. A cementitious grout of creamy consistency can be applied by brush on the floor slab immediately before placing the topping mix. The proportion of mix of 1: 1:2 by mass of cement, sand and I0 mm size coarse aggregate has been found quite satisfactory for the topping. The sand to be used should be of medium grade (zone 11) and, the coarse aggregate should be hard and clean. Generally granite aggregate is used. In addition to granite, flint or quartzite, gravel, ballast and hard lime stone can also be used. The quantity of water to be added should be minimum to attain full compaction. The topping mix should be laid in 20 to 40 mm thick layers in bays such that the construction joints of old floor must reflect up through topping,

The mix should be competed on the old floor and troweled level at intervals while topping is hardening. After final troweling, the topping should be left for curing by covering it with polythene sheet for at least 7 days.

In case of polymer modified Portland cement topping, a bond coat consisting of bromide latex mortar or an epoxy adhesive should be applied immediately before placing the topping. The polymer modified topping should be mixed, placed and finished rapidly within 15 minutes in warm weather. 24 hours curing of such toppings is sufficient.

Unbounded toppings

This is an additional slab laid over the old floor slab, hence no surface is required. However the construction joints in the old floor must be reflected through the new slab. As a damp proof membrane properly lapped polythene sheets are laid over the base slab. Concrete of compressive strength of 300 kg/cm^2, having cement 350 kg/m^3 concrete should be placed and compacted. The concrete should be laid in hays of sizes up to 15 m^2. The thickness of concrete may be 100 mm. Before hardening of this concrete a high strength topping of 10 to 15 mm thickness should be placed over it and compacted well over the surface. The mix of the topping may be as 1: 1:2 cement sand and 10 mm coarse aggregate as above.

3.11.2 Methods of water treatment for roof water harvesting

As water from Haffir dam /berkad is likely to be turbid and contaminated, treating the water before use is recommended, using any of the following methods:

- Boiling
- Filtration,
- Chlorination
- Solar disinfection

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 boil one litter 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.

Figure 3-4: Example of Household Filter from Local Materials

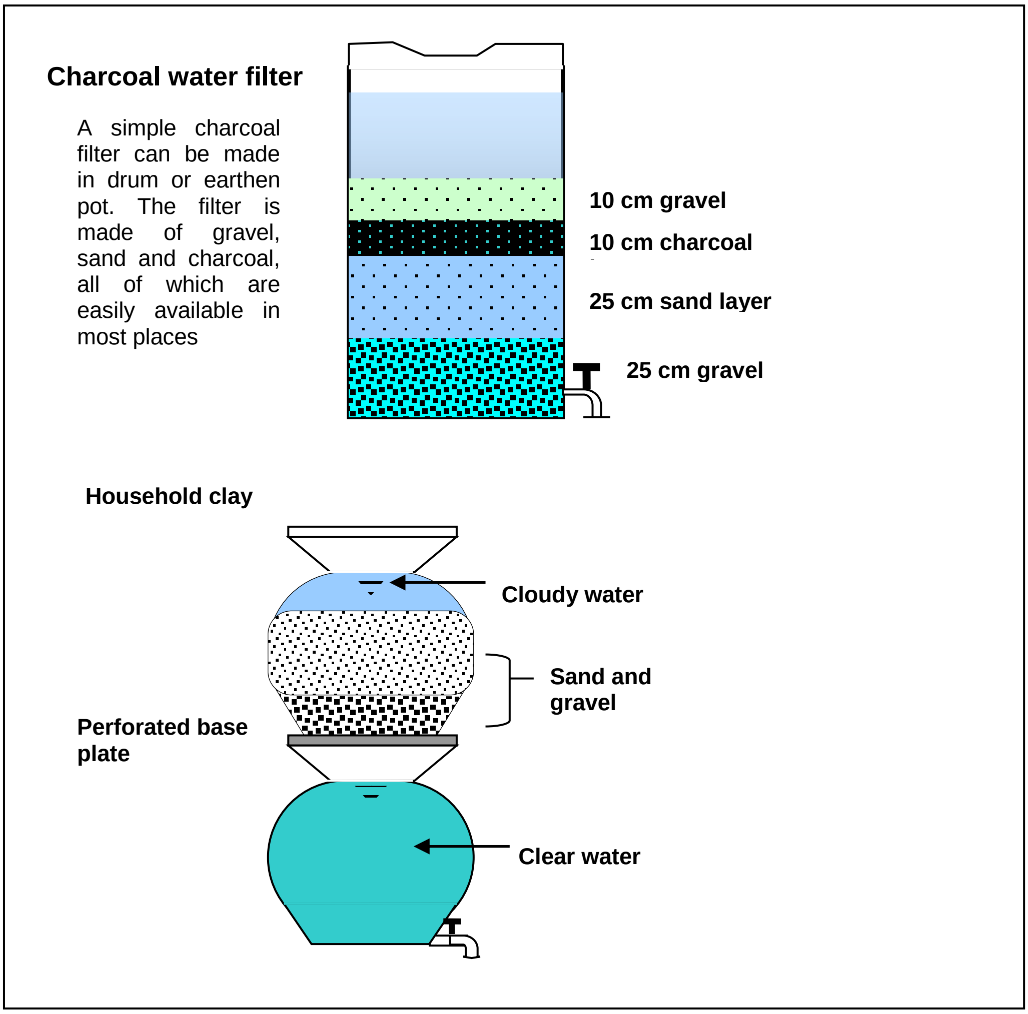
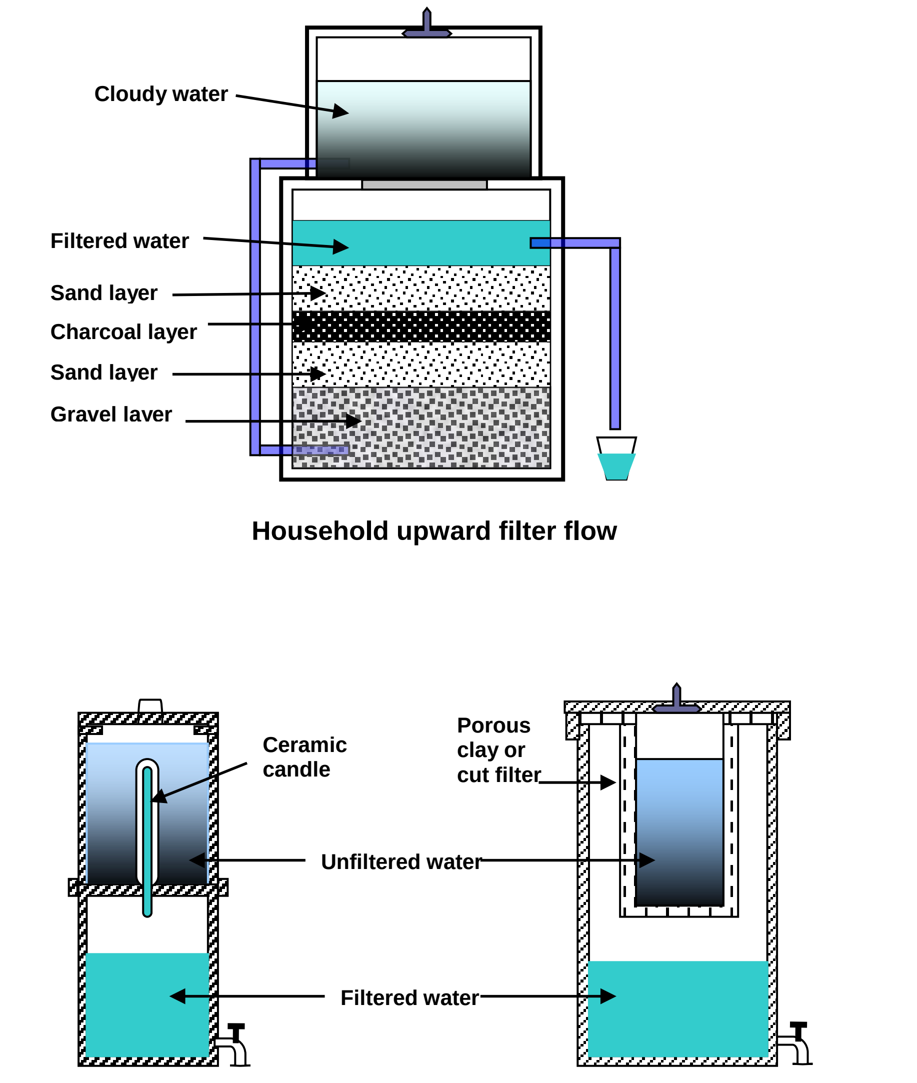


Figure 3-5: Example of Household Upward Filter Flow



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 litter of 1% chlorine stock solution:

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

Table 3-2: Disinfection Requirements for RWH

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

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

Container size	4.5 litter	20 liters	200 litters
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 cleared (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.

Annexes

Annex B: References

Technical Guidelines for Improved Haffirs, A Manual for Field Staff and Practitioners, Developed in Partnership with UNICEF, MWRI, GOSS, APRIL, 2009

MoWIE, Somali Region WASH Inventory, Tamene Hailu, May, 2014

Annex C: Detailed Plan and Section of Haffir Dam from Rain water harvesting

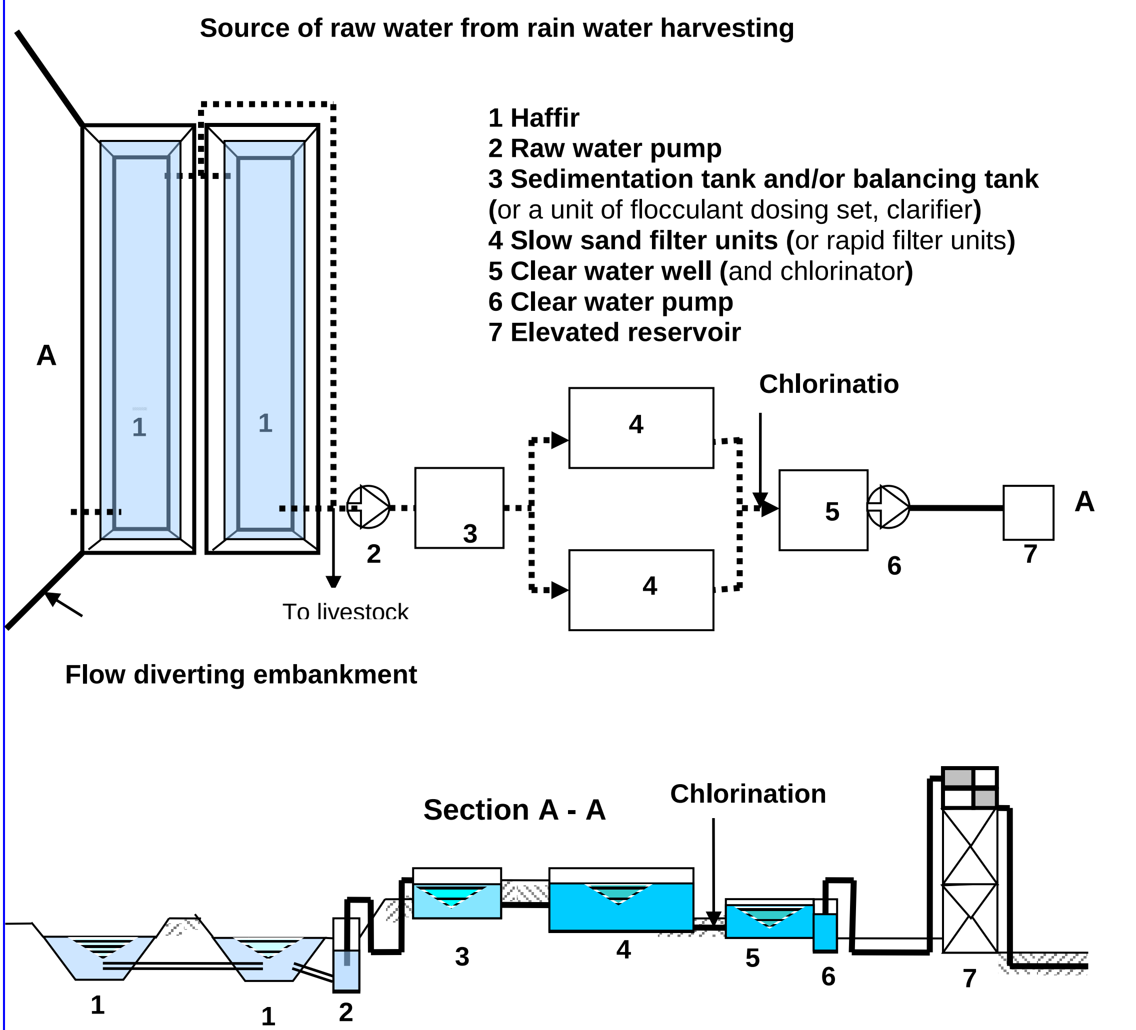


Figure 4. Schematic flow diagram of improved Haffir for raw water source from rain water harvesting

Annex D: Detailed Plan and Section of Haffir Dam from Irrigation canals or Perennial or Seasonal streams

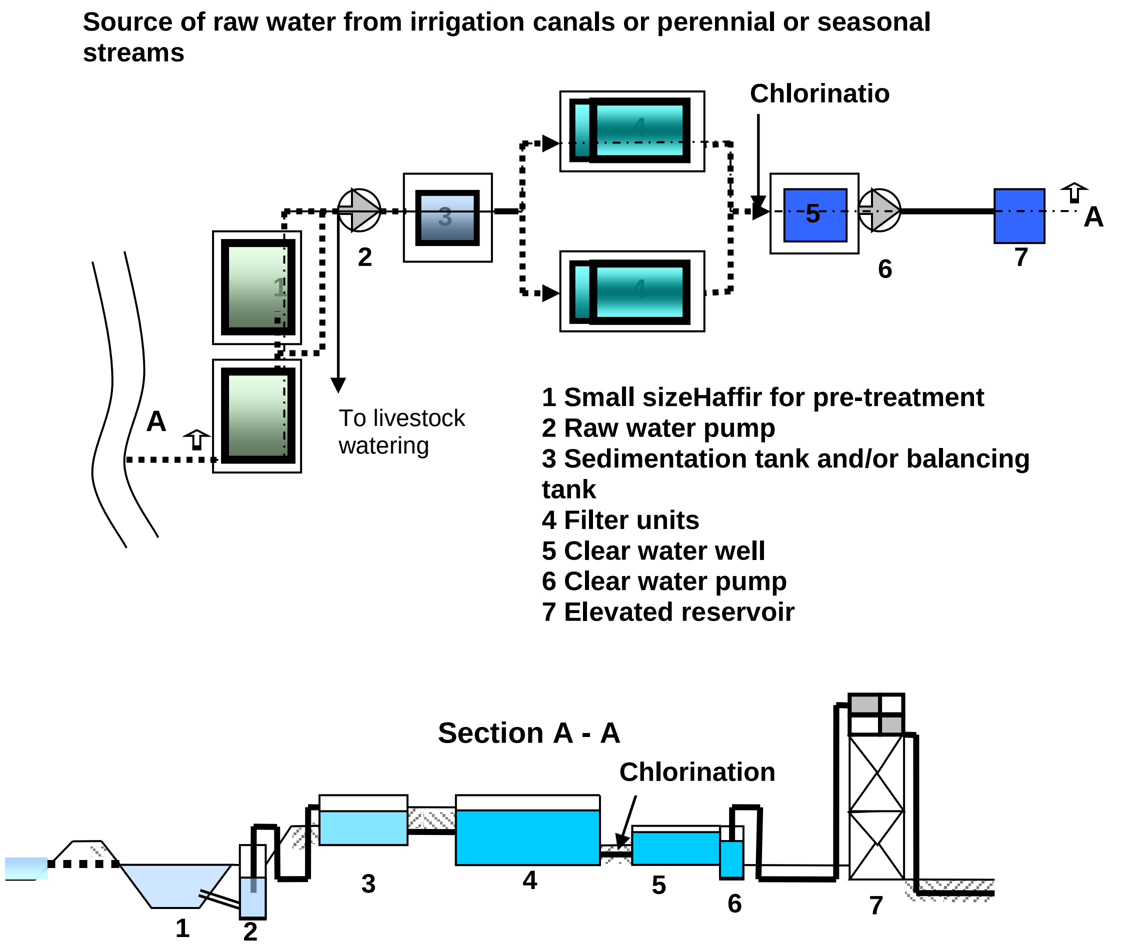


Figure 5. Schematic flow diagram of improved Haffir for raw water source from irrigation canals, perennial or seasonal streams

Pastoral Areas Water Supply

(Parts A, B, C, D)

Sand and Haffir Dams, Berkas, Rainwater Harvesting

PART – D: ROOFTOP AND ROCK CATCHMENT RAIN WATER HARVESTING

Document 9

PART – D: ROOFTOP AND ROCK CATCHMENT RAIN WATER HARVESTING

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Definition of Terms

Aquifer	Underground bed or layer yielding ground water for wells and springs
Catchment	The component of a RWH system from which rainwater is collected (especially a natural drainage area). Typical catchment surfaces include building rooftops, roads and pavements.
Chlorine residual	The amount of chlorine that remains in water at the end of a period of time following chlorination
Cistern	A receptacle for holding water typically integrated as a structural part of a building
Conveyance system	The component of the RWH systems that includes the gutters and pipes that carry the water from the catchment to the storage tank. The filter screens and first-flush diverters are also included in this component
Disinfection	Treatment process to destroy harmful microorganisms
Down-pipe	The pipe that carries water from the gutter down to the storage
First-flush diverter	An installation typically on the downpipe (from the roof gutter) that diverts the initial ‘dirty’ wash off the roof when it starts to rain from entering the tank
Groundwater	Water beneath the surface of the earth which saturates the pores and fractures of sand, gravel, and rock formations
Gutter	A channel installed along the edge of a catchment surface that carries collected rainwater toward the storage
Potable	Fit to drink
Vector	An organism, such as a mosquito that carries disease-causing microorganisms from one host to another

4. ROOFTOP AND ROCK CATCHMENT RAIN WATER HARVESTING

4.1 Introduction

Almost all water that we use every day is from rain. The water bodies in Rivers, Lakes, Reservoirs, Ponds, in the soil and all under groundwater have their origin from the rainwater that finds its way to each type of water bodies through different hydrological process. The average rainfall in Ethiopia is 800mm per annum. 80% of the rainfall occurs over a three months from June to August, and nearly 20% occurs in March and April (short rainy season). October to May is the dries period. Roof water harvesting has high potential in areas that receive higher rainfall and gave longer rainy season.

Roof top water harvesting is the simplest, less expensive and obvious choice for many part of the Country, where there are several and large roof structures made of corrugated galvanized iron sheets and with possible rock outcrops. The rain water harvesting is always useful for many purposes and hence is an important choice for the following reasons:

- In areas where groundwater development is either difficult or has been rendered unusable by high level of fluoride content, salinity and other poor water quality problems,
- In areas where the only available option is surface water.

4.2 Scope of the Manual

This manual deals with both the rooftop and rock catchment rain water harvesting of water supply system. It encompasses the purification of rooftop water as well as stored rock catchment water for drinking and other purpose. The manual associates with the sand filtration O&M requirement as well as household treatment system. The aim of this manual is to be provided as operation and maintenance for semi and arid region that other water sources are very scarce. Harvesting rain water is mainly uses for domestic and institutions like schools, clinics and other public institutes.

