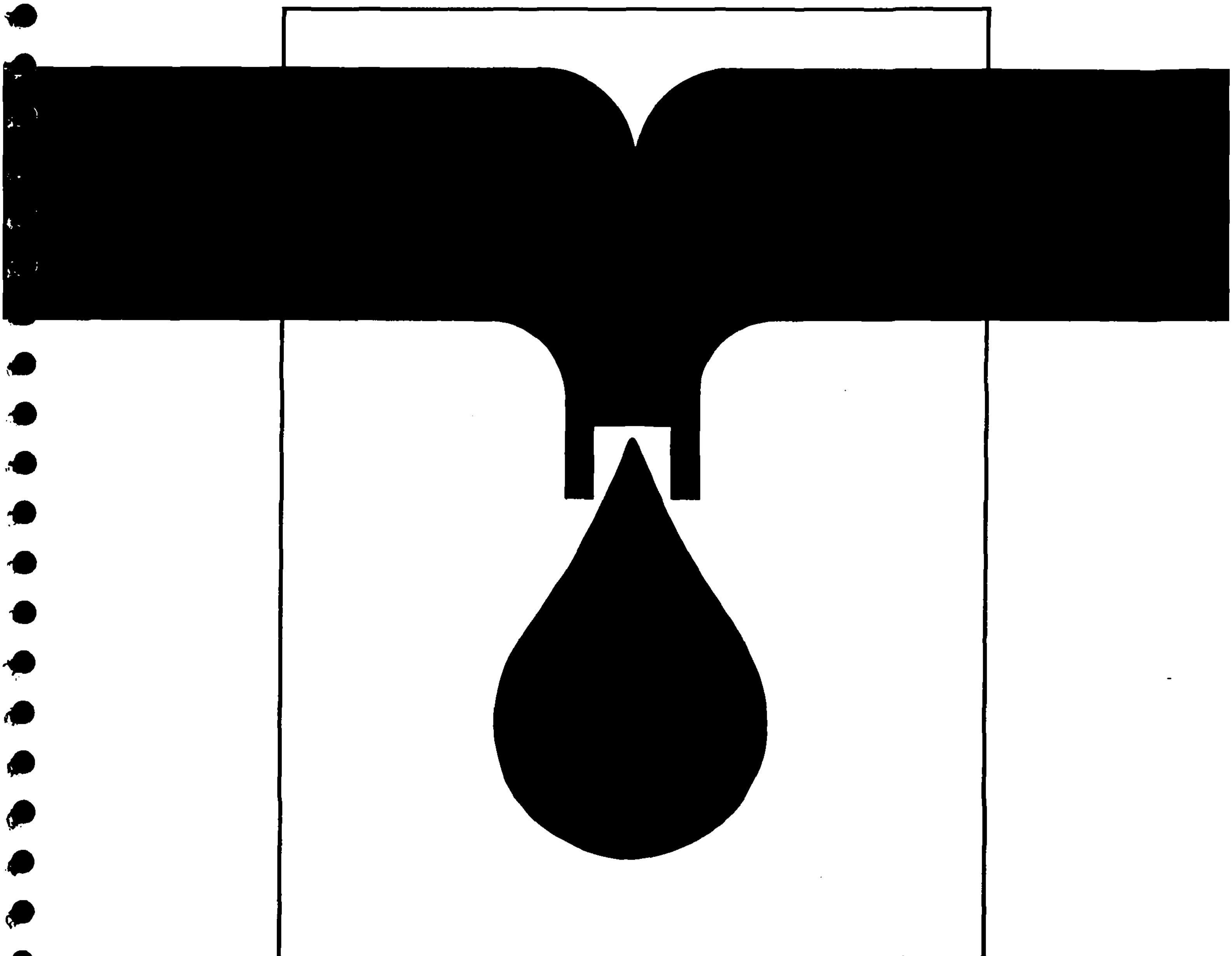
TRAINING MODULES
FOR
WATERWORKS PERSONNEL



Special Knowledge

2.8

Construction of water supply units

Foreword

Even the greatest optimists are no longer sure that the goals of the UN "International Drinking Water Supply and Sanitation Decade", set in 1977 in Mar del Plata, can be achieved by 1990. High population growth in the Third World combined with stagnating financial and personnel resources have led to modifications to the strategies in cooperation with developing countries. A reorientation process has commenced which can be characterized by the following catchwords:

- use of appropriate, simple and – if possible – low-cost technologies,
- lowering of excessively high water-supply and disposal standards,
- priority to optimal operation and maintenance, rather than new investments,
- emphasis on institution-building and human resources development.

Our training modules are an effort to translate the last two strategies into practice. Experience has shown that a standardized training system for waterworks personnel in developing countries does not meet our partners' varying individual needs. But to prepare specific documents for each new project or compile them anew from existing materials on hand cannot be justified from the economic viewpoint. We have therefore opted for a flexible system of training modules which can be combined to suit the situation and needs of the target group in each case, and thus put existing personnel in a position to optimally maintain and operate the plant.

The modules will primarily be used as guidelines and basic training aids by GTZ staff and GTZ consultants in institution-building and operation and maintenance projects. In the medium term, however, they could be used by local instructors, trainers, plant managers and operating personnel in their daily work, as check lists and working instructions.

45 modules are presently available, each covering subject-specific knowledge and skills required in individual areas of waterworks operations, preventive maintenance and repair. Different combinations of modules will be required for classroom work, exercises, and practical application, to suit in each case the type of project, size of plant and the previous qualifications and practical experience of potential users.

Practical day-to-day use will of course generate hints on how to supplement or modify the texts. In other words: this edition is by no means a finalized version. We hope to receive your critical comments on the modules so that they can be optimized over the course of time.

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It is my sincere wish that these training modules will be put to successful use and will thus support world-wide efforts in improving water supply and raising living standards.

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Eschborn, May 1987

CONSTRUCTION OF WATER SUPPLY UNITS

CONSTRUCTION OF WATER SUPPLY UNITS

1. Introduction

1.1 General

This module summarizes principles and procedures for the construction of water supply units. It is designed to provide a uniform approach to trainers and trainees in different countries, thereby enlightening the task of each trainer in preparing or conducting courses, and in exchanging experience with other trainers.

The trainer would have to use the module in conjunction with the related modules and appropriate construction manuals, etc. In addition the trainer's experience is a significant input; particularly in dealing with local conditions.

This module is not a construction manual and should not be used as such. Actual construction must be carried out in accordance with drawings, specifications and bills of quantities.

1.2 Presentation

Section 2 lists the water supply units considered in this module, and describes the basic requirements for construction.

Section 3 is on water supply units as a whole and deals with location criteria, earthwork, and composition and features that are common to most water supply units.

The water supply units listed in Section 2 are presented in sections 4 through 8.
Section 9 deals with miscellaneous questions.

2. General

Construction is the transformation of materials into a stable and functional structure by the optimal use of available funds, labour, equipment and construction methods.

A water supply unit, which we shall call "unit" for short in this module, is a part of a water supply system that serves a specific purpose. The units that are considered in this module are:

Spring Collection Chambers;
Hand Dug Wells;
Water Tanks;
Wellhead Chambers for Boreholes;
and Shafts.

2.1 Basis Requirements

A structure is designed and constructed considering the basic requirements related to it. For water supply units the basic requirements are:

a) structural;
b) operational; and
c) hygienic.

2.1.1 Structural requirements

The structural requirements are that the unit must be stable and durable. These are met when the work is done in accordance with drawings, specification and bills of quantities:

- the ground on which the unit is to be built must be correctly prepared;
- correct levels and dimensions must be used;
- materials must meet quality requirements;
- concrete, reinforcement and other materials must be placed in such a manner and position that they are not adversely affected by water, soil, or groundwater.

2.1.2 Operational requirements

To meet the operational requirements it is necessary to ensure that the appurtenances (inlet pipes, outlet pipes, overflow pipes, wash-out pipes, by-pass pipes, vents, screens, manhole covers, ladders, climbing irons, valves, watermeters, and level indicators) have suitable sizes or dimensions and are located at appropriate positions. Furthermore surfaces and grooves should be given the necessary slopes, sumps and sand traps with adequate dimensions should be provided.

2.1.3 Hygienic requirements

Hygienic considerations require the prevention of entry of unwanted water *), small animals, rubbish, etc., into units constructed to contain drinking water. This is achieved by making the structures watertight: by providing screens, and tight fitting and watertight manhole covers, by constructing diversion ditches and by protecting the surrounding area, where appropriate, with fences.

3. Water Supply Units

3.1 General

Depending on their position relative to ground level, water supply units can be classified as wholly underground, partially underground, ground level, or elevated.

As most of the structures are ground level, or wholly or partially underground, their common characteristics, features and components will be discussed together.

These common characteristics, features and components do not apply to each type of water supply unit. They have been considered here together to avoid repetition of descriptions under each of the examples given in Sections 4 through 8. Particular features, are discussed further in the section devoted tc the unit in question.

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*) This can be surface water, seepage water, split water, or polluted water or any combination of these.

3.2 Location

There are a number of factors that influence the location of the unit. Such factors include nature of the ground, level and nature of the ground water, and exposure of the site to floods.

In most cases the choice of the site is primarily governed by the predominant function that is to be fulfilled by the unit.

In general the unit must be located to enable easy access during construction, operation and maintenance; easy access being necessary for labour, personnel, fuel, equipment, etc. Where appropriate the shortest connection for an electric supply line should be made possible.

It is important that the stratum on which the unit is to be built must be capable of safely bearing the loads imposed by the structure and its contents. Settlements must be avoided, since the resulting cracks will cause loss and contamination of water and further damage to the structure.

Furthermore the unit should be located in such a way that the possibilities of contamination of the water, and damage to the structure by surface water, floods, ground water, aggressive soils and waters, etc., are avoided.

It should be noted that thorough preliminary site explorations and, where necessary, more extensive investigations are necessary for choosing a suitable location.

Only if there is no alternative site should the water supply unit be constructed in waterlogged ground which cannot be drained economically. In such circumstances the unit must be constructed to withstand external hydrostatic pressure.

Depending on the type and nature of the unit, possibilities for future expansion must also be considered in choosing the site.

3.3 Earthwork

Top soil must be removed and excavation continued to such a depth that foundation or floor slab will be laid on firm soil or rock. This can entail considerable amount of earthwork.

The provision of temporary support, the removal of water, the preparation of the sub-grade, the placing of gravel layers, backfilling, and safety in excavation are considered under this "Earthwork" Section.

3.3.1 Temporary support

The sides of excavations must be adequately supported to ensure the safety of workmen, to prevent cave-ins, to facilitate the work, and to protect structures already constructed.

3.3.2 Removal of water

Water will generally reduce the stability of excavations. Wherever possible it should be diverted at the outset. Excavations must be kept free from water by using suitable manual or mechanical means or both. Concreting or other constructional work should only be carried out when the excavations are dry. Furthermore excavations should be kept free from water until the concrete has set sufficiently so that the concrete is not adversely affected by water.

3.3.3 Sub-grade

The sub-grade is the natural ground on which the structure will be founded.

To ensure that the bottom of the excavated ground is not adversely affected by weather conditions, the excavation of the last 20 cm should only be carried out immediately before the foundation or floor slab is laid.

In cohesive soils the excavation should be well drained to avoid the softening of the soil.

When the team is ready to start foundation or floor slab construction, the exposed ground surface of the excavation pit is thoroughly compacted; the top 20 cm of the compacted ground excavated and given the necessary slope.

3.3.4 Gravel layer

Specially in cohesive soils a compacted gravel layer up to about 20 cm thick is placed on the sub-grade together with any drainage pipes that might be necessary.

Drainage is necessary for monitoring any leakage which may develop in the floor of a water tank, for example. It is also necessary for preventing any build-up of ground water uplift pressure under a water supply unit, or under a water retaining structure when it is emptied, for example during cleaning operations, at a time when the ground water level is high.

3.3.5 Backfill

After the construction of the unit, the space between the wall of the structure and the excavated ground should be filled and made watertight to prevent the infiltration of surface water originating in the immediate vicinity of the structure. For this purpose puddled clay and excavated material previously set aside are laid and compacted in layers.

Before backfilling, it must be ascertained that the structure has attained sufficient strength. If the unit is a water retaining structure it must be full of water during the backfilling process.

3.3.6 Safety

Further to the provision of adequate temporary support, safety requirements demand that excavated material or other objects should not be placed near the edges of excavations. Adequate and proper means of access to and from excavations must be provided. As a matter of routine excavations should be examined daily to ensure that it is safe to work within them.

3.4 Composition and features

For ease of presentation a water supply unit is deemed to consist of the following components and features: sub-base (or blinding layer), foundation, floor slab, walls, roof slab, and joints. Furthermore hydraulic, mechanical and electrical installations, and appurtenances have to be provided, as necessary, for the proper functioning of the unit.

3.4.1 Sub-base

A blinding layer of lean concrete, is laid on the sub-grade (on top of the gravel layer in cohesive soils), to provide a clean, even, and firm surface upon which the floor slab proper, or foundation will be laid. If the concrete is placed in direct contact with the soil formation, it will mix with the soil; and this will adversely affect the quality of the concrete.

Where units are founded on clean rock, the blinding layer is still highly desirable; otherwise the restraint rock will inevitably lead to the development of cracks in the slab as the concrete shrinks on setting.

3.4.2 Foundations and floor slabs

The foundation is determined by the bearing capacity of the soil, the loads imposed by the structure, and by the maximum water that it contains. Settlements must be avoided as the resulting cracks do not only cause further damage to the structure, but they will also lead to loss and contamination of water, Great care is required in the construction of the foundation or floor slab of the unit. Any failure of the foundation or floor slab endangers the safety of the structure and causes leakage which is more difficult to locate and remedy than leakage through the walls.

The floor slab must be watertight. Where the nature of the unit requires a screed can be laid as the final exposed surface of the floor. The screed should be placed after the completion of all carcass work. Furthermore the floor must be non-skid, easy to clean and inclined towards drainage grooves which should lead any water to a sump.

3.4.3 Walls

Wall thickness depends on loads, ease of construction required, and available means and materials of construction; wall height, on functional and operational requirements. The walls must be watertight to avoid loss of water and to ensure protection against seepage water.

3.4.4 Roof slabs

The reinforced concrete roof slab must have, where appropriate, an access hole with a locable manhole cover. The roof slab can be cast in-situ or pre-fabricated. It must be watertight.

3.4.5 Joints

Depending on the function and size of the unit, a jointed system of construction is essential. Waterstops are placed in the construction joints of water tanks. All joints should be located and constructed according to drawings and specifications.

3.5 Appurtenances

For the purpose of this module appurtenances include inlet pipes, outlet pipes, overflow pipes, wash-out pipes, by-pass pipes, vents, screens, manhole covers, ladders, climbing irons, valves, watermeters, and level indicators. (See Module 3.8b.)

3.6 Construction materials

Concrete is the ideal construction material for the majority of water supply units. Stones, bricks, or hollow concrete blocks can be used for walls. Hollow concrete blocks are reinforced by placing steel in the mortar at intervals between courses. Steel reinforcement can also be placed inside the hollow portions of the blocks that are then filled with concrete. Brick and stone walls can be strengthened by laying galvanized wire mesh horizontally at intervals.

The raw materials for concrete are cement, sand, coase aggregate and water. Steel reinforcement is necessary for reinforced concrete.

Stones are also used for the inlet of a spring collection chamber; gravel and sand, for the gravel pack at the intake of a spring collection chamber or a hand dug well.

Steel sheets are used for the construction of elevated water tanks, bituminous felt, for the insulation of walls that are subjected to hydrostatic pressure, and waterstops, for the construction joints of reinforced concrete water tanks.

The choice of materials and the method of construction depends on:

- the nature and function of the unit or the component;
- the quality of the water the unit will retain;
- the nature of the soil;
- the ground formation;
- the groundwater;
- the skills and construction equipment available locally; and
- the availability of the construction materials themselves

3.7 Watertightness

Because of hygienic and structural considerations, the floor slabs, walls and roof slabs of the units must be made watertight. This avoids water loss and contamination, and impairment of the structure. Water containing structures are normally made watertight by making dense concrete and by applying bituminous paint on the outer face of the walls; and in unavoidable situations, by plastering or by applying special paint on the floor slab and inner face of the walls or both.

