VOLUME – III	**OPERATION AND MAINTENANCE REQUIREMENTS FOR PASTORAL AREAS WATER SUPPLY TECHNOLOGIES**

PART - A	**INTRODUCTION TO PASTORAL WATER SUPPLY TECHNOLOGIES**
PART- B	**SAND/SUBSURFACE DAM**
PART - C	**HAFFIR DAM AND BERKAD**
PART - D	**ROOFTOP AND ROCK CATCHMENT RAIN WATER HARVESTING**
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Operation and Maintenance Requirements for Pastoral areas Water Supply Facilities: VOLUME – III, 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 *Bekads* 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 Berkad 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.

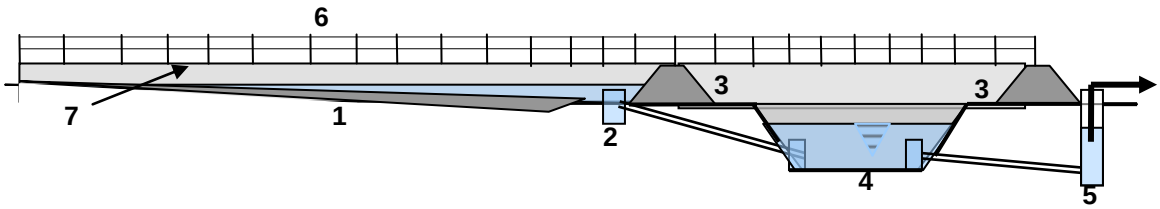
An 'improved haffir' is one with a water treatment system that can provide drinking water primarily for human consumption. A haffir without a water treatment system that is used for purposes other than drinking may not be classified as 'improved haffir'

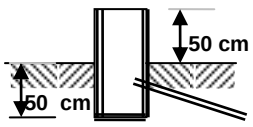
- Haffirs are rectangular or semi-circular impoundments that store water to be used by both human and livestock population during the dry season.
- Haffir size varied from 15,000m^3 to 100,000m^3.

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





DETAIL OF 2

Components:

1 Silt retention basin (pool)
2 Raw water inlet 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 Brekads 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:

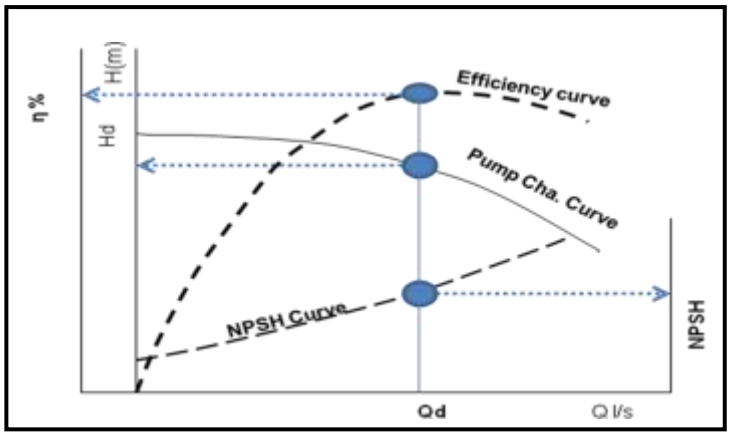
a) Dry running of the pumps should be avoided,

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.

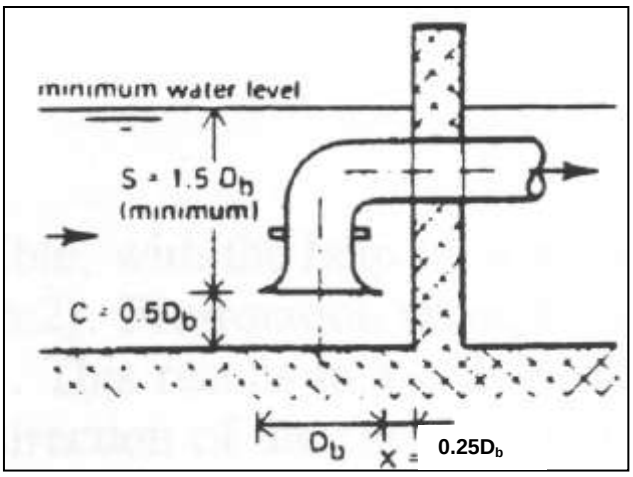
5. Operation with Strainer/Foot Valve Clogged