4.3 Roof Top Rainwater Harvesting

4.3.1 General

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.

It means capturing rain where it falls or capturing the run off in your own village or town. And taking measures to keep that water clean by not allowing polluting activities to take place in the catchment.

Therefore, water harvesting can be undertaken through a variety of ways:

- Capturing runoff from rooftops
- Capturing runoff from rock catchments

- Capturing seasonal floodwaters from local streams
- Conserving water through watershed management.

Here in this manual, it is address only roof and rock catchments rain water harvesting operation and maintenance.

4.3.2 System Component

The system of rainwater harvesting from roofs has six main components: the roof, the gutters, the downpipe and the tank. These are discussed briefly.

a. Roof (Catchment Surface)

The most suitable roofs for rainwater harvesting are made of galvanized metal sheets, tiles and concrete. Roofs that are thatched with grass can also be used though the water harvested is not as clean and may be tainted.

A flat roof with a concrete or tiled surface can provide a good catchment surface. Roofing felt is less satisfactory.

Plastic sheets placed over thatch or used for greenhouses can be very useful for harvesting rainwater.

b. Gutters

Gutters are normally made from sheet metal or plastic. Metal gutters are made in sections that can be bolted or soldered together. Plastic gutters are made in sections that are either glued together or connected with plastic connecter pieces. The brackets supporting the gutters should be placed close enough so that the gutters cannot sag when full of water.

c. Downpipes

Downpipes are normally metal or plastic. Tall buildings sometimes have a chain to carry water to the ground.

d. Storage Tanks

Tanks have traditionally been brick, stone, reinforced concrete, rubble stone or plastic. Tanks made of galvanized corrugated irons are common but prone to rusting and leakage after a few years. Oil drums can be used and may be plastered inside with cement plaster to reduce contamination. Black plastic tanks have proved advantageous in many situations because they are light and easy to move. They are especially useful where building materials such sand and stone are hard to get or very expensive. Tanks are normally placed on a plinth about 50 cm from the ground to facilitate filling buckets and jerry cans at the outlet. Where the roof is low this may not be possible and a pit may have to be dug with steps to access the outlet. Pipe inlet to tanks, and tank overflow pipes should be at the top so that no storage space is wasted. Details on tanks are given in a separate section of the manual.

e. Delivery System

This is on-spot at the storage or gravity-fed or pumped to the end users.

f. Treatment/Purification

This is done to make the water potable, chlorination or use of filters and other methods to make the water safe to drink.

4.3.3 Operation and Maintenance Requirement

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.

4.3.3.1 Roof

The roof is the largest single source of contamination to a rooftop water harvesting system. It is usually recommended to throw away the first shower or two after the rains; however this can be avoided if the roof itself is cleaned of all dust and debris before the rains start. Cleaning the roof is clearly only possible if the roof is flat or has only a slight slope, however the water used will usually be considerably less than would otherwise have been thrown away.

4.3.3.2 Gutters and Down Pipes

These are conveyance channels for the harvested water from the roof to the storage container. In Ethiopia gutters are constructed from galvanized iron sheet folded to the required dimensions, and most often they are rectangular or trapezoidal in shape. Down pipes can be made from PVC or Galvanized Iron Sheet. Gutter and down pipes should have filters to remove solid materials along with the water flowing through.

The main problem with gutters is overflowing during heavy storms and leakage from joints. Overflowing can be due to the accumulation of trash, so cleaning the gutters should be a routine measure before each rainy season. In order to minimize leaves dropping into gutters it is advisable to cut back the branches of any trees overhanging the roof. Overflowing may also be due to a failure in design. Either the gutter is not large enough in relation to the size of the roof or it has insufficient slope to the outlet. Also placing brackets too far apart can cause the gutter to sag and lead to overflowing. Leakage at joints may be prevented using a bitumen sealant.

As a rough guide, there should be 1 square cm of gutter cross section for every square metre of roof area.

Gutters should normally have a 1% slope to the outlet. Gutters are normally semi-circular or square shaped. It may sometimes be cheaper to make V shaped metal gutters and to install splash guards to ensure that runoff from the roof does not shoot over the gutter during heavy storms. These gutters can be installed where there is no facia board attached to the end of the rafters.

Gutters seem to be the forgotten children of rainwater harvesting systems. Many a user will fastidiously clean their tanks, carefully throw the first rains away but never even look at their gutters. Out of sight it seems is out of mind. A gutter full of debris will taint the water and will eventually prevent the flow down the gutter. It may also present a fire hazard with a great deal of dry vegetable matter close to the dwelling and will ultimately develop ecology of its own. It is essential that gutters are cleaned out periodically.

Gutters can simply be swept out with a brush from time to time. Certainly it should be before the rains and preferably several times during the season. The exact spacing will depend on the levels of blown dust, overhanging trees and the propensity of the gutters themselves to block.

4.3.3.3 Filters

Dirty filters will not pass water as efficiently and may become a source of contamination themselves so unless the filters are self-cleaning they will need inspection and occasional washing. Even a self-cleaning design should be inspected periodically to ensure it is working correctly.

As gravel and sand filters become duty, they impede the flow of water. When this happens, the filters will need to be emptied and the filter media thoroughly rinsed through.

Cloth filters can become dirty over time. They will not impede the flow of water like a sand filter but will allow dirt to be washed through the filter into the tank. They should be washed with the household laundry whenever they look dirty.

Filters made from mesh may catch larger debris such as sticks as they become blocked, they will impede water flow and provide a home for wildlife. They can be brushed or simply tapped out if they are removable.

First flush systems should be self-emptying to they automatically reset, they should also

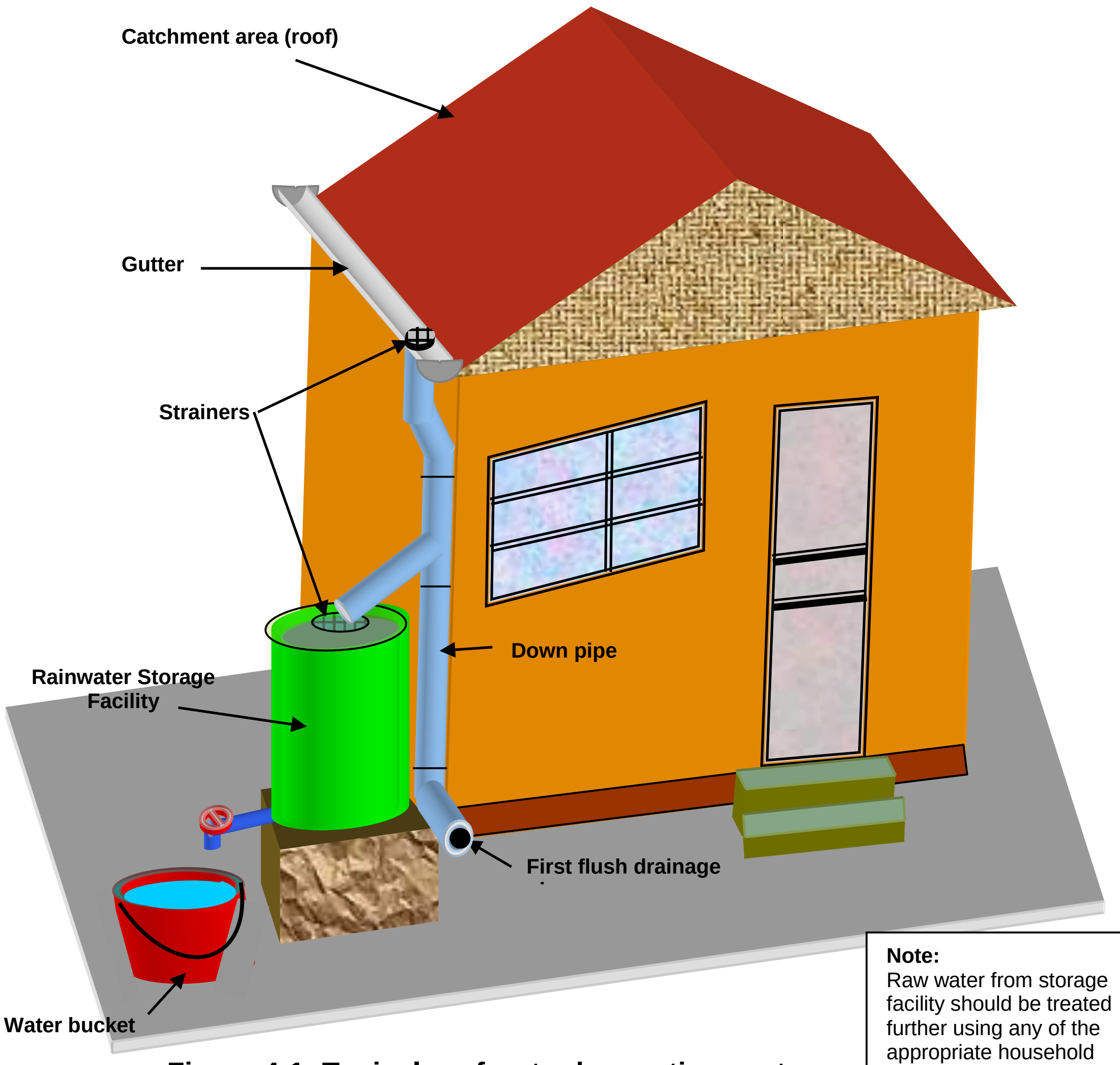


Figure 4-1: Typical roof water harvesting system

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

be cleared of any accumulated sludge at least every 3'* storm or they will themselves become a source of contamination.

4.3.3.4 Storage Tanks

Storage tank is the most expensive component of the RWH system. The availability of readymade plastic storage facilities made rooftop water harvesting less time taking, attractive and an important water supply option for domestic as well as institutions. Unless cost restricted, as much as possible the storage needs to be large enough to capture all the harvested rainwater particularly in areas where other sources of water supply system are technically or environmentally less feasible. The shape of the storage can be cylindrical, spherical, rectangular or square, and they can be constructed from Ferro-Cement (RC), concrete, masonry, readymade plastic containers (ROTO), and etc.

The repair of RWH tanks, unlike maintenance, is not a regular activity; nevertheless, it is one of the most important tasks in the management of RWH systems. The repair of tanks normally involves locating leakage points and making them water tight. Most of the following remedies are suggested to repair tank leakages:

a) Leakage between Wall and Foundation

Many tanks built of masonry leak water through the joint where the wall joins the foundation. The reasons could be insufficient reinforcement, poor mixture of mortar, or lack of cleanliness when the joint was made. The joint can be made watertight by cleaning the joint, adding more reinforcement and making an apron on both sides of the joint.

The procedure for this is as follows:

- Drain all water out of the tank and clean the floor and the foundation on the outer side of the tank.
- Chisel a groove (on the wall), about 3cm x 3cm, all around the joint on both the interior and external sides of the tank.
- Roughen a 15cm wide stretch of the foundation on both sides of the joint. Clean the joint and the roughened surface with plenty of water.
- Wrap 5 rounds of barbed wire tightly around the tank in the external groove.
- Compact mortar 1:3 into the external and internal grooves with a piece of timber.
- Compact a 15cm wide and 10cm high apron over the external and internal grooves.

b) Leakage through a cracked foundation

Water may leak through cracks in the foundation. The reasons for this could be soft soil under the foundation, insufficient reinforcement, poor mixture of concrete or improper curing. The leakage can be sealed by constructing a new foundation onto the old cracked foundation.

The procedure is as follows:

- Drain all water out of the tank and clean the floor.
- Fill all cracks with bitumen paste.
- Cut sheets of weld mesh to fit the foundation. All overlaps must be at least 20cm and tied together with binding wire for every 10cm.
- Mix concrete (1:3:3). Compact a 7cm thick layer of concrete onto the old foundation.
- Lay the weld mesh on the concrete in the tank.
- Compact a second layer of 7cm concrete onto the weld mesh in the tank.
- Compact a 1cm thick layer of mortar 1:3 onto the concrete. Smoothen the plaster and press a coat of NIL onto the plaster the same day.
- The next day, compact a rounded apron into the joint between the new foundation and the wall.
- Keep the foundation moist and under shade for 3 weeks.

c) Leakage through walls without cracks

Water may leak through the wall of a water tank, although the wall has no cracks. This is due to porosity caused by mortar mixture with insufficient cement, insufficient curing or poor workmanship. The wall can be sealed by replacing the porous parts with mortar 1:3 and with NIL. Should the wall still leak after that treatment, the interior of the tank should be coated with water proofer.

The procedure is as follows:

- Drain all water out of the tank and clean its interior.
- Chisel away the porous parts of the interior wall.
- Clean the chiseled parts with water and throw dry cement onto the watered parts of the wall.
- Mix mortar of 1:3 and throw a thin layer of it onto the watered parts of the wall.
- Next day, fill up the coated parts with mortar 1:3 and apply NIL with a square steel trowel. Keep the plastered parts moist under shade for three weeks, and then fill the tank with water.
- Should the tank still leak, its internal side has to be painted with a water proofer, such as swimming pool paint, non-toxic bitumen, oil paint or 1 part of cement with 10 parts of lime mixed with water.

d) Leakage through cracked walls

Water may leak through cracks and fissures in the wall of a water tank. The reason for this could be vertical cracks that are caused by insufficient horizontal reinforcement and/or incorrect joining of bricks and blocks; or horizontal cracks due to incorrect joining between the horizontal courses between bricks and blocks. The remedy for this is to build a new wall on the outside of the cracked tank by wrapping reinforcement mesh or wire around the tank and plastering it.

The procedure for this is as follows;

- Drain all water out of the tank and clean it.
- Chisel off any loose part on the external side of the tank wall.
- Tie sheets of weld mesh together with binding wire and wrap them tightly around the tank and plaster the outside of the tank with 3cm of plaster 1:3.
- Alternatively, wrap chicken mesh tightly around the cracked tank after which a spiral of barbed wire, gauge 12.5 is wrapped tightly around the chicken mesh with a spacing of 5cm at the lower half of the tank and 10cm apart on the upper part of the tank. Thereafter, plaster the outside of the tank with 3cm of plaster 1:3.and keep it moist under shade for 3 weeks. Paint the tank with a weather proof paint made of 1 part cement to 10 parts of lime mixed with water.

e) Repair of leaking ferrocement tank walls

The repair of ferro-cement tanks is relatively easy and involves the following steps:

- Chisel out the damaged area around the leak;
- Wet the whole area to make it really moist;
- Apply new mortar with the same cement to sand ratio as the original;
- Apply a coat of Nil the next day; and
- Cover the patch with plastic sheet and cure for at least for 3 weeks
- The key points to remember here are:
    - The quality and mix ratio of the material (cement, sand and water) used should be the same as that used for the initial construction; and
    - If a different mix ratio or sand type is used, then, there will be differential expansion stresses, and thus a new leak.
    - Small leaks in ferrocement tanks are much easier to repair in rainwater tanks.

- There are two ways to do this:
  - Chisel out the hole and enlarge it until it is at least 10mm across; the wire reinforcement should be visible. Mix rapid setting cement with water in a tin and stir, then mould in the hand until it has a plastic consistency. It becomes warm and starts hardening. Just before hardening apply/force an appropriate amount into the hole, and plug it firmly by a hammer and timber (smaller than the hole) before the cement sets. The whole work should be fast
  - Sand down the wall around the leak; and then apply sodium silicate to the leak. Sodium silicate is a clear viscous material which hardens on contact with air
  - These two methods are successful in sealing tanks; and even if they fail, they do not prohibit more serious attempts.

f) Plastic and metal tanks

Plastics and metals are harder to repair. It may however be possible to use water tight plastic or rubber liners. Plastic jerry cans are repaired by sealing the leaking points with melted plastic material. Corrugated iron tanks can be lined with cement or ferrocement.

Oil drums corroding at the bottom can be repaired as follows:

- Mix cement with coarse river sand at a ratio of 1:3
- Smear the mixture onto the inside in 1 cm thick layer and let it dry for a day
- Next day, apply a 2cm thick 1:3 mixture on to the previous layer and smoothen it
- Within the same day, apply Nil (cement slurry) and press it with a trowel onto the plaster
- Keep the oil drum under shade and sprinkle the plaster 3 times a day for a week, and then fill up with water.

The main concern is to prevent rubbish, insects, rats, etc entering the tank and polluting the water. There must be a tight lid that is large enough to allow cleaning periodically. Prevention of mosquitoes breeding is important and can be achieved using a screen around the lid and the inlet to the tank.

There are two approaches to removing trash:

- One is to have a first flush device which diverts water at the beginning of the rainy season into a container from which the trash can be removed periodically. Once it is full the rainwater goes straight to the tank.
- Another arrangement is to have a self-cleaning mesh screen over the entrance to the tank. If the screen is at 45 degrees most of the rubbish will be washed off while most of the water goes into the tank.

Leaking or broken taps are a major problem with tanks. Where the tank is a communal water point, the tap should be lockable or enclosed in a lockable box. Leaks are often caused by worn out washers which are easily replaced if the necessary tools are available (usually a pipe wrench and/or adjustable spanner).

A tank should be cleaned from time to time depending on the amount of trash that comes in with the rainwater. This can be done when it is empty or nearly empty. If the tank is a large one a ladder will be needed for a person to climb in.

4.3.4 Specific O & M Tasks for RWH Systems

The relevant tasks to the operations and maintenance of the system components of RWH are the following:

- Inspect gutters for cracked joints or loose brackets
- Clean gutters of silt and organic material
- Clean or replace mesh/sieve
- Check tap and replace washer if tap is leaking;
- Check drainage from draw off point and improve drainage if required
- Clean out tank
- Disinfect tank
- Where feasible, ensure water is retained in tank to avoid cracking.

4.3.5 Trouble Shooting

The potential unexpected problems, what might be the causes and solutions.

Table 4-1: Troubleshooting of RWH

Problem	Problem Causes	Possible Solutions
Water does not enter tank	Blockage in downpipe Gutter is not installed at a gradient to allow water to flow to the tank; gutter sag	Remove blockage Clean or replace screens Check levels on gutter and reset levels if required; put more brackets on the gutter
No water in tank	Leaky tap Leaky tank Overuse	Check for leaks and Repair Monitor usage
Water does not last	Storage volume is low	Regulate consumption

Problem	Problem Causes	Possible Solutions
long after end of rains	compared to consumption	Provide additional storage if more water can be harvested. However, check whether tank usually overflows. If not, then additional roof area and storage is required.
Smelly water	Organic matter in tank decomposing	Drain tank and clean tank

4.4 Rock Catchment Rain Water Harvesting

4.4.1 General

Rock catchments are suitable in areas with massive un-jointed rock outcrops. These are ground catchments, with the following distinctive features.

- They have high runoff coefficients;
- They provide with relatively cleaner water;
- They allow gravity flow supplies; and
- They are generally constructed for community water supplies.

Rock catchments have large surface areas which could cover several hectares and supply whole community if good dam sites are available above settlements for gravity supply.

The advantages of rock catchments include the followings:

- They are economical and reliable source of water in arid, semi-arid and desert areas where the groundwater is saline, surface water unavailable and rainfall is low. The large catchment areas yield plenty of water from a limited amount of rainfall.
- The maintenance of rock RWH systems is simple and cheap. Maintenance of rock catchments involve only cleaning the catchments before rainy seasons, and replacement of water taps.
- Rock catchments do not occupy farmland, and they are no body's property.

Exposed rocks surfaces provide excellent opportunities for harvesting runoff.

- The quality of water will not be as good as that harvested from roofs.
- There will often be sediment and organic matter. Therefore removal of sediment and treatment of water may be needed if the water is used for domestic purposes such as food preparation and drinking.
- Water that is not good for domestic purposes can be used in many other ways e.g. for cleaning, watering livestock, watering plants, brick making, etc.

4.4.2 System Component

Table 4-2 presents the different components of rock catchment system.

Table 4-2: Components of Rock Catchment Rain Water Harvesting

No.	Component	Purpose
1	Catchment area	The area that drains towards the rock catchment weir or tanks
2	Gutter	Low wall that is built on the rock surface to direct the runoff water towards the collection point
3	Dam	The dam stores the runoff water and spills any excess water
4	Intake/filter box	Ballast acts as a partial filter and prevents sticks from entering the draw off pipe
5	Draw off pipe	Gravity line that conveys water from the dam to the storage tanks
6	Scour pipe	Used to flush out sediments from dam
7	Storage Tanks	Covered reservoir where the water is stored
8	Control valve	Controls the flow of water between the dam and the storage tanks
9	Water Point	Point where consumers can draw water in a controlled way.

4.4.3 Operation and Maintenance Requirement

4.4.3.1 Rock Catchment Specific O & M Tasks

The following are task to the operations and maintenance of the system of rock catchment rainwater harvesting:

- Monitor pollution of the rock surface by wild animals, livestock and/or human activity;
- Develop and enforce bylaws for the protection of the rock catchment;
- Patrol and repair the perimeter fence;
- Patrol the gutter and repair as needed;

- Monitor for leakage along contact line between dam/weir and rock surface;
- Open and close all gate valves once per month;
- Maintain the ballcock/float valve on the tank to prevent all water draining out of weir – see modules on Tanks;
- Clean silt out of the dam. This can be done manually or, if there some residual water in the dam, the silt can be flushed out through the scour pipe;
- Wash and renew ballast in filter box;
- Remove any residual water from the dam to ensure there is no stagnant water that can become a breeding ground for mosquitoes.

4.4.3.2 Troubleshooting Schedule

Table 4.3 describes the potential unexpected problems, what might be the causes and solutions.

Table 4-3: Troubleshooting for rock catchment RWH

Problem	Problem Causes	Possible Solutions
Leakage along toe of dam wall	Poor design and construction	▪ Monitor leakage ▪ Plaster internal face of joint with waterproof sand/cement grout
Water in dam but no water in storage tanks	Control valve closed Blockage along draw off pipe	▪ Check control valve on draw off pipe ▪ Remove blockage from draw off pipe
No water in dam after rainfall event	▪ Break in gutters so runoff water is lost ▪ No regulation of overflow from storage tank	▪ Check and fix gutters ▪ Check and fix float valve or system for controlling overflow from storage tank.
No water in tanks	Unregulated consumption	▪ Control consumption. ▪ Keep consumers informed of water availability

4.4.3.3 Spares, Tools, & Technical Assistance

Tools:

- Shovels and wheel barrows for moving silt;
- Masonry tools for undertaking repairs to gutter, dam and tanks
- Pipe wrenches for pipework

Spares – include:

- Valves for outlet
- Taps and tap washers for water point

Supply Chain – O & M materials can be purchased at a well provisioned hardware store.

Technical Assistance – technical assistance should be sought if the dam shows signs of excessive seepage, erosion of spillways and in cases where dam structural integrity is in doubt.

4.4.4 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

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 boil one litter 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.

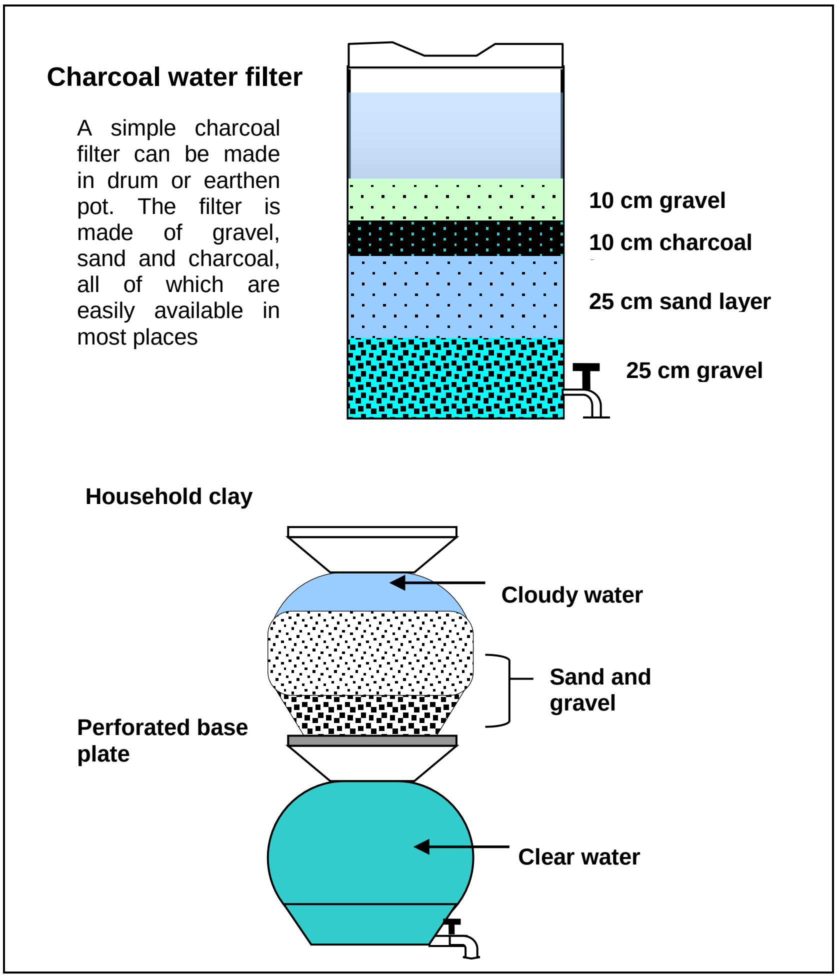
Filtration: There are several types of household filters such as candle filters, stone filters, household sand filters etc. In a candle filter the contaminated water is filtered slowly through a porous ceramic material. Most pathogens are left in the outer layer of the filter material and must be washed 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).

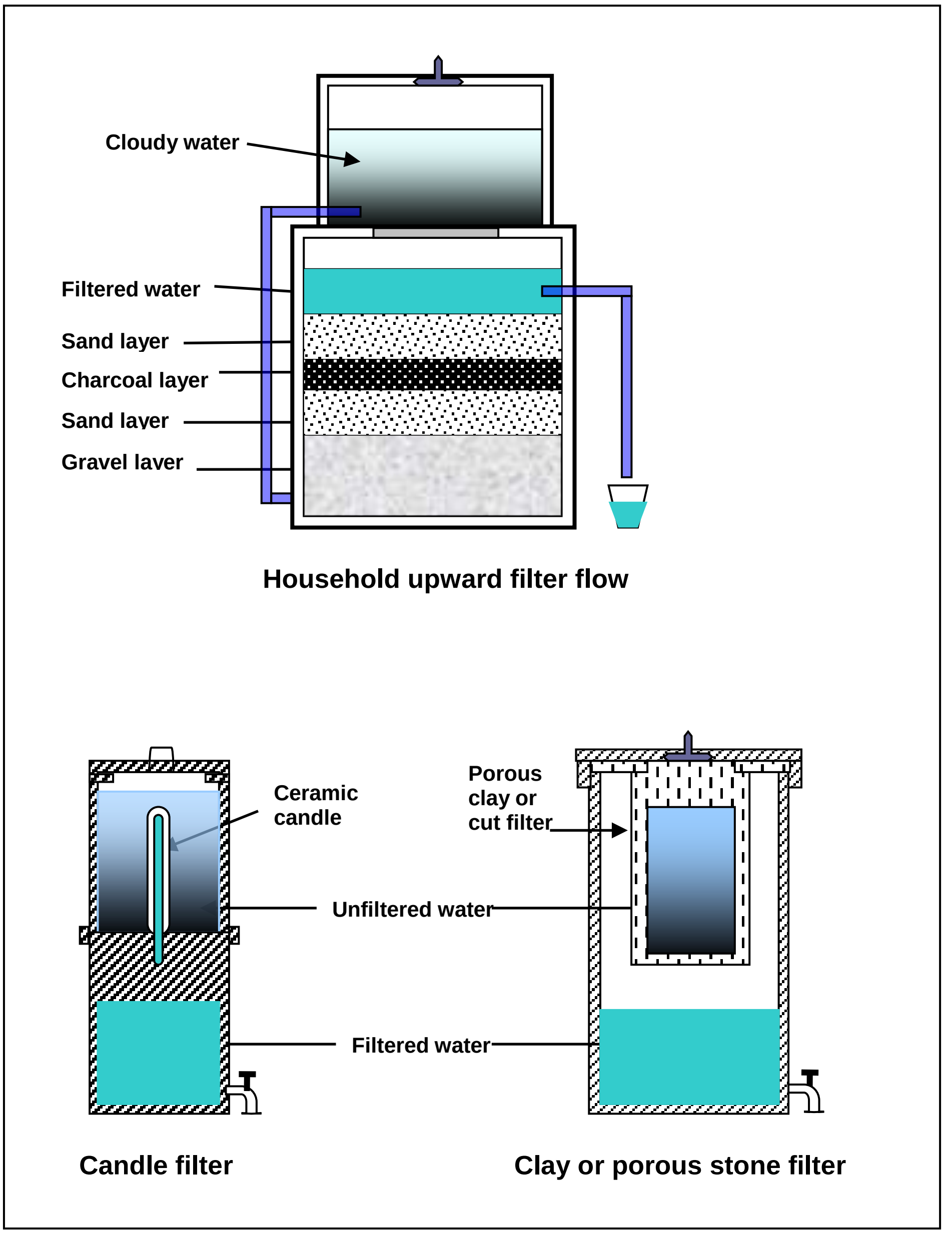
Figure 4-2: Example of Household Filter from Local Materials



- 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.

Figure 4-3: Example of Household Upward Filter Flow



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 litter of 1% chlorine stock solution:

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

Table 4-4: Disinfection Requirements for RWH

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

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

Container size	4.5 litter	20 liters	200 litters
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 cleared (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.

4.4.5 Maintenance and Vector Control

Rainwater is nearly pure water with zero hardness and, therefore excellent for drinking, washing clothes or irrigation. However contamination is invariably a possibility when the water comes into contact with the catchment surfaces, the conveyance and storage components. Of concern is microbiological contamination (bacteria, viruses, and protozoa) originating from faecal deposits from birds, rodents, bats and other animals on the catchment surface. Dirt, soot and other deposits on the catchment surface, in the gutters or in the tank will also degrade water quality. Residents in close proximity to industrial zones and solid waste facilities will need to be mindful of potential contamination from airborne particulate matter (from burning and industrial emissions) that may settle on the catchment surfaces.

The use of screens, filters, first-flush and water extraction measures (from the tank) will serve to reduce the entry of harmful materials into your RWH system.

4.4.6 Contamination during storage

It is important to prevent mosquitoes from breeding inside the storage tank, so as to reduce the likelihood of diseases spread by these vectors such as dengue and malaria. In addition, other animals need to be excluded from access to the water storage such as vermin (rodents, other insects), frogs and toads, as they too can transmit potentially harmful pathogens. Once storage tanks are fitted with properly fitting lids, all openings are screened, and water extracted using a tap or pump, the likelihood of contamination can be reasonably reduced. With control on the introduction of new contamination (through use of screens and first-flush diverters), any bacteria and other pathogens that are in the tank will eventually die-off, resulting in improvement of the stored water over time.

Additional risks exist in the case of below-ground storage facilities located in areas that may be prone to flooding. Should polluted flood waters, particularly when contaminated with human septage, inundate underground storage, this will render the water unusable and will need to be drained and the tank disinfected. Precautionary structures to exclude flood waters from contaminating ground storage tanks should be installed in high flood-risk zones.

4.4.7 Contamination during maintenance (mainly for masonry cisterns)

When performing maintenance tasks such as de-silting, tank cleaning, cleaning screens, catchment surfaces and sediment traps, it is possible to inadvertently introduce these accumulated residues into the system, contaminating it in the process. In cleaning out cisterns, there is a possibility of introducing noxious substances and faecal matter that may be carried on the soles of one’s feet or on footwear if not careful. Washing feet or footwear with soap is strongly recommended before entering the cistern.

The water tank should be cleaned once a year. The following is required:

- Liquid chlorine/bleach such as Sodium Hypochlorite 3%, 4%, 5%, or 5.5% by weight (these are most common on the market) or chlorine tablets such as Calcium hypochlorite and trichloro-striazinetrione (40%, 70%, up to 90% active chlorine). If household bleach is used, it should be the un-scented and un-coloured type.
- Bucket
- Scrub-brush
- Eye and hand protection (glasses, rubber gloves)
- A helper to monitor the person inside the tank (guard against accidents)

Cleaning procedure:

- Drain any water in the tank to the level at the tap. If this is being done during the dry season to avoid loss, transfer water to a clean, contaminant-free storage or temporary vessel. If tanks are cleaned during the rainy season, any lost water will soon be replaced. For two-chambered cisterns, there is the advantage of cleaning one chamber at a time.
- Once inside the tank use the scrub brush to thoroughly scrub the bottom and sides of the tank. Make sure that ventilation is adequate and that the helper is watching should any emergency arise.
- Remove the water and bleach solution remaining below the tap with the bucket.
- Refill the tank with water.
- Leave the water to settle overnight before use.
- Disinfect as outlined in Section 4 to ensure that any contamination from entry into the tank is minimized.

4.4.8 Summary: Protecting collected rainwater from contamination

Good system design and proper operation and maintenance will reduce the possibility of contamination of the water supply. The following are summary best-practice guidelines in maintaining water quality:

- Use an appropriate roofing material and ensure that it is kept clear of dirt and soot. When this material accumulates, it promotes the growth of moss, lichen or other vegetation. Use a clean brush to sweep roofs and gutters especially before the start of the rainy season and at other times as necessary;
- Replace rusted roofing as needed. Fix any holes to realize maximum runoff. If minor rusting is present, paint using lead-free paint;
- Remove branches from overhanging trees to prevent leaf debris from falling on and accumulating on the catchment area. Branches also provide roosting for birds (with the increased opportunity for defecation), and access to the roof by rodents and other animals;
- Keep gutters clear. If the gutters sag or leak, they need to be repaired. Sagging gutter systems will retain water, providing breeding sites for mosquitoes. Leaking gutters will also cause valuable water to be wasted. Ensure guttering is slanted toward the down-pipes to ensure steady flow;

- Install a coarse filter and/or first-flush device to prevent dirt and debris entering the tank.
- Inspect and clean/drain these devices periodically;
- Cover all openings to tanks with mosquito mesh to prevent insects, frogs, toads, snakes, small mammals or birds entering the tank. You must inspect and clean the mesh periodically;
- Install taps or draw-off pipes above the tank floor to avoid entraining any settled material into the water flow that is to be used;
- If the tank is exposed to sunlight, make sure that it is covered or made of opaque materials or painted with opaque paint. This will exclude light and prevent the growth of algae and microorganisms;
- Clean and disinfect the tank annually. A tank floor sloping towards a sump and washout pipe can greatly aid tank cleaning;
- Tree roots can intrude underground masonry including water tanks causing them to leak. Trees in close proximity to the water tanks should be pruned or cut to restrict advancement of encroaching tree roots;
- If mosquito breeding is observed in the tank (larvae present), it is best to seek advice from your environmental health department for assistance on control measures.
- In the event when the water is contaminated by a dead animal, the tank should be drained immediately, cleaned, and disinfected with chlorine;
- Monitor tanks for leaks and repair as needed;
- Hygienically store and dispense water within the household. Usually water collected from the storage tank is stored for short periods in small containers in the home. To protect the quality of this water:
  - Place storage containers out of reach of small children and animals
  - Keep containers covered or sealed.
  - Ensure containers are clean
  - Draw water from containers in a hygienic manner.

4.4.9 O&M for Slow Sand Filter

If the rock catchment rain water harvesting is equipped with the Slow Sand Filter (SSF) for treating the water, the operation and maintenance aspect of the SSF need to be address in this manual.

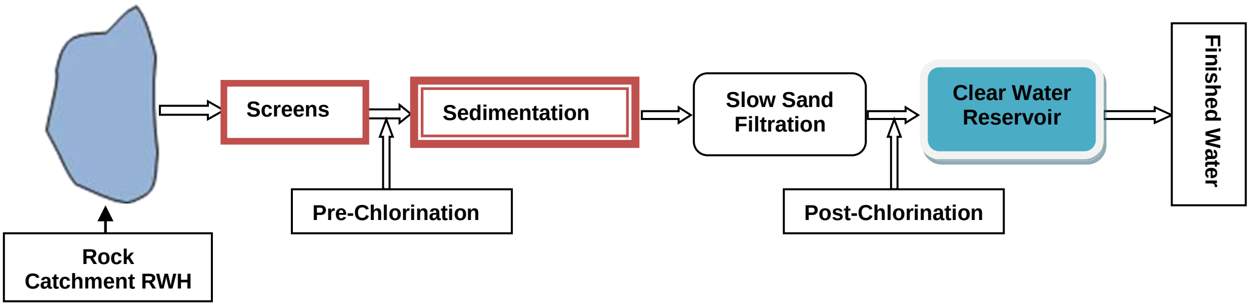
In slow sand filtration, the water is allowed to pass slowly through a layer of sand placed above the base material and thus the purification process aims at simultaneously improving the biological, chemical and physical characteristics of water.

4.4.9.1 Process

Slow Sand filtration was the first type of porous media filtration used in water treatment. This process is known for its simplicity and efficiency.

During the initial operational period of slow sand filters, the separation of organic matter and other solids generates a layer of biological matter on the surface of the filter media. The process of slow sand filter is presented in Figure 4-4.

Figure 4-4: Process of Slow Sand Filter



4.4.9.2 Filter Controls

The pipe work, valves and devices used to regulate the operation of a filter should be properly planned. Adequate means must be available to:

- Deliver raw water into the supernatant reservoir,
- Remove scum and floating matter,
- Drain off supernatant water prior to filter cleaning,
- Lower water level in the bed,
- Control the rate of filtration and adjust it as bed resistance increases,
- Ensure that negative pressures cannot occur within the bed (the weir is the device usually used for this purpose),
- Convey filtered water to the filter water tank,
- Run filtered water to waste or to the inlet side of other filters during the ripening process,
- Fill sand bed from below with filtered water (from other filters) after cleaning.

4.4.9.3 Operation

The operation of the filter is determined by the filtration rate, which is controlled at the effluent outlet. Inflow, which may be by gravity from a constant level reservoir, or by a pump, is adjusted so that the head of water in the supernatant reservoir remains constant at all times.

Excessive raw water delivery will cause overflow through the scum outlets, while a reduction in the rate of inflow will cause the level in the supernatant water reservoir to drop; either condition should alert the operator to a defect in the mechanism controlling the supply of raw water.

The filtration rate is controlled by a single regulating valve on the effluent delivery. At the beginning of the filter run this will be partially closed, the additional resistance thereby provided being equal to that which will later build up within the filter bed. Day by day as the run continues this valve must be checked and opened fractionally to compensate for the choking of the filter and to maintain a constant filtration rate. In the early part of the filter run the daily build up of resistance will be almost imperceptible, calling for very little valve adjustment, but towards the end of the filter run the resistance will increase more rapidly, necessitating a more positive opening of the valve and signalling the impending need for filter cleaning.

To enable the operator to regulate the valve precisely it is necessary to have some form of measuring device on the effluent outlet.

4.4.9.4 Control of Algal Growth

Excessive algal growth may cause trouble in the operation of open filters. Pre-treatment by micro strainers is one method of removing the algae contained in the raw water.

4.4.9.5 Dissolved Oxygen

If the dissolved oxygen content of the raw water drops below the potential oxygen demand, anaerobic conditions may develop within the bed. To some extent a reasonable growth of algae in the supernatant reservoir oxygenates the supernatant water. Where the composition of raw water or climate does not favour the growth of algae, or where chemical dosing or some other device has been used to remove or exclude them, it may be necessary to use other expedients to increase the dissolved oxygen content, such as aeration of the incoming raw water.

Ventilators are provided as an integral part of the filter bed. It should be ensured that these function properly.

4.4.9.6 Water Quality

Samples of raw and treated water will be taken at regular intervals for analysis. In case of small plants with no laboratory facilities, an attempt should be made to conduct sampling on regular basis. Field testing equipment may be used to measure water quality. For more details please refer to Water Quality Monitoring and Surveillance part of the manual.

4.4.9.7 Filter Cleaning

While the filter is in operation, a stage comes when the bed resistance increases so much that the regulating valve has to be fully opened and it is the right time to plan the cleaning of the filter bed since any further resistance is bound to reduce the filtration rate.

Resistance accelerates rapidly as the time for cleaning approaches. Indicators may be installed showing the inlet and outlet heads, from which the head loss can be regularly checked; this gives a clear picture of the progress of choking and the imminence of the end of the run. Without any measurement of the head loss the only true indicator of build up of resistance is the degree of opening of the regulating valve, though the experienced operator may be able to recognize preliminary visual warnings in the condition of the filter bed surface. A slight deterioration in the effluent quality may be a reason for the need for cleaning.

To clean a filter bed, the raw water inlet valve is first closed, allowing the filter to discharge to the clear water well as long as possible (usually overnight). As the head in the supernatant reservoir drops, the rate of filtration rapidly decreases, and although the water above the bed would continue to fall until level with the weir outlet, it would take a very long time to do so. Consequently, after a few hours, the effluent delivery to the clear water well is closed, and the supernatant water outlet is run to waste through the drain valve provided.

When the supernatant water has been drained off (leaving the water level at the surface of the bed) it is necessary to lower the water within the bed still further, until it is some 10 cm or more below the surface .This is done by opening the waste valve on the effluent outlet pipe. As soon as the Schmutzdecke is dry enough to handle, cleaning should start.

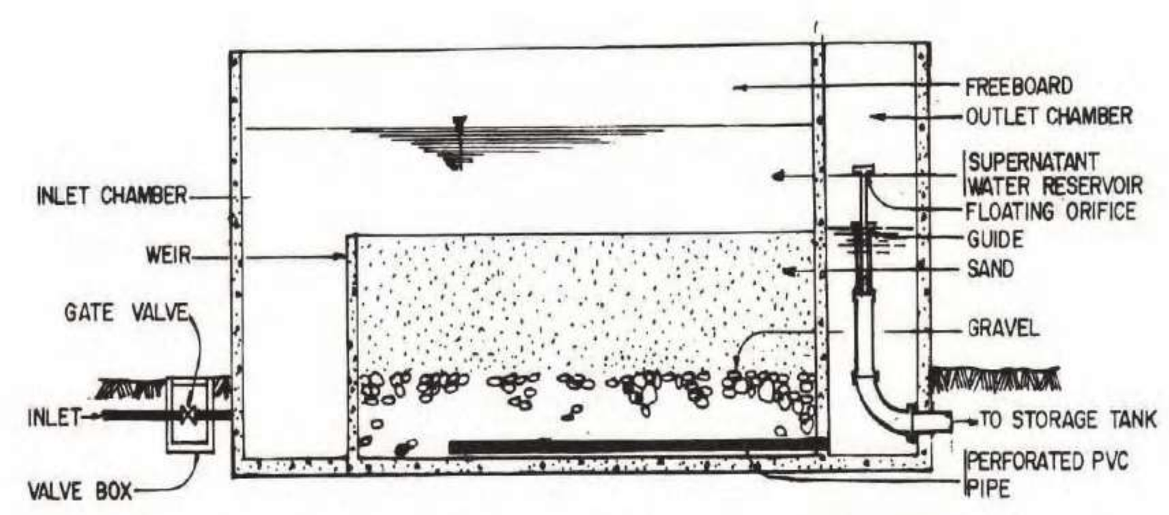
If the filter bed is left too long at this stage it is likely to attract scavenging birds that will not only pollute the filter surface but also disturb the sand to a greater depth than will be removed by scraping.

The cleaning of the bed may be carried out by hand or with mechanical equipment. Working as rapidly as possible, they should strip off the Schmutzdecke and the surface sand adhering to it, stack it into ridges or heaps, and then remove the waste material by barrow, hand cart, basket, conveyor belt or other device.

After removal of the scrapings the bed should be smoothed to level surface. The quicker the filter bed is cleaned the less will be the disturbance of the bacteria and shorter the period of re-ripening. Provided they have not been completely dried out, the microorganisms immediately below the surface will quickly recover from having been drained and will adjust themselves to their position relative to the new bed level. In this event a day or two will be sufficient for re-ripening.

Before the filter box is refilled, the exposed walls of the supernatant water reservoir should be well swabbed down to discourage the growth of adhering slimes and algae, and the height of the supernatant water drain and of the outlet weir must be adjusted to suit the new bed level. The water level in the bed is then raised by charging from below with treated water from the clear water well or from one of the other filters. As soon as the level has risen sufficiently above the bed surface to provide a cushion, the raw water inlet is gradually turned on. The effluent is run to waste until analysis shows that it satisfies the normal quality standards. The regulating valves on the effluent line will be substantially closed to compensate for the reduced resistance of the cleaned bed, and the filter will then be ready to start a new run.

During the cleaning operations precautions must be taken to minimize the chances of pollution of the filter bed surface by the labourers themselves. Such measures as the provision of boots that can be disinfected in a tray of bleaching solution should be taken. Hygienic personal behaviour must be rigidly imposed, and no labourers with symptoms that might be attributable to water borne or parasitic diseases should be permitted to



come into direct or indirect contact with the filter medium.

The filter bed is cleaned as follows:

1. Close the raw water inlet valve and allow the water level in the supernatant water reservoir to drop to the filter bed surface;
2. Close the outlet valve and open the drain valve. Allow the water level to drop further to at least 10 cm below the filter bed surface;
3. As soon as the biological layer is dry enough to handle, immediately scrape off the upper 25 to 50 mm layer of the filter bed using flat square-bladed shovels. If cleaning is delayed, scavenging birds will pollute the filter surface and disturb the sand;
4. After removing the scrapings, smooth the bed to a level surface. Also, inspect for the presence of mud ball cracks in the sand which may result in channeling, which would cause the deterioration of effluent quality.

4.4.9.8 Re-sanding

Re-sanding becomes necessary when the depth of the sand bed drops to its minimum designed level (usually about 0.6 – 0.8 m above the supporting gravel, depending on the grain size of the filter sand). This depth is usually indicated by a marker set in the structure during the original construction. Re-sanding may be done completely or by a "throwing-over" procedure described below.

a. Complete Re-sanding

In this method, the upper 0.3-0.5 meter layer of the sand bed is scraped before new clean sand is added. It should be emphasized that it is necessary to scrape the said layer to avoid fouling and to reduce the greater resistance in the filter due to the raw water impurities and some products of biochemical degradation which may have penetrated the sand bed to this depth. After scraping, add new clean sand up to a level shown in Figure 5.9 and place back the old sand that was scraped off the top. The old sand will reduce the number of days needed for ripening the filter.

b. "Throwing Over" Re-sanding

This is carried out in strips. The old filter sand is moved to one side, then the new clean sand is added, and finally the old filter sand is replaced on top of the clean sand. This is to retain the active material found in the old filter sand so that the re-sanded filter will become operational with a minimum re-ripening time. The procedure is as follows:

1. With a flat square-nosed shovel, scrape 50-100 mm of the upper layer of sand bed. Place the scrapings in a box for cleaning;
2. Divide the whole length or width of filter into strips;
3. With a flat square-nosed shovel, scrape 0.3 – 0.5 meter of the upper layer of the first strip and stack it to one side;
4. Fill the excavated trench with the new clean sand and scrape 0.3 – 0.5 meter of the adjacent or second strip and place it on top of the first strip;
5. Fill the second strip with new sand and scrape 0.3 – 0.5 meter of the adjacent or third strip and place it on top of the second strip;
6. When the whole bed has been re-sanded, use the material scraped from the first strip to cover the new sand in the last strip;
7. Operate the filter as described in sub-section

Figure 4-5: Details of Sand Filter

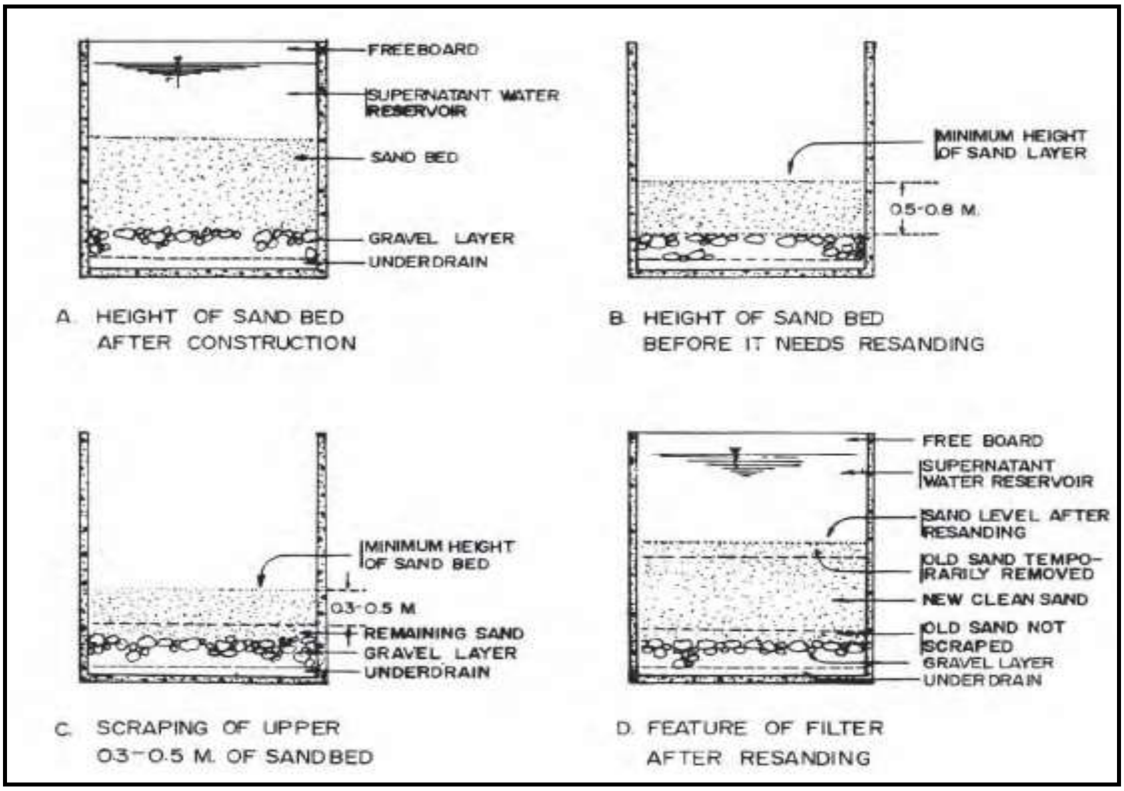
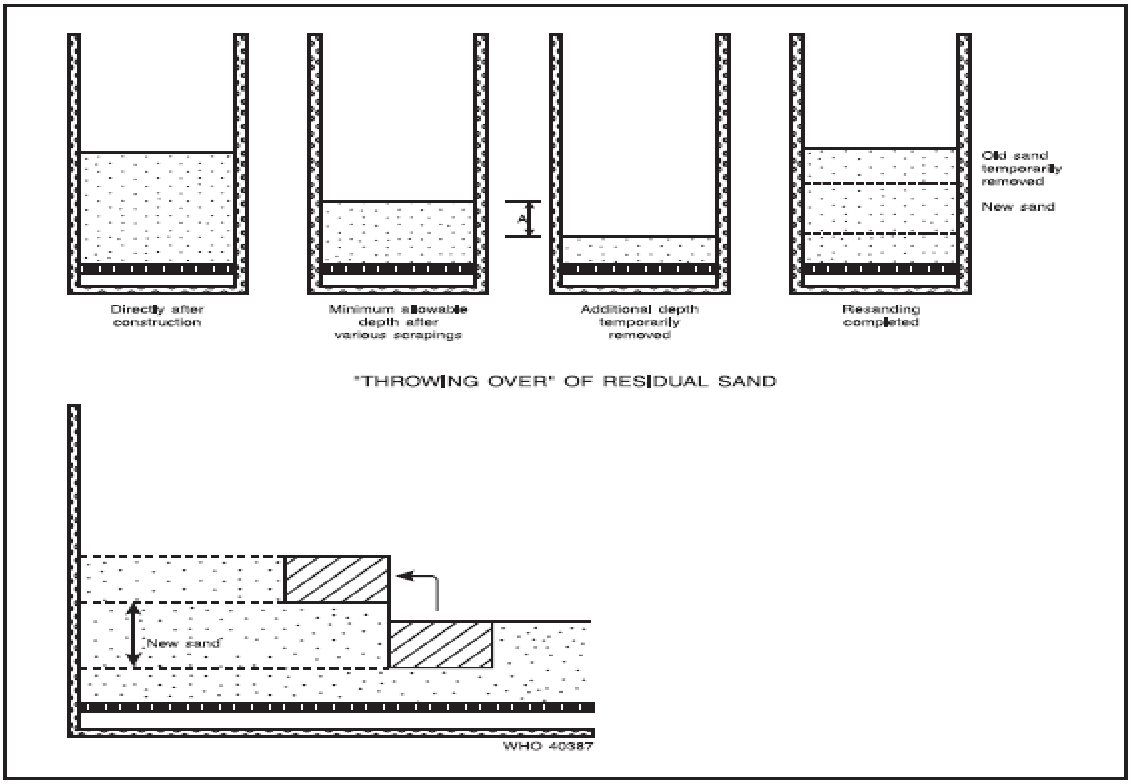


Figure 4-6: Re-sanding of Slow Sand Filter



4.4.9.9 Washing Filter Sand

In areas where sand is expensive or difficult to obtain, surface scrapings or used sand should be recycled. Scrapings should be washed immediately to remove organic matter. .

Filter sand may be washed manually or mechanically:

a. Manual Washing

1. Transfer the scrapings to a box;
2. Fill the box with clean water;
3. Stir the sand in the box with a spade or shovel vigorously enough to separate the sand particles from the impurities;
4. Transfer the sand into the second box and add clear water. Stir the contents of the box to separate the organic matter from sand particles;
5. Repeat the above procedure until the wastewater is fairly clear;
6. Store the sand.

b. Mechanical Washing

A machine called the ejector type, mechanical sand washing machine is used for this purpose. The machine consists of a cylindrical drum with conical bottom and stirrers.

The used sand is fed at the top and at the same time, clean water is injected under pressure at the bottom of the drum. The impurities are removed in the overflow while the clean sand is discharged at the bottom of the drum. The stirrers inside the drum aid in dislodging undesirable substances from the sand particles.

4.4.9.10 Record Keeping

The following are the basic records that must be maintained:

8. The date of each cleaning (commencement)
9. The date and hour of return to full service (end of re-ripening period)
10. Raw and filtered water levels (measured each day at the same hour) and daily loss of head.
11. The filtration rate, the hourly variations, if any.
12. The quality of raw water in physical terms (turbidity, colour) and bacteriological terms (total bacterial count, E.Coli.) determined by samples taken each day at the same hour.
13. The same quality factors of the filtered water.
14. Any incidents occurring e.g. plankton development, rising Schmutzdecke, and unusual weather conditions.

4.5 Management of RWH Schemes

It is necessary that the management of RWH systems is done by the users themselves, unlike design and construction which in many cases are initiated and implemented by outsiders. The users of RWH systems could be individual households, institutions such as schools, or communities for whom the RWH systems are built for communal use In RWH systems that are built for communal use by a community, water users committee is selected for the management with a trained technician/tap attendant assigned for the day to day work.

The communal management of RWH systems is generally more difficult and complicated when compared with those are individually owned, owing to the communal nature of ownership. It is therefore important to refer the other manual for the scheme management that bylaws are developed for applying such systems to this scheme. It would also be useful if the management have links with organizations that are capable and willing to extend support in situations where external assistance needed. It is however preferred that users are self reliant to the extent possible; in which case external assistance is by and large limited to setting up a management system and providing training in operation, maintenance and repair. The communal management of RWH systems should be participatory and inclusive of women in all decision making and other forms of participation.

The guidelines/bylaws to be prepared for the management of RWH systems need to lay out clear duties and responsibilities in respect of the following items.

- the management arrangement/system and responsibilities;
- Physical safety and protection of the RWH system;
- Maintenance and control of water quality;
- Regulation of water abstraction rates and time, and advice on its appropriate use;
- Operation, maintenance and repair of the system; and
- Allocation/collection of water fees/budget for operation, maintenance and repair;
- The management of finance and other properties.

Like any other water supply system, it is important that communities are made aware of/educated on matters related to hygiene and sanitation.

In any case, proper maintenance is an important aspect in the management of RWH systems and needs to include, among others, the following activities;

- Inspection, regular cleaning and minor repair of the whole RWH system; the catchment, the conveyance, the tank and the various tank components such as tap.
- Removal of branches of trees over hanging on roofs. Not only leaves and debris, but also the droppings of birds and small animals contaminate rainwater. Dust and other such dirts also need to be cleaned regularly from the catchment/roof.
- Cleaning and minor repair of the conveyance system (gutters and downpipes/gutters) at least once a year;
- Inspection of water quality in the tank, testing from time to time and treating/disinfecting regularly.
- There should be no opening that allows small animals to enter into the tank; it is therefore necessary to inspect, clean and repair/replace screens and filters. Screens

and filters unless cleaned regularly can themselves be a source of water contamination.

- Clean/wash-out accumulated sediment and sludge when necessary; take the opportunity to clean the tank when it is empty.
- There should be no tree growing within 10 m from the tank to protect the foundation from damage/crack by roots searching for moisture underneath.
- Dispose of safely runoff and/or ponding water around the tank as this may damage the tank or bring health risks.
- Inspect regularly the amount of water in the tank, and compare with demand and abstraction rates.
- Inspect and maintain/repair/replace water taps.

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