If the unit is going to be subjected to hydrostatic pressure, it is necessary to construct a protective masonry wall. The second wall is built after bituminous felt has been placed on the outer surface of the wall that is to be protected.

On the other hand because of the functional considerations, one of the walls of a spring collection chamber and the floor or lowest part of the shaft lining of a hand dug well are made permeable. These parts are the intakes that are constructed to permit water to flow in, excluding solids that might enter with the water.

3.8 Plastering and painting

Masonry walls may be plastered or pointed *), Metal parts are painted to protect them from corrosion.

3.8.1 Inner surfaces

Sometimes it is seen that concrete surfaces are plastered or painted or both, to make them watertight. Plastering of concrete surfaces should be avoided, as should painting of inner surfaces. Better results can be obtained by careful preparation of the shuttering and proper placing, compacting and curing of the concrete.

If painting becomes absolutely necessary, paints that contain substances endangering health or imparting bad taste or odor to water should not be used on surfaces that come in contact with drinking water. Furthermore painting should be carried out following the manufacturer's instructions; special attention being paid to safety precautions.

3.8.2 Outer surfaces

The outer surfaces of the walls are painted with bituminous paint in the region of the backfill.

3.8.3 Painting of steel water tanks

The inner and outer surfaces of steel water tanks should be painted to prevent corrosion. (See paragraph 3.8.1 about restrictions on paints for use on inner surfaces).

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*) To point a masonry wall each vertical and horizontal joint is cleaned up, accentuated, and smoothed out with cement paste.

3.9 Electrical installations

Electrical installations should be carried out by qualified electricians in accordance with the governing standards and subject to the regulations of the electric supplying body. Attention should be paid to voltage limits. Lamps and switches suitable for damp rooms should be installed, and the control panel fixed in a dry place.

3.10 Examples

The water supply units that are considered in this module are:

(a) Spring Collection Chambers;
(b) Hand Dug Wells;
(c) Water Tanks;
(d) Wellhead Chambers for Boreholes; and
(e) Shafts.

They are presented in Sections 4 through 8.

4. Spring Collection Chambers

4.1 Purpose

Spring collection chambers are constructed for the hygienic collection and supply of groundwater that emerges naturally to the surface.

Other main points of construction are:

- watertightness of the structure, and of the ground for at least 3 metres below the surface;
- safe disposal of overflow or waste water or both from the structure;
- prevention of back-flow into the intake; and
- diversion of surface water from the structure.

4.2 Components

The components of a spring collection chamber are

- a chamber with an access hole;
- an intake consisting of an open stone wall and gravel pack[1];
- an outlet pipe to a reservoir or supply point, or pumping station when the spring outcrops below the consumer location;
- a screened overflow pipe;
- a drain pipe; and
- a lockable manhole cover for the access hole.

4.3 Shapes and dimensions

Spring collection chambers are rectangular. Their dimensions are determined on the basis of the maximum inflow. Their depths are further influenced by hydrogeological conditions, hygienic considerations, and characteristics of covering strata.

4.4 Location

To prevent pollution the spring collection chamber should be located and built so as to force surface water to pass through at least 3 meters of soil before reaching the ground water.

In general the intake side of the chamber should be placed at right angles to the direction of flow of the ground water.

Spring collection chambers should be located above and as far away as possible, at least 30 meters, from sources of possible contamination such as latrines, refuse dumps, manure piles, fertilizers, etc.

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1) Carefully selected and graded gravel and sand is placed behind the stone wall. This gravel pack prevents the aquifer material from flowing into the chamber and eroding the soil behind. However, the sand should not be finer than the existing soil or it will block the flow. On the other hand the filter material should not be liable to being washed out.

4.5 Construction

1. Clear the site.

2. Excavate into the hillside and down to the water-bearing layer. Remove excavated material. Set aside for backfill. When excavating for the foundation take great care not to disturb, damage, or penetrate the impervious layer. Otherwise the water will seep down and the spring will move downhill or disappear.

3. Place and compact in layers gravel below formation level in foundation trench.

4. Place blinding layer 5 cm thick (sloping).

5. Construct floor slab (inclined).

6. Firmly pile, against the eye of the spring, loose stones that are big enough to guarantee the stability of the open stone wall.

7. Construct the walls of the collection chamber using either reinforced concrete or masonry; installing the appurtenances. The chamber should be provided with a reinforced concrete slab that has a covered access hole. To prevent surface water from entering the chamber, the top of the slab should be at least 30 cm above the highest ground level close to the chamber.

8. Provide a drain pipe at the bottom of the chamber. A flap must be fixed at the outer end of the drain pipe to prevent entrance of small animals.

9. Install an outlet pipe big enough to discharge the water. The outlet pipe should be placed at least 10 cm above the inclined floor of the chamber, but below the level of the eye of the spring. The end of the outlet pipe inside the chamber must be covered with a screen to prevent stones, rubbish, and frogs from blocking the supply pipe or pipes.

10. Provide an overflow pipe big enough to carry the maximum flow during the rainy season. The overflow pipe should be below the level of the eye of the spring. If the water level in the chamber is too high there will be

a backflow. Silt may then settle in the filter pack as well as in the water bearing layer behind it, and block up the entry of water into the chamber, forcing the spring to the side. The end of the overflow pipe inside the chamber should be covered with a screen fine enough to keep out mosquitoes and strong enough to hold back frogs, etc., that may block the pipe.

11. Place a gravel pack behind the open stone wall.

12. Place and compact in layers puddled clay in the space above the gravel pack and behind the chamber walls.

13. Backfill space above the puddled clay by laying and compacting in layers the excavated material previously set aside.

14. Pave the ground on which water is discharged from the overflow and drain pipes.

15. Dig a diversion ditch above and around the chamber. Place the excavated material on the downhill side of the ditch to form a ridge.

16. Fill up and adjust the area in the vicinity of the chamber, giving it a slope away from the chamber.

17. Fence the protected zone to keep out animals and nonauthorized persons.

5. Hand Dug Wells

5.1 Purpose

A well is a device for tapping groundwater. There are different types of wells depending on ground conditions and construction methods. The type that makes use of local skills is the hand dug well.

5.2 Features

The features of a hand dug well are

- intake;
- shaft and shaft lining;
- wellhead consisting of head wall and drainage apron;
- wellhead cover with opening and lockable cover; and
- drainage channel and pipe to soakaway.

A suitable pump is installed to complete the work for hygienic consideration and to ease water withdrawal.

5.3 Shapes and dimensions

The circular section is recommended by experts in the field, because of its advantages of economy and strength.

For normal sized hand dug wells used for domestic supplies experts recommended a finished diameter of about 1.3 metres since this provides the room needed for two men to work inside a well, and an increase in diameter beyond this does not give any great advantage.

The depth is determined by the water table in the dry season and the type of ground formation.

5.4 Location

Prospects of obtaining adequate quantities of water should be good. Expert advice has to be obtained to ensure this. Wells should be located as far away as possible from all potential sources of pollution.

5.5 Construction

1. Prepare construction site (see Module 3.8 a).
2. Start manufacturing reinforced concrete rings.
3. Prepare well site and set up equipment (see Section 5.6).

4. Start the excavation and provide temporary support for surface soil (see Section 5.8).
5. Dig and line shaft (see Section 5.9).
6. Remove the temporary support when the lining below it is constructed up to the level of the base of the support. Trimm back the walls to full diameter and continue the lining to ground surface; providing the top part with a continuous watertight lining.
7. Construct inlet.
8. Place puddled clay around the upper 3 metres of the well.
9. Construct wellhead.
10. Construct soakaway.
11. Construct drainage channel and pipe to soakaway.
12. Determine yield of well (pump test).
13. Install pump.
14. Disinfect.

5.6 Preparation of well site and setting up of equipment

- Clear site.
- Mark centre of well shaft.
- Provide a working space of about 10 to 15 metres radius.
- Set up tripod and related equipment.
- Install offset pegs.

5.7 Installation of offset pegs

By means of a plumb bob hanging from the tripod pulley at the position of the hoisting rope, mark the centre of the well.

Install offset pegs by using the plumb line and a plumbing rod. The well centre is transferred from these offset pegs for checking well alignment and diameter during construction.

5.8 Temporary support forsoil near surface

To prevent the collapse of the soil near the surface a temporary support should be provided. The dimensions and form of the temporary support depend on the method of construction or the available materials for its construction. Mark a circle or square about the centre. Excavate to a depth of 90 cm, provide a temporary support 1 metre high to prevent the soil from collapsing. The temporary support projects 10 cm above the ground. This reduces the risk of accidents that would be caused by tools and other objects falling into the well shaft during construction.

5.9 Methods of excavating and lining the shaft

There are different methods for excavating and lining the shaft. The method to be used depends on ground formation, construction materials, local skills, available equipment, and experience.

5.9.1 Excavating to the entire depth and constructing the lining.

This method is suitable in firm ground formations. The lining can be constructed

a) in masonry, or
b) by lowering reinforced concrete rings.

In both cases the risk of danger is greater, the deeper the excavation is and the longer it remains unsupported.

Stone, concrete block, or brick masonry can be used for the shaft lining. To prevent deformation and cracks because of uneven settlement the masonry lining has to be provided with a steel or reinforced concrete shoe at the base.

Masonry is only used where suitable stone, good quality bricks and concrete blocks, and skilled masons are available, and ground conditions are favourable. The walls are then thicker, the corresponding excavation greater, the work slower, and the risk of danger higher than in the other methods.

5.9.2 Excavation and construction of the lining alternately in stages

The depth of each stage of excavation can vary from 1 metre to 5 metres, depending on ground formation.

The lining is built by pouring concrete behind removable shutters. This is done in stages which should not exceed a depth of 5 metres at a time. Each stage is completed before the next one is started. This method is used in loose ground formations and above the water table.

5.9.3 Excavating and lowering reinforced concrete rings alternately in stages

This method is also called caissoning. The depth of each excavation depends on the height of the reinforced concrete ring.

The rings are lowered one by one into the shaft and allowed to sink under their own weight as the soil is excavated from within. A new ring is added when the top-most ring is in level with the top of the temporary support.

This method is suitable for loose ground fromations and deep hand dug wells.

5.9.4 Combination of 5.9.2 and 5.9.3

In this combination the method described in 5.9.2 is used from ground level down to the water table, and that described in 5.9.3 for constructing the part of the shaft that lies below the water table. Reinforced concrete rings whose outside diameter is slightly less than the internal diameter of the upper lining are used.

This method has the advantage of easing the deepening of the well: If construction is carried out when the water table is not at its lowest level, the well may dry when the water level drops at the end of a long dry period. To avoid this drawback the reinforced concrete rings (caisson tubes) are left projecting into the upper lining and the well deepened when the water table is at its lowest level. The length of the projection of the caisson tubes into the upper lining depends on the depth the water table is expected to fall. The deepening will only involve excavation. Further concreting or other construction will not be necessary, because the concrete caisson tubes are already there ready to be sunk.

5.9.5 Safety precautions

Whatever method is used safety precautions must be taken always. If the ground appears to be unstable before the planned depth is reached, a support must be placed around the shaft.

5.10 Improvements of existing wells

5.10.1. Purpose

Wells which are open, unlined, unprotected, badly located, poorly constructed and containing unsafe water have to be improved so that they cease to be sources of spreading disease, and causes of accidents and danger. The sources of pollution of an insanitary well are seepage water, surface water, split water, polluted groundwater, dirty vessels and rubbish.

5.10.2. Survey and check

A survey is made to identify the causes of the pollution and to determine the means of improvement.

A check is made of the location of buildings and possible sources of pollution with respect to the well; the existence and condition of lining, well-head and cover; the surface drainage around the well; and the slope of the ground surface. Further, after the well has been cleared of rubbish and sediment, tests are made to determine the yield of the well and the quality of the water.

If the well is too close to a source of pollution it will have to be condemned and abandoned.

5.10.3 Improvement

If there are no doubts about the yield and the well must not be abandoned it can be improved and made safe by:

- cleaning out and deepening the well to improve the yield;
- building a new lining or improving the existing one;
- making the soil around the top 3 metres of the lining watertight;
- constructing a new head wall and drainage apron or improving the existing ones;
- draining surface water away from the well;
- covering the well and installing a pump or a suitable device for drawing water in a sanitary manner; and
- providing an access hole with a lockable cover.

The methods described for the construction of new wells are used as appropriate for the improvement of existing wells.

6. Water Tanks

6.1 Purpose

A water tank is primarily built to store water for use during periods of peak demand.

6.2 Basic requirements

Water tanks should be designed, constructed, operated, and maintained in such a way that pollution, contamination or deterioration of the quality of the stored water is avoided. Therefore, the water tank, its connections and installations must be water-tight. To prevent the breeding of mosquitoes and the formation of algae the tank should be tightly covered and have no windows or openings.

Safe and easy access to the inside must be possible. The access opening should be provided with a cover that can be hermetically closed and locked to prevent entry of unauthorized persons to the tank or the stored water. It should be possible to carry out cleaning, maintenace, and repair activities without interrupting the service.

A water tank requires an inlet, outlet, overflow, wash-out, by-pass, vents, a valve chamber, a water meter and a level indicator.

A valve chamber allows the execution of operational activities and measurements without the risk of contaminating the water in the tank. It also ensures that the control devices are secure and not accessible to unauthorized persons. Taps, fitted on the inlet and outlet pipes, from which water samples can be taken, and a watermeter on the outgoing main are installed in the valve chamber.

6.3 Shapes and dimensions

The size of the tank and the methods that are used to construct it can influence the choice of shape. The usual tanks are either rectangular or circular in plan. Rectangular tanks are easier to build while circular ones are statically favourable. For small rectangular tanks the ratio length:width should not be greater than 2 : 1.

For small communities a single chamber water tank is usually adequate. If the supply to a large community will be insufficient during repair and maintenance activities, it is advisable (if funds are available and priority is not given to other works) to build two reservoirs instead of one. A reservoir with two chambers of equal capacity would also ensure an uninterrupted and adequate supply at all times.

6.4 Location

The location is determined by the topography and the layout of the area to be served. Where possible it should be attempted to locate the reservoir near the centre of the area it is supposed to serve. An elevated water tank can easily be situated as centrally as possible.

The optimum location is on high ground that allows water to flow from the reservoir to all taps of the distribution system by gravity without causing damage to pipes or fittings in the lowest parts of the distribution system.

If due to local conditions the elevation of the tank is so great that the pipes in the lowest parts of the system cannot withstand the pressure, it is necessary to provide break-pressure tanks. On the other hand water has to be pumped to those areas (if any) in the distribution system that are at higher elevations than the reservoir.

6.5 Construction

1. Clear the site.

2. Stake out the reservoir location.

3. Start excavation; remove excavated material and set aside for backfill.

4. Prepare the sub-grade.

5. Place and compact in layers gravel below formation levels in foundation trench, and on remaining sub-grade.

6. Construct concrete strip foundation and blinding layer.

7. Construct floor slab, wall, and roof slab; placing waterstops and other construction joints, and installing appurtenances [1)]

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1) Pipes should be built through the concrete at the time it is placed. The pipes should be accurately positioned and fixed in such a way as to secure watertight connections. Great care should be taken to prevent the displacement of pipes before or during the concreting. Boxing-out for subsequent installation should only be adopted in unavoidable situations. If there is no provision for boxing-out the concrete is chipped off before it has hardened. The appurtenances are fixed by use of cement mortar.

8. Install ladder and other appurtenances not placed according to item 7.

9. Inspect all concrete faces after formwork has been removed; and make necessary improvements.

10. Lay floor in cement mortar; providing a smooth finish and chamfered junctions with the wall.

11. Construct pipe anchor block.

12. Paint outer surface of water tank wall in the region of the backfill with bituminous paint.

13. Install water level indicator.

14. Test water tank for watertightness.

15. Backfill.

16. Adjust surrounding area; make an embankment if necessary, and plant grass.

17. Construct fence.

18. Disinfect before putting into operation.

6.6 Elevated water tanks

An elevated water tank is constructed when suitable high ground is not available in or close to the area to be served.

If the elevated water tank is made of steel, the steel parts should be properly prepared and painted to provide a sound structure and to minimize future maintenance and maintenance costs.

6.7 Steel tanks at ground level

It may sometimes be necessary to construct a steel tank at ground level. In such a case the tank should be mounted on short walls of concrete or masonry having a height and an opening that would also allow an easy inspection and painting of the lower parts.

7. Wellhead Chambers for Boreholes

A wellhead chamber is an essential structure for water supply from boreholes.

7.1 Purpose

Wellhead chambers are built

- to protect the well water from pollution;
- to safeguard the well from being tampered with:
- to protect the wellhead and the operating facilities;
- to accommodate the fittings, valves, measuring devices and other facilities that are necessary for operation; and
- to facilitate access for maintenance and repairs.

7.2 Features

In addition to its structural components:

- floor slab (foundation);
- walls, and
- roof slab with access holes 1);

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1) The roof slab of the wellhead chamber can be provided with one or two access openings. In the interest of safety and convenience it is advisable to build two access openings: One to serve as an access, and the other to permit the safe and easy installation, removal and replacement of the pump. The second opening must be directly above the wellhead.

the wellhead chamber has the following features:

- vents;
- manhole covers; and
- ladders.

7.3 Shapes and dimensions

The structures can be rectangular or circular in plan. The dimensions depend on the layout and sizes of the different facilities, such as valves, fittings, measuring devices, etc., and pipes which have to be accommodated in the chamber. Provision should be made for adequate space to facilitate installations, as well as safe and convenient operation and maintenance. The clear height should not be less than 2.0 metres. The length and width of the floor are determined by the loads and the bearing capacity of the soil. However, the clear width must be at least 1.5 metres.

7.4 Location

The location of the chamber depends on that of the borehole, which ought to be located so as to avoid possibilities of water contamination and damage to the wellhead chamber by floods.

7.5 Construction

The construction can be considerably influenced by the nature of the ground and the depth of the water table.

The ground under and around the wellhead chamber must be rendered watertight and the borehole cemented to cut off downward flow of possibly contaminated water into the well. This avoids erosion outside the casing, protects the casing against exterior corrosion, and prevents leakage when casing ultimately rusts through from within.

1. Clear the site.
2. Set out for excavation and fix offset pegs.
3. Excavate for pit, providing temporary support as necessary.
4. Remove excavated material and set aside for backfill.

5. Waterproof the ground under the wellhead chamber by putting cement grout around the casing and puddled clay on the sub-grade.
6. Place gravel layer.
7. Place blinding layer.
8. Put the wellhead and observation pipe duct in their correct positions.
9. Construct the reinforced concrete slab foundation of the unit; anchoring the wellhead and observation pipe duct in the slab.
10. Construct wall in masonry or reinforced concrete; installing appurtenances, providing joints, placing pipe ducts, and applying insulation material as necessary.
11. Construct the roof slab of the chamber with access openings; installing vent.
12. Construct floor; providing drainage grooves and sump.
13. Paint outer face of wall with bituminous paint.
14. Backfill partially.
15. Place and compact in layers puddled clay.
16. Backfill.
17. Adjust surrounding area.
18. Construct fence.

8. Shafts

8.1 Purpose

Shafts are constructed to accommodate and protect valves, measuring devices and other operating facilities; thereby ensuring possibility of access to these facilities, at all times, for operation, maintenance and repair.

8.2 Basic requirements

The pipeline should not be affected by the settlement of the shaft. To ensure this, appropriate provisions should be made in the construction of the opening in the wall through which the pipe passes, or suitable fittings installed on the pipe. The shaft should be provided with a manhole cover that is simple to use, safe to operate and that can only be opened by means of special tools.

The construction of the shaft and the arrangement of the devices should allow safe entry and exit. Ladders or climbing irons that enable safe access must be provided.

Sufficient space must be made available between the internal surfaces of the shaft and the installed facilities to enable erection, operation, maintenance and replacement. In some cases it would be advisable to build fixing clamps and hooks.

8.3 Shapes and dimensions

Shafts can be rectangular or circular in plan. The dimensions depend on the diameters of the connected pipes, the types, sizes and particular functions of the facilities to be accommodated, and their operational requirements. The shaft must be large enough to allow installation, repair and maintenance works to be carried out with ease.

8.4 Location

Shafts should be located outside streets, roads and highways, so that they are easily accessible at any time. The shafts are normally placed on the pipeline. Shafts for emptying and flushing devices are placed at depressions in the pipelines; and those for aeration devices, at the summits.

8.5 Construction

The construction is described in two parts

a) Shaft construction; and
b) Installation of fittings.

8.5.1 Shaft construction

1) Excavate to formation level.

2) Construct floor in reinforced concrete.

3) Construct walls in masonry or reinforced concrete.

4) Install climbing irons or ladder.

5) Construct support piers to pipelines and fittings.

6) Construct removable cover, or roof slab with manhole cover.

8.5.2 Installation of fittings for flushing device

1) Install tee, valve, flanged socket and discharge pipe with flap, all suitable for the diameter of the pipeline.

2) Prepare the area at the outlet: place stones to avoid erosion, and excavate ditch.

8.5.3 Installation of fittings for aeration device

1) Install air valves, sluice valves, tapers, tees suitable for the diameter of the pipe line.

9. Miscellaneous

9.1 Introduction

The units that are described in this part of the Module have a number of points in common. Some of these common points are discussed here instead of being repeated for each unit.

The points considered are entitled

- Fencing;
- Soakaways;
- Records;
- Safety; and
- Outside appearance.

9.2 Fencing

The area around a water supply unit such as a spring collection chamber or a water tank should not only have a proper appearance, but it should also be protected against contamination and intrusion. Therefore, fencing has to be included in the construction work.

Use can be made, with advantage, of hedges or other simple and effective types of fences that are built by the local inhabitants. A lockable gate ought to be included.

9.3 Soakaways

9.3.1 General

Split water, overflow water or wash-out water which lies near the different units such as hand dug wells, spring collection chambers, public water points, etc. forms pools that are not only nuisances, but also direct sources of pollution and in certain areas breeding sites for mosquitoes. Such water must be drained into a soakaway. Any channel or trough used for the drainage must have an adequate and continuous slope so that no pools are formed in it.

9.3.2 Construction

The soakaway is a pit in the ground filled with rubble or gravel and covered with concrete or soil. The water should enter the top of the fill centrally; preferably on a small concrete slab or a large flat piece of stone.

9.4 Records

Records of construction describe and show what has been built and where it is located. Thus a proper record should be made, on completion of the job, of all construction work. The record can be either

- a written description, or
- a drawing (or drawings)

or both.

The written form is used to give a general description of the work. It is also suitable for example for giving information on the construction of a structure such as a well. It describes the strata through which the well has been sunk, the level and thickness of the aquifer tapped and any special difficulties encountered during the construction, etc.

Drawings help in the understanding of the design and how the structure is intended to function, be operated and maintained. Further they are used to locate the components of the structure on the ground. The information also facilitates improvement or extension. It may also be of assistance to others who wish to make a similar construction, require an information or who could give technical advice or comments.

An as-built drawing to a suitable scale and according to normal conventions should be made for any structure, however small. Thus records of measurements and clear sketches that shall be useful for the preparation of the as-built drawing should be made during the construction and at the completion of the works. Such sketches and records of measurement should enable oneself or someone else to prepare a complete drawing. Reference points and bench marks should be clearly established on the ground and defined or pointed out in the description or on the drawing.

For purposes of indentification the name or number of the structure or both, and the date of construction should be marked on the structure itself; by writing in the wet concrete, for instance.

Such work may appear tedious, and its execution unnecessary. Information may not be required for a long time; but it will be required one day without doubt, and it should be readily available then. Thus a habit must be cultivated to make and keep records of all constructions.

Records should be registered and kept in safe places. Information on any future change in the structure must be incorporated in the records.

9.5 Safety

A discussion of safety may be beyond the scope of this chapter. However, the reader and those concerned in construction must be aware of safety in construction.

Accidents can occur on any construction work, but the risk may vary on the the work or structure. The basic step towards safety is to make sure that all those involved understand what can go wrong and take preventive measures and use their common sense.

Thus standard safety measures, even where they are not explicitly or legally required, must be adopted and enforced by all concerned.

9.6 Outside appearance

Water is a precious element which is indispensable to life. This precious element is made available by means of waterworks which are important and valuable assets.

The few visible parts of the water supply system and their immediate surroundings, therefore, ought to have an appearance which reflects the value and purity of the water that is provided. A clean structure with the grounds attractively landscaped and well maintained should not be considered as a luxury. It will be justified by public confidence, esteem and good will.

A neat outside appearance would create pride in those responsible for operation and maintenance and give them an incentive to keep the works in a neat and presentable condition. The public would not only have due respect to the waterworks and their valuable content, but it will also be discouraged from littering their neighbourhood.

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TRAINING MODULES FOR WATERWORKS PERSONNEL

List of training modules:

Basic Knowledge

- **0.1** Basic and applied arithmetic
- **0.2** Basic concepts of physics
- **0.3** Basic concepts of water chemistry
- **0.4** Basic principles of water transport
- **1.1** The function and technical composition of a watersupply system
- **1.2** Organisation and administration of waterworks

Special Knowledge

- **2.1** Engineering, building and auxiliary materials
- **2.2** Hygienic standards of drinking water
- **2.3a** Maintenance and repair of diesel engines and petrol engines
- **2.3b** Maintenance and repair of electric motors
- **2.3c** Maintenance and repair of simple driven systems
- **2.3d** Design, functioning, operation, maintenance and repair of power transmission mechanisms
- **2.3e** Maintenance and repair of pumps
- **2.3f** Maintenance and repair of blowers and compressors
- **2.3g** Design, functioning, operation, maintenance and repair of pipe fittings
- **2.3h** Design, functioning, operation, maintenance and repair of hoisting gear
- **2.3i** Maintenance and repair of electrical motor controls and protective equipment
- **2.4** Process control and instrumentation
- **2.5** Principal components of water-treatment systems (definition and description)
- **2.6** Pipe laying procedures and testing of water mains
- **2.7** General operation of water main systems
- **2.8** Construction of water supply units
- **2.9** Maintenance of water supply units Principles and general procedures
- **2.10** Industrial safety and accident prevention
- **2.11** Simple surveying and technical drawing

Special Skills

- **3.1** Basic skills in workshop technology
- **3.2** Performance of simple water analysis
- **3.3a** Design and working principles of diesel engines and petrol engines
- **3.3b** Design and working principles of electric motors
- **3.3c** –
- **3.3d** Design and working principle of power transmission mechanisms
- **3.3e** Installation, operation, maintenance and repair of pumps
- **3.3f** Handling, maintenance and repair of blowers and compressors
- **3.3g** Handling, maintenance and repair of pipe fittings
- **3.3h** Handling, maintenance and repair of hoisting gear
- **3.3i** Servicing and maintaining electrical equipment
- **3.4** Servicing and maintaining process controls and instrumentation
- **3.5** Water-treatment systems: construction and operation of principal components: Part I - Part II
- **3.6** Pipe-laying procedures and testing of water mains
- **3.7** Inspection, maintenance and repair of water mains
- **3.8a** Construction in concrete and masonry
- **3.8b** Installation of appurtenances
- **3.9** Maintenance of water supply units Inspection and action guide
- **3.10** –
- **3.11** Simple surveying and drawing work

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