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:

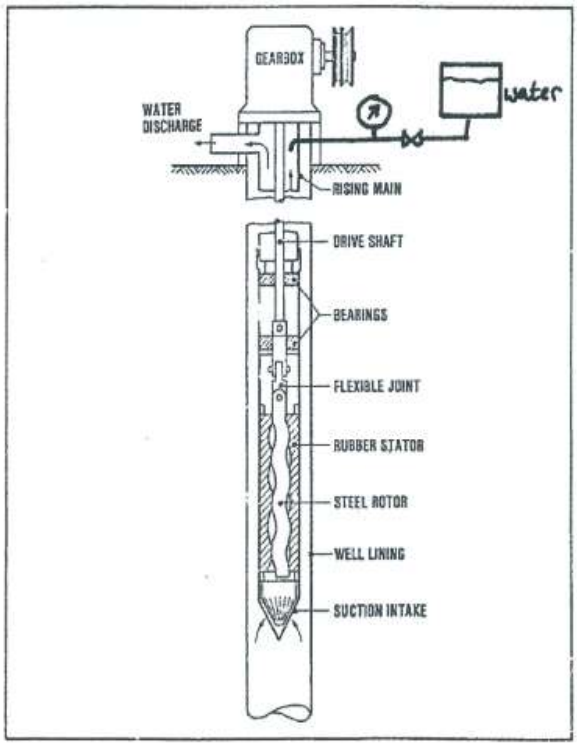
a. Centrifugal Pump (low and medium specific speed)

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)

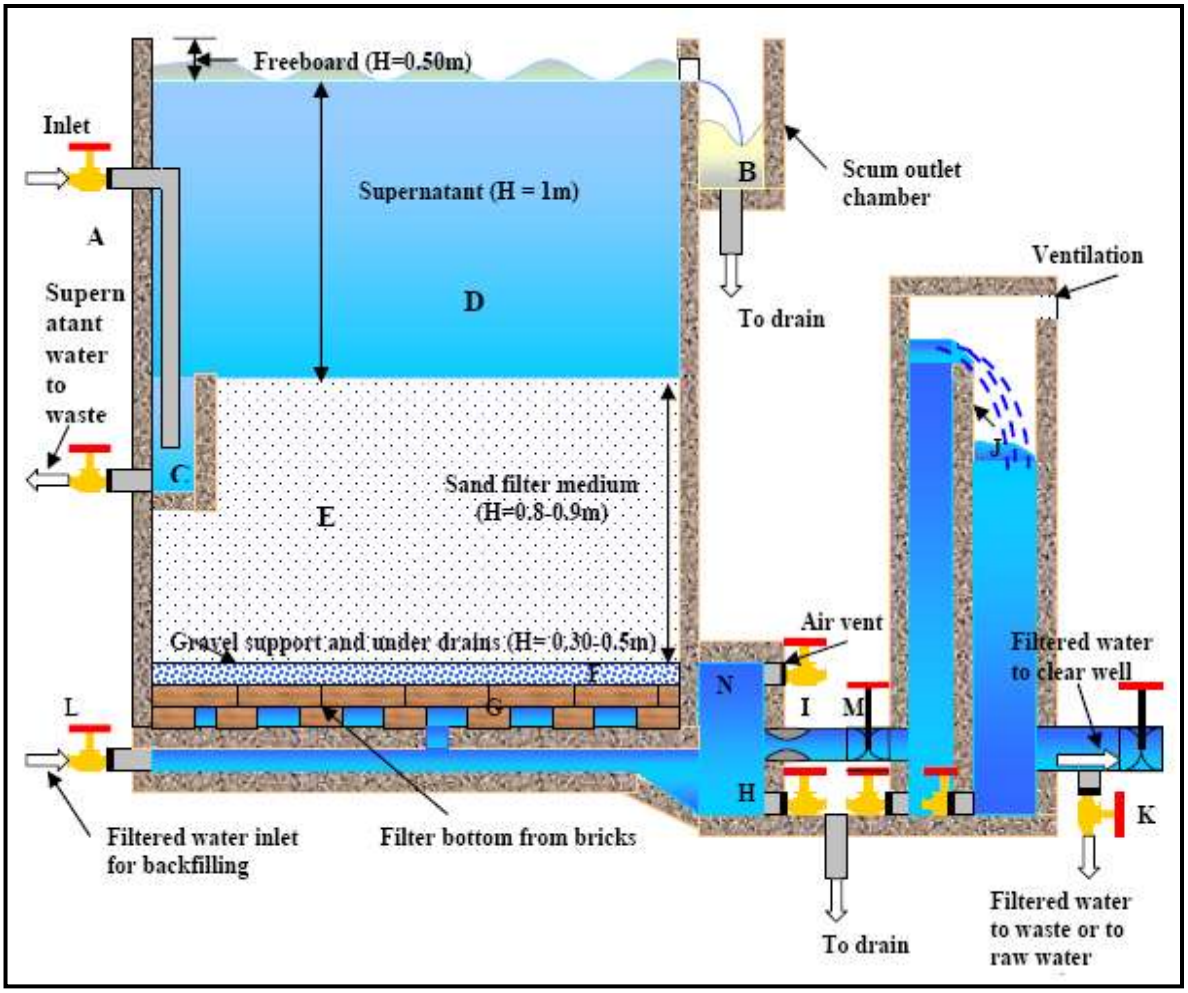
Slow sand filters should function on a continuous basis for two major reasons: to build confidence among the users on the availability of quality water; and to use efficiently the bacteria that has been oped in the 'schmutzdecke' (filth cover) of the filter media.

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



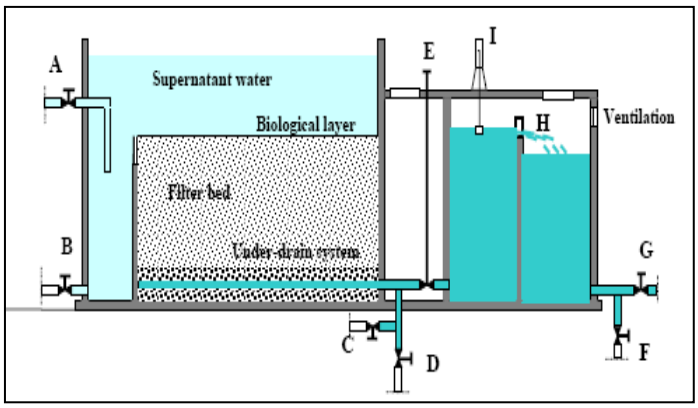
3.8.1 Process

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.

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.

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

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.

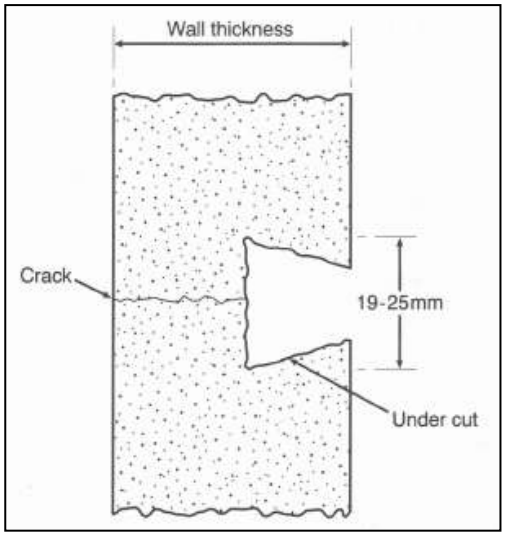
4.1.1.1 Crack Maintenance

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 with in 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 cementicious 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

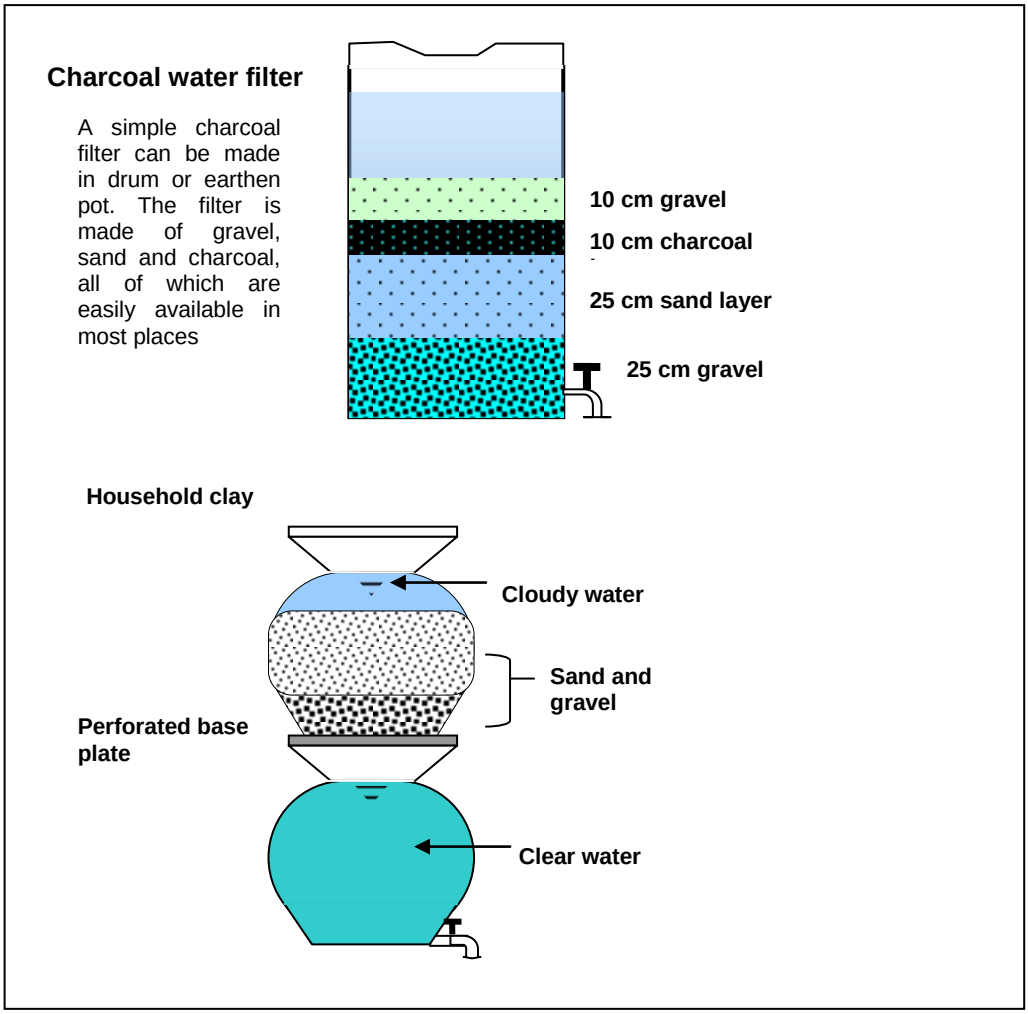
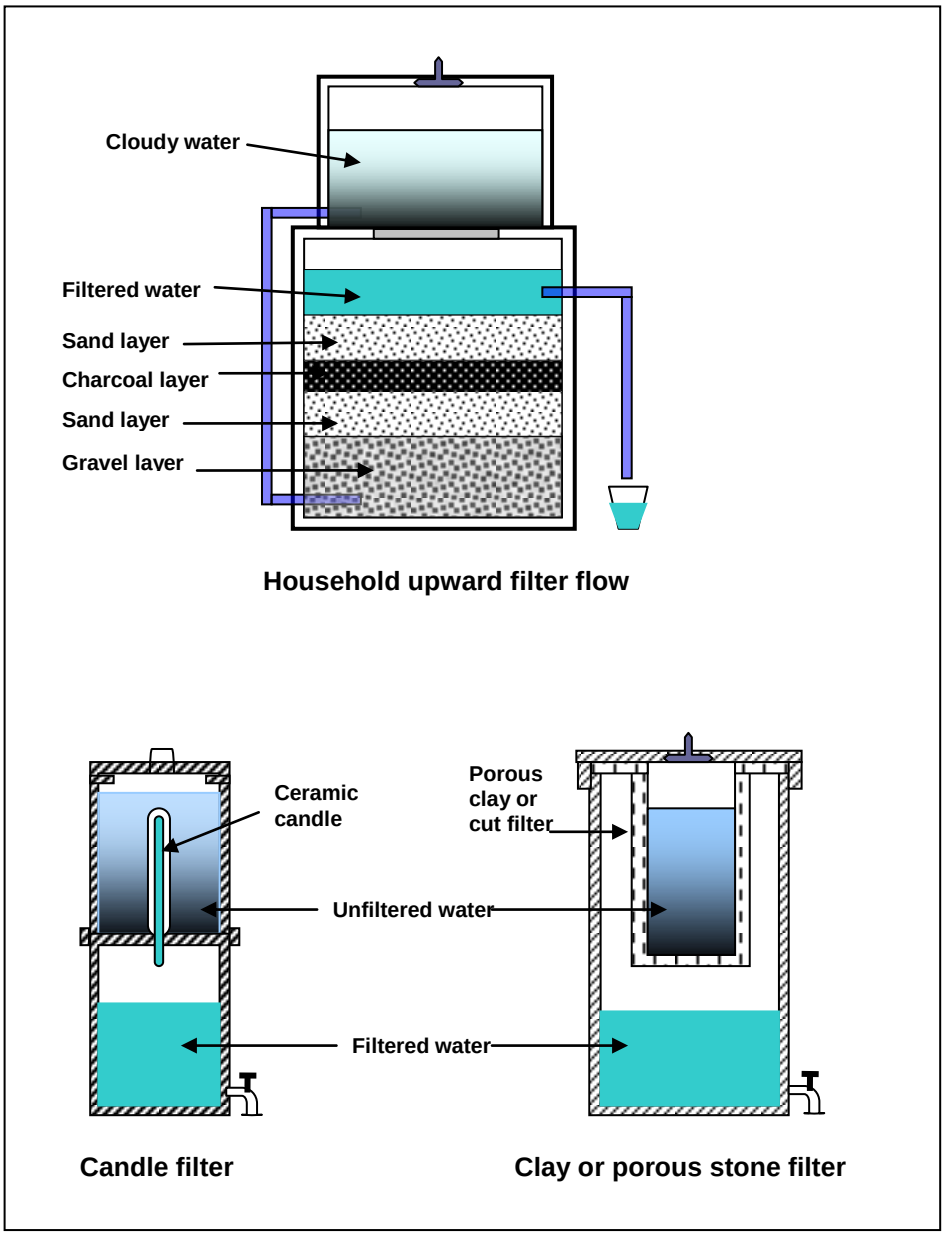


Figure 3-5: Example of Household Upward Filter Flow



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 A: References

Technical Guidelines for Improved Hafirs, 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 B: Detailed Plan and Section of Haffir Dam from Rain water harvesting

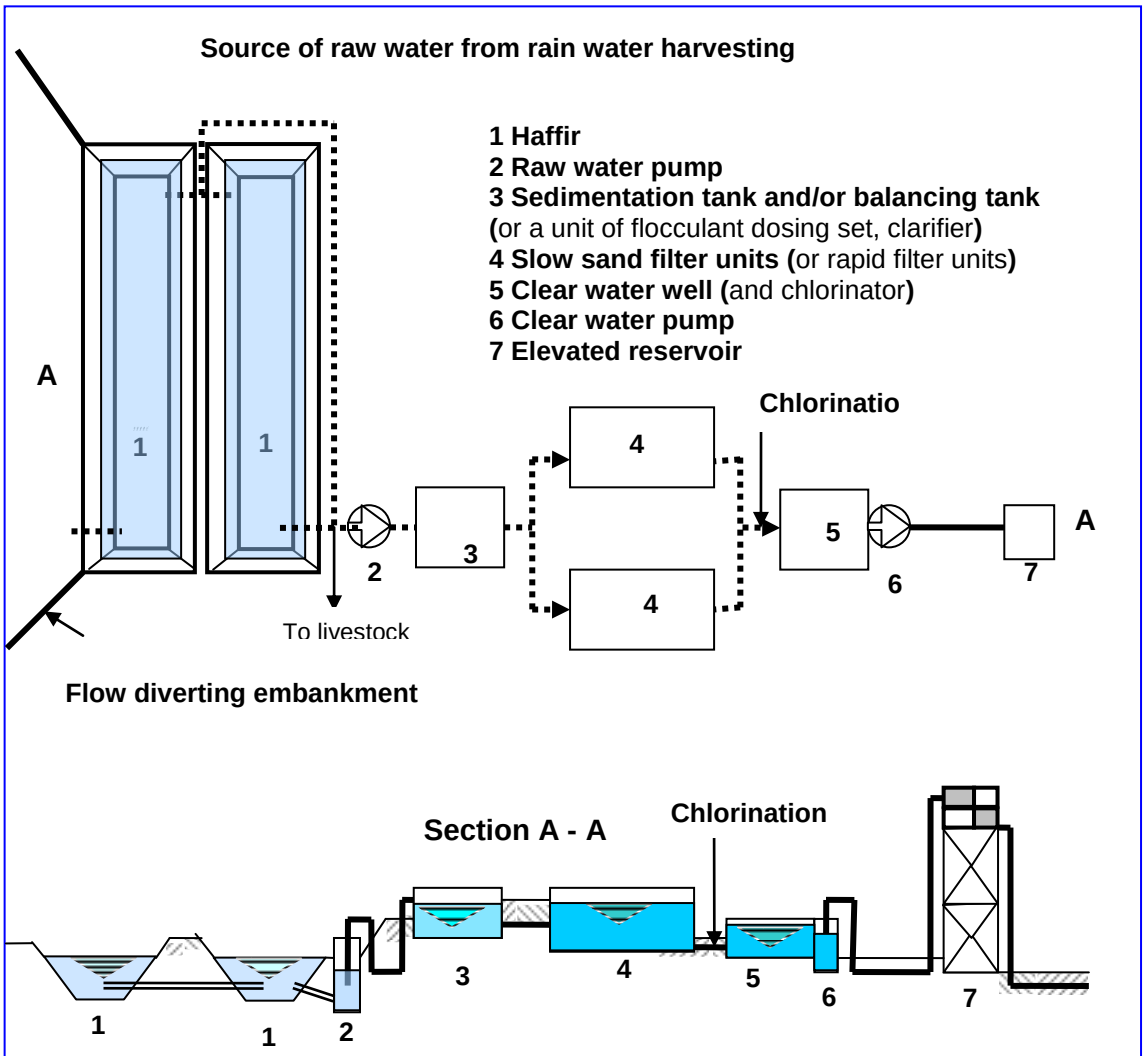


Figure 4. Schematic flow diagram of improved Haffir for raw water source from rain water harvesting

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

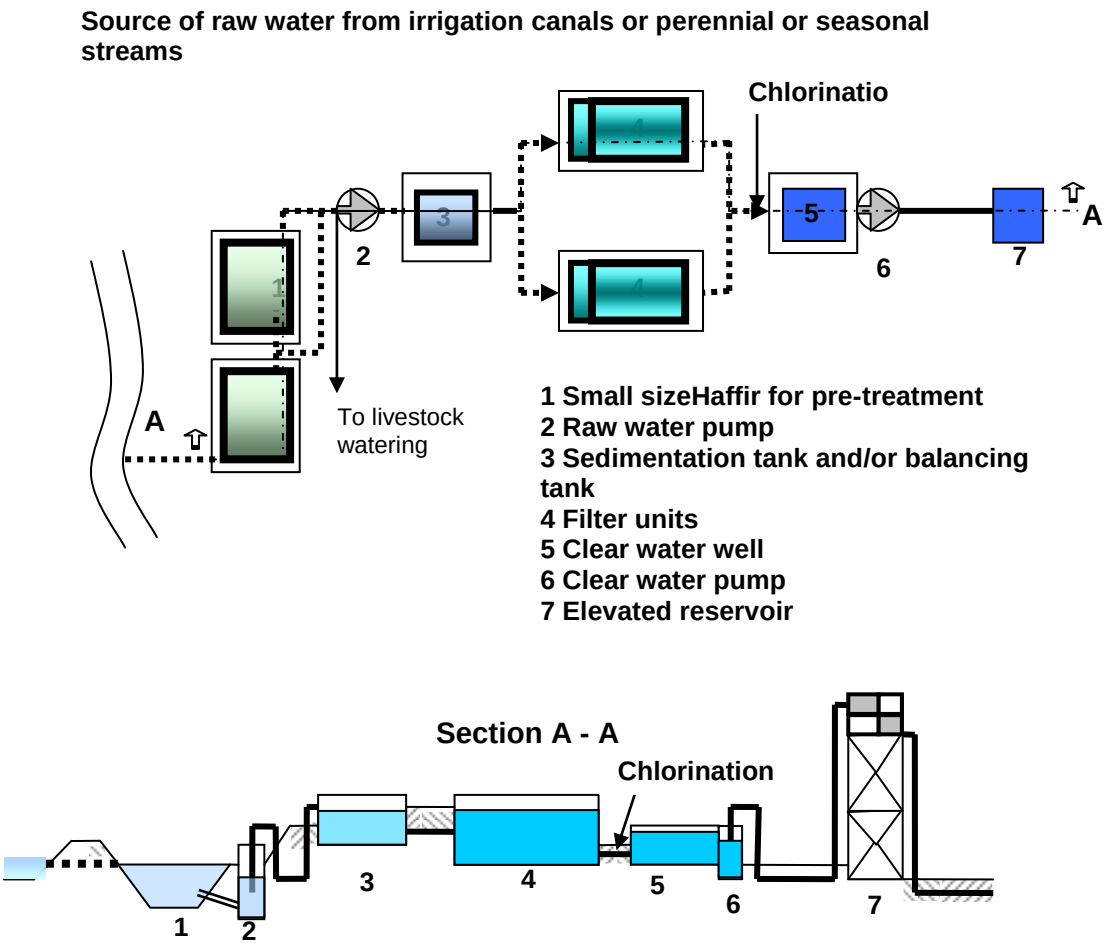


Figure 5. Schematic flow diagram of improved Haffir for raw water source from irrigation canals, perennial or seasonal streams