Water for the World

Designing Structures for Springs
Technical Note No. RWS. 1.D.1

Protective structures are a very important part of developing springs as sources for a community water supply. A properly designed protective structure ensures an increased flow from the spring. To protect the spring, silt, clay and sand deposited at the spring outlet, and other material washed down from the slope by surface run-off, must be cleared away. When these materials are removed, water flow increases. Clearing away vegetation from the spring effluent will also allow better flow. A protective structure will improve the accessibility of the water. By channeling the spring flow into one collection area, a good quantity of water can be stored for the community. Spring water can be distributed to community standpipes or to individual houses. A third benefit of a protective structure is that it protects the spring water from contamination.

This technical note discusses the design of structures used to protect and develop springs for community water supplies and makes suggestions for spring development in a specific area. The design chosen for a particular project will depend on local conditions, materials available and spring yield. Read this entire technical note and refer to "Selecting a Source of Surface Water," RWS.1.P.3, before choosing a design that will best meet a community's needs.

The design process should result in the following three items which should be given to the construction supervisor:

1. A map of the area. Include the location of the spring; the locations of users' houses; distances from the spring to the users, elevations, and important landmarks. Figure 1 is a map of a small village with a spring located on high ground above it. A map of this type is useful in helping the people building the spring box locate the spring site.

2. A list of all labor, materials and tools needed as shown in Table 1. This will help make sure that adequate quantities of materials are available so construction delays can be prevented.

3. A plan of the spring box with all dimensions as shown in Figure 2. This plan shows a top, side, and front view, and the dimensions of a cover for a spring box 1m x 1m x 1m.

Useful Definitions

DISCHARGE - The flow of water from an opening in the ground or from a pipe or other source.

EFFLUENT - At a spring site, the point from which water leaves the ground.

GROUT - A thin mortar used to fill chinks, as between tiles.

HEAD - Difference in water level between the inflow and outflow ends of a system.

HYDRAULIC GRADIENT - The measure of the decrease in head per unit of distance in the direction of flow.

MORTAR - A mixture of cement or lime with water in a basic proportion of 4 units of sand to 1 unit of cement or lime.

PERPENDICULAR - Exactly upright or vertical; at a right angle to a given line or plane.

PUDDLED CLAY - A mixture of clay with a little water so clay is workable.

REINFORCING ROD - Steel bars placed in concrete structures to give it tensile strength.

UNDERFLOW - Flow of water under a structure.

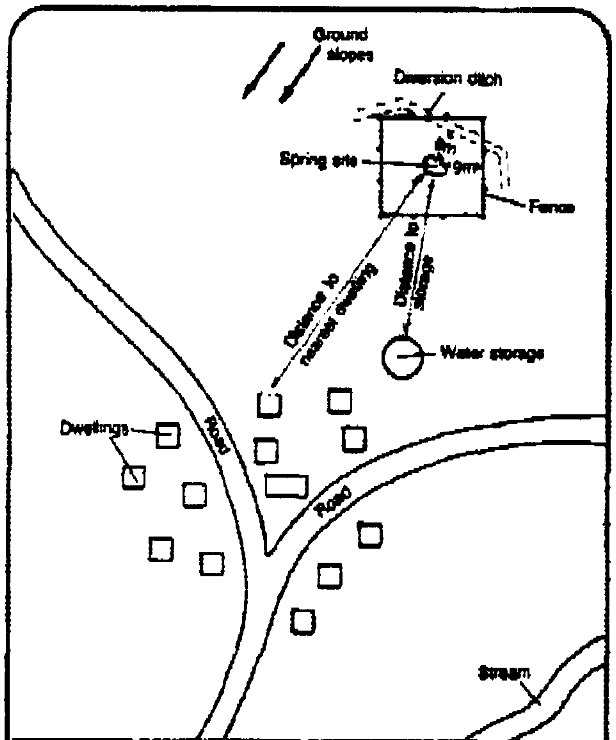

Figure 1. Location Map

Spring Box Design

There are several possible designs for spring boxes but, generally their basic features are similar. Spring boxes serve as collectors for spring water. They are sometimes used as storage tanks when a small number of people are being served and the source is located near the users. When larger numbers of people are served, the water collected in the spring box flows to larger storage tanks. The two basic types of spring boxes discussed in this paper are a box with one pervious side for collection of water from a hillside, and a box with a pervious bottom for collection of spring water flowing from a single opening on level ground. To determine which design to use dig out around the area until an impervious layer is reached, locate the source of the spring flow, and design to fit the situation.

Table 1. Sample Materials List

Item	Description	Quantity	Estimated Cost
Labor	Foreman	____	____
	Laborers	____	____
Supplies	Portland cement	____	____
	Clean sand and gravel, if available, or locally available sand and gravel	____	____
	Water (enough to make a stiff mixture)	____	____
	Wire mesh or reinforcing rods	____	____
	Galvanized steel or plastic pipe (for outlets, overflow, and collectors)	____	____
	Screening (for pipes)	____	____
	Boards and plywood (for building forms)	____	____
	Old motor oil or other lubricant (for oiling forms)	____	____
	Baling wire	____	____
	Nails	____	____
Tools	Shovels and picks (or other digging tools)	____	____
	Measuring tape or rods	____	____
	Hammer	____	____
	Saw	____	____
	Buckets	____	____
	Carpenter's square or equivalent (to make square edge)	____	____
	Mixing bin (for mixing concrete)	____	____
	Crowbar	____	____
	Pliers	____	____
	Pipe wrench	____	____
	Wheelbarrow	____	____
	Adjustable wrench	____	____
	Screwdriver	____	____
	Trowel	____	____

Total Estimated Cost ____

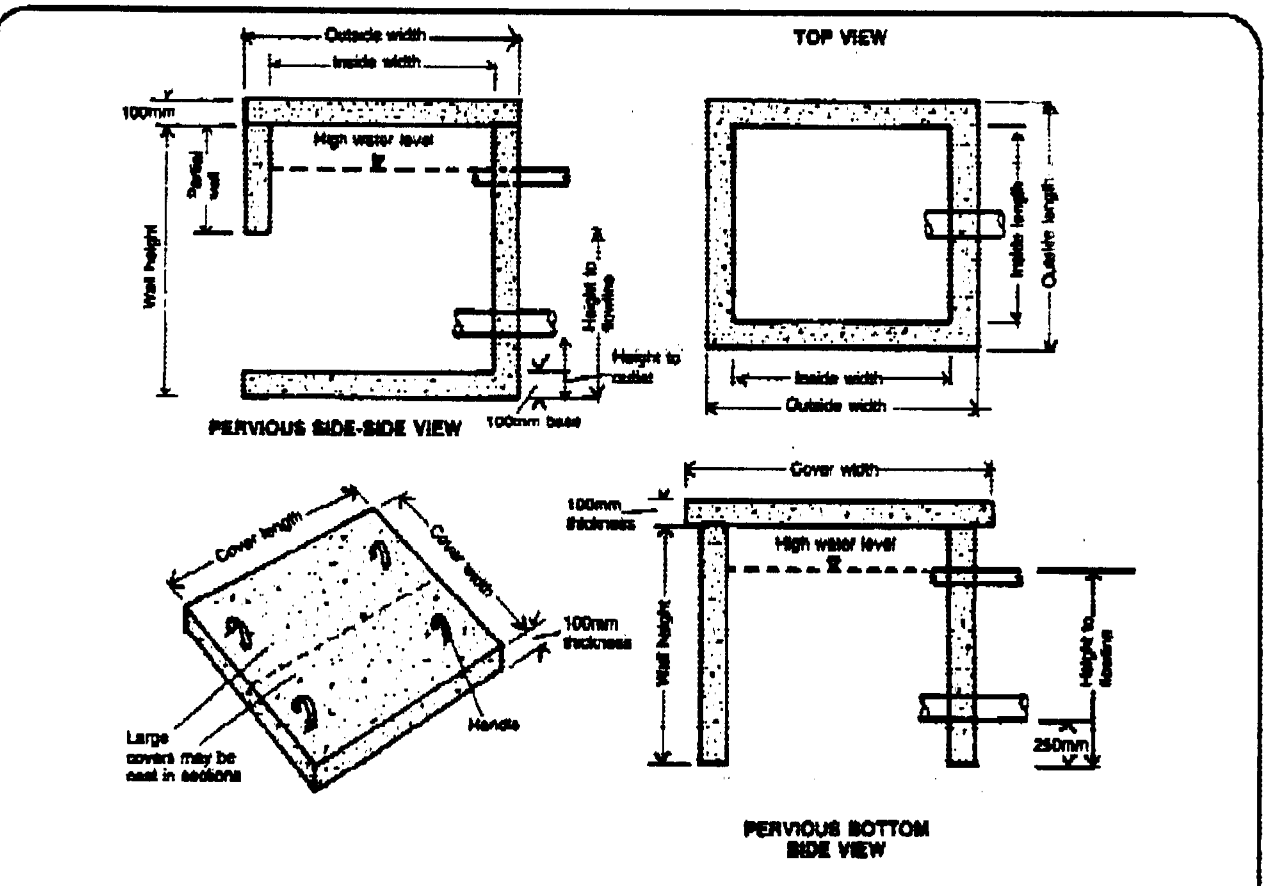

Figure 2. Spring Box Design

Spring Box with Open Side. A spring box with a pervious side is needed to protect springs flowing from hillsides. The area around the spring must be dug out so that all available flow is captured and channeled into the spring box.

After this has been done, a collection box can be built around the spring outlet as shown in Figure 3. The dug-out area should be lined with gravel. The gravel placed against the spring opening serves as a foundation for the box and prevents the spring water from washing soil away from the area. The gravel pack also filters suspended solids. The gravel-filled area should be between 0.5-1m wide depending on the size of the spring collection area. To ensure that no contamination reaches the water, the gravel pack should be at least 1m below the ground surface. This is done either by locating the spring catchment in the hillside or by raising the ground level with backfill.

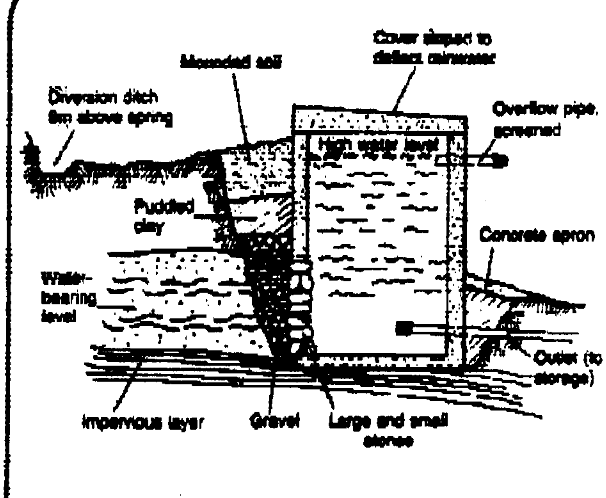

Figure 3. Spring Box with Open Side

Caution must be taken not to disturb ground formations when digging out around the spring. Without care, the flow of the spring may be deflected in another direction or into another fissure. The area must, however, be dug out enough so that the spring box fits into impermeable material. In cases where the box does not reach impermeable material, puddled clay should be used to seal the area around the sides of the spring box.

<u>Spring Box with Open Bottom</u>. If a spring flows through a fissure and emerges at one point on level ground, a spring box with an open bottom can be developed as shown in Figure 4. The area around the spring is dug out until an impermeable layer is reached. The area around the spring is then leveled and lined with gravel. The spring box is placed over the spring and gravel to collect the flow, and clay or concrete is packed around the box to prevent seepage between the ground and the box. Sometimes a small sump can be built at the bottom so that sediment settles in one place.

The design of both types of spring boxes is basically the same and includes the following features:

(a) a water-tight collection box constructed of concrete, brick, clay pipe or other material,
(b) a heavy removable cover that prevents contamination and provides access for cleaning,
(c) an overflow pipe, and
(d) a connection to a storage tank or directly to a distribution system.

The spring box with an open bottom is simpler and cheaper to construct. Generally, on level ground, flow from only one source must be captured and collection of all available flow is much easier. Costs are lower because less digging and fewer materials are required.

The spring box should be constructed at the spring site for easy installation. If the appropriate materials are available, the spring box should be made of concrete. Information on the use of concrete is included in Worksheet A. Three sides of the spring box must be impervious and depending on the type of spring selected for development, either the bottom or the

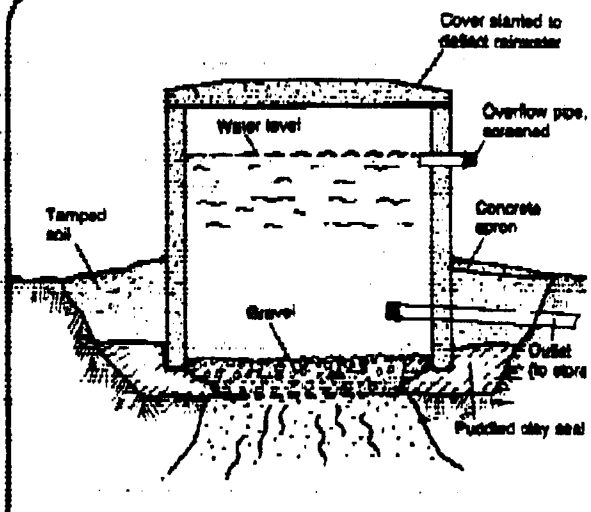

Figure 4. Spring Box with Open Bottom

upslope side must be pervious or open The upslope side of an open sided spring box can be constructed partial with concrete and partially with larg rocks and gravel as shown in Figure 3 Large rocks support the spring box an allow water to enter. Smaller stones should be used between the large rock to close large openings so that sediment is filtered from the water.

If materials for building a concre box are not available, or are expensive, there are alternatives that are particularly useful in developing a single source spring. Large prefabri cated clay or concrete tubes, like regular spring boxes, can be placed around the spring. Water rises in th tube and flows out the outflow pipe. Rings for collecting spring water can even be constructed using bricks and mortar. Half or broken bricks can be used to build a ring as shown in Figu 5. The bricks are laid in a circular pattern, so that vertical joints do not line up. Spaces between the bric are filled with gravel and mortar. Bricks are laid until a height of between 0.9-1.2m is reached. The diameter may vary but should be aroun 0.7-1.0m. An outlet and overflow pip should be placed in the structure before installation and with reinforc ment added. This type of structure i very practical and inexpensive to construct. Little cement is needed and locally available materials can b used.

Worksheet A. Calculating Quantities Needed for Concrete

(Calculations for a box 1m × 1m × 1.0m with open bottom)

Total volume of box = length (l) x width (w) x height (h)

Thickness of walls = 0.10m

1. Volume of top = l 1.2 m x w 1.2 m x t 0.10 m = 0.144 m^3
2. Volume of bottom = l 0 m x w 0 m x t 0 m = 0 m^2
3. Volume of two sides = l 1 m x w 1 m x t 0.10 m x 2 = 0.20 m^3
4. Volume of two ends = l 1 m x w 1 m x t 0.10 m x 2 = 0.20 m^3
5. Total volume = sum of steps 1, 2, 3, 4, 5 = 0.54 m^3
6. Unmixed volume of materials = total volume x 1.5; 0.54 m^3 x 1.5 = 0.81 m^3
7. Volume of each material (cement, sand, gravel, 1:2:3):

   cement: 0.167 x volume from Line 6 0.81 = 0.13 m^3 cement.
   sand: 0.33 x volume from Line 6 0.81 = 0.26 m^3 sand.
   gravel: 0.50 x volume from Line 6 0.81 = 0.4 m^3 gravel.

8. Number of 50kg bags of cement = $\frac{\text{volume of cement}}{\text{volume per bag}}$

   volume of cement 0.13m^3 – .033m^3/bag = 4 bags.

9. Volume of water = 28 liters x 4 bags of cement = 112 liters.

(NOTE: 1) Do not determine volume for an open side or bottom.
2) The top slab has a 0.1m overhang on each side.
3) The same calculations will be used to determine the quantity of materials for construction of a seepage wall.
4) To save cement a 1:2:4 mixture can be used.)

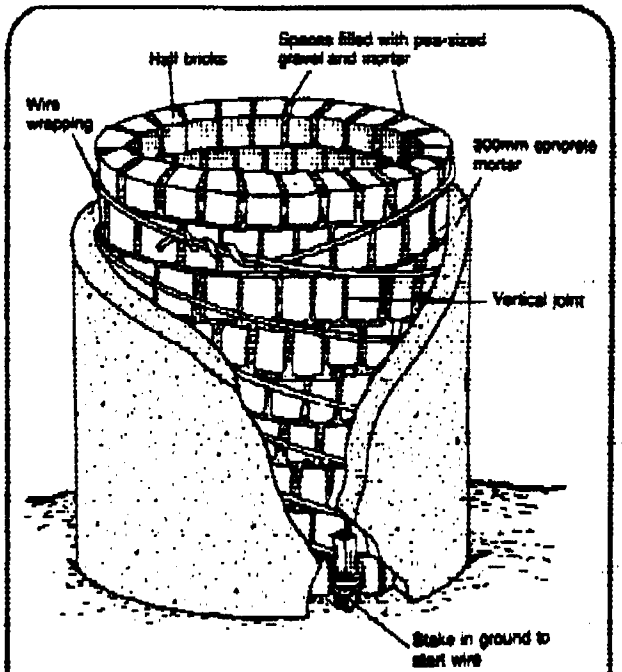

Figure 5. Brick Spring Box

The capacity of the spring box depends on whether it is being used for storage or pre-storage. If the spring box is used for storage, it should be large enough to hold a volume of water equal to the needs of the users over a 12-hour period. For example: If 100 people each use 25 liters of water per day, the amount of water consumed in 12 hours is 1250 liters. There are 1000 liters per m^3. Therefore the volume of the spring box should be 1.25m^3. (Volume = length x width x height). If the collection box is used only for pre-storage and water flows on to another storage tank, the collection box can be smaller.

A reinforced concrete cover must be constructed to protect the tank from outside contamination. The cover should be cast in place to ensure proper fit. It should extend over the spring box about 0.1m on each side so rain does not fall at the base of the spring box. The cover should be heavy enough so children cannot lift it off.

The spring box should have an overflow pipe. The pipe is placed a little below the maximum water level and at least 0.15m above the floor of the tank. If the pipe is above the maximum water level, water will not flow out and pressure is created in the tank. The pressure could cause a back-up and diversion of the spring. The overflow pipe should be covered with a screen fine enough to keep out mosquitoes and strong enough to keep out small animals. The size of the pipe depends on the flow of the spring. A rock drain or concrete slab should be placed outside the tank below the overflow pipe to prevent erosion near the base and to carry the water away from the spring. A pipe which extends 3-5m from the tank is desirable in order to keep the site free from still water.

An outlet pipe for connection to a distribution system should be located at least 0.1m above the bottom of the spring box to prevent a blockage due to sediment build-up. The pipe size depends on the grade to the storage tank and the spring flow. A general rule to follow is that at a one percent grade, a 30mm pipe should be used. A grade between 0.5 and one percent requires a 40mm pipe, while a 50mm pipe should be used for grades of less than 0.5 percent. In some cases the same pipe will be both outlet and overflow. The outlet pipe should slope downward for best flow.

After the spring box is installed, the space behind it must be filled with soil and gravel. The gravel is the bottom layer. On top of it, a water-tight layer should be formed to prevent the entrance of surface water. This can be done with concrete or puddled clay. Puddled clay is a mixture of clay and water formed into a layer 150mm thick. The layer is placed on the ground and worked in by trampling on it. Several layers of puddled clay should be placed behind the box.

After sealing the area, the box can either be completely covered with soil or stand above the ground surface. The box should be at least 0.30m above ground level so that run-off does not enter it. For further sanitary protection, a ditch should be dug at least 8m above the spring box to take surface water away from the area. The soil from the ditch should be piled o[n] the downhill side to make a ridge and help keep surface water away. A fenc[e] around the area will keep animals fro[m] getting near the spring box and help prevent contamination and destruction of the area. The fence should have a radius of between 7-8m.

Seep Design

Designs for seep development are similar to those for spring boxes. Figure 6 shows the basic design. Intakes (collectors) are very importa[nt] features of seep development. The collector system consists of small channels containing 100mm clay open-joint or 50mm plastic perforated pipe packed in gravel. The collectors are installed in the deepest part of the aquifer. They take advantage of the saturated ground above them for stora[ge] during times when the groundwater tab[le] is low. The perforations in the pipe[s] must be about 5mm in diameter or larg[e] enough to collect sufficient water but small enough to prevent suspended matter from entering the pipes. In fine and medium-sized sand, perforate[d] pipe should be packed in gravel but suspended material often will enter t[he] pipe in spite of the gravel.

To prevent clogging, the collector[s] should be sized so that the velocity [of] water flow in them is between 0.5m pe[r] second and 1m per second. See "Metho[ds] of Delivering Water," RWS.4.M.

Water collected by the pipes is channeled to the spring box through a gravel pack. The collectors must extend across the entire width and length of the water-bearing zone and should be perpendicular to the flow o[f] the aquifer. These intakes should extend below the water-bearing zones [to] collect the maximum amount of water a[nd] permit free flow into the collector. The advantage of a collector system i[s] that water seeping over a large area can be channeled into a central stora[ge] basin.

Clean-out pipes to flush sediment from the collection pipes should be attached to the collection pipes. To install clean-out pipes, add a length of pipe to the far end of the collection pipe. At the end of this length place an elbow joint facing upwards and attach a vertical length of pipe.

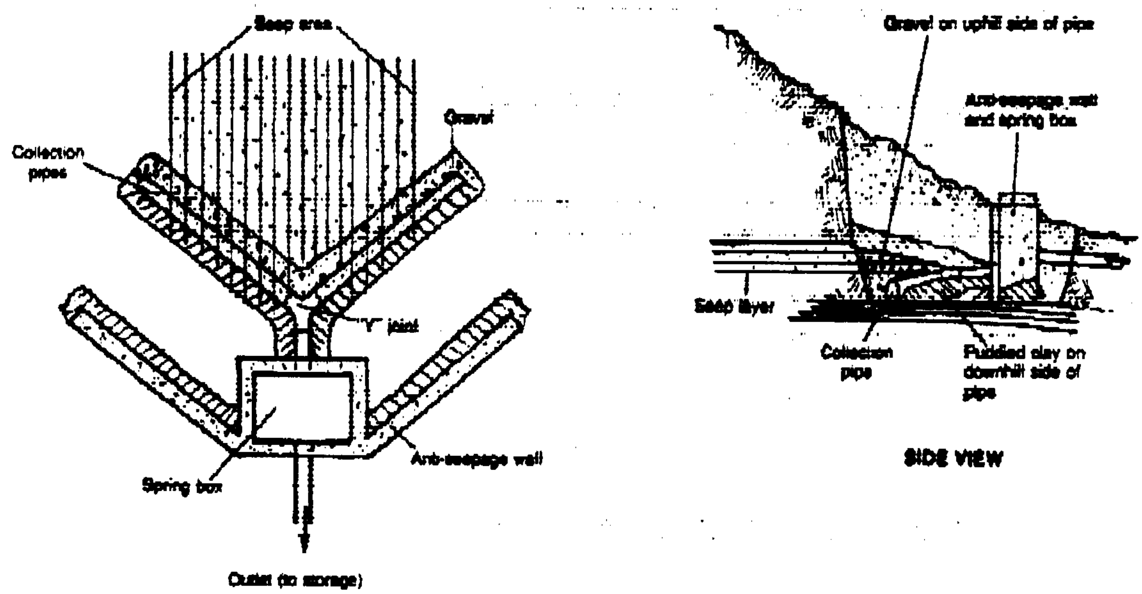

Figure 6. Seepage Collection System

The pipe should extend a little above the ground and be capped. If the collector system clogs, water can be added to the clean-out pipes to flush out the system.

For seep development, a cutoff wall of clay, concrete or other impervious material should be constructed. The cutoff is usually constructed as a large "V" pointing downhill with wing walls extending into the hill to prevent water from escaping. The cutoff should extend down into impervious material to force the flowing water to move to the collection point and to prevent loss of water due to underflow.

The use of concrete for the cutoff wall is best but most expensive. A wall 0.15m thick will ensure adequate strength against increased flow. The height of the cutoff wall depends on the size of the flow being collected. If desired, a spring box may be constructed inside the "V" shaped meeting of two walls as shown in Figure 7. The spring box will provide a settling basin for sediment removal and storage. The spring box should be designed so that water enters it

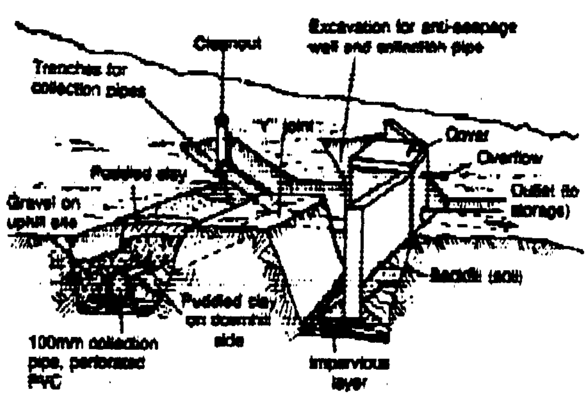

Figure 7. Basic Design Feature of a Seep Collection System

through openings in the upper wall. These openings must be screened to prevent entrance of debris.

Puddled clay instead of concrete ca be used to form the cutoff wall. The clay is piled up and tamped down to form an impervious wall. It acts as a small dam which prevents spring water from flowing away from the collection area. The clay cutoff wall works as well as the cement wall and is much cheaper and easier to install. Good impervious clay should be available if this type of cutoff wall is chosen.

An outlet pipe is installed to move water from the collection point to storage. The diameter of the pipe depends on the grade to storage and will generally range between 30-50mm. To determine the correct pipe size, see "Methods of Delivering Water," RWS.4.M. The outlet pipe for a spring box or simple collection wall should be at least 150mm from the bottom of the collection area. A watertight connection should be made where the pipe leaves the spring box or goes through the cutoff wall. As in the case of spring boxes, the outlet pipe must be screened with small mesh wire. Because of the cost, this type of structure should be used only where seeps cover an extensive area. Skilled laborers will be needed for construction.

Horizontal Well Design

Horizontal wells are very simple and can be quite inexpensive. In order to use a horizontal well, an aquifer must have a steep slope or hydraulic gradient. Steep hydraulic gradients generally are found in chilly, sloping land and follow the ground surface. Horizontal wells, shown in Figure 8, are installed in much the same manner as vertical driven and jetted wells. See "Designing Driven Wells," RWS.2.D.2, and "Designing Jetted Wells," RWS.2.D.3 for specific design features.

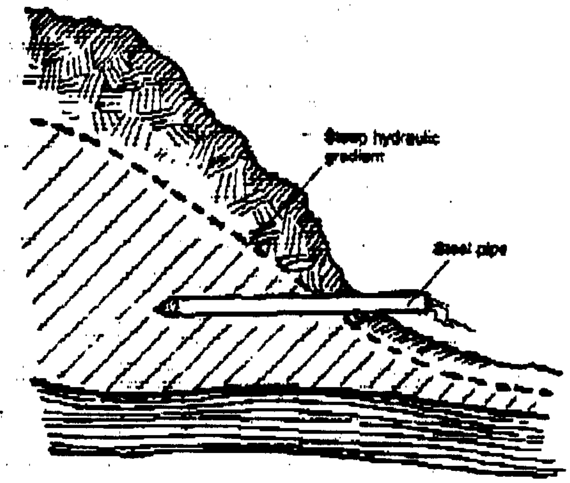

Figure 8. Horizontal Well

A horizontal well can be driven if the spring flows from an aquifer in permeable ground. A pipe with an open end or with perforated drive points is driven into the aquifer horizontally or at a shallow slope to tap it at a point higher than its normal discharge. In some soils, the pipe can be driven by hand. Generally the pipe is driven using machinery.

"Designing Driven Wells," RWS.2.D.2, outlines the steps in designing a driven well. These same steps should be followed in designing horizontal wells. One design difference is that extra care must be taken to avoid leakage between the driven pipe and the ground. If exterior flow occurs, it can be stopped by forcing clay or grout into the space, or by digging by hand 1m back along the pipe and installing a concrete cutoff wall. The wall should have a diameter of $0.6m^2$ and no more than 0.05m thick. After the concrete slab hardens, the dug-out area should be packed and back filled with clay.

If the aquifer that feeds the sprir is behind a rock layer, driving a horizontal well will be very difficult if not impossible. In this case, a jetted horizontal well will have to be installed. "Designing Jetted Wells," RWS.2.D.3, explains the process of jetting wells. The problem is that horizontal well drilling is different from vertical drilling, and may be toc difficult for inexperienced people. Drilled horizontal wells should only ı considered when there are no other reasonable alternatives.

Materials List

In addition to a location map and design drawings, give the person in charge of construction a materials list similar to Table 1 showing the number of laborers, types and quantities of materials needed to construct the spring protection. Some quantities will have to be determined in the field by the person in charge of construction.

Concrete. Concrete is the major material used in the construction of spring boxes and cutoff walls. Concrete is a mixture of Portland cement, clean sand, and gravel in a fixed proportion. The proportion generally used is one part cement, two parts sand, and three parts gravel (1:2:3). Water is used to mix the concrete. Twenty-eight liters of water should be used for each bag of cement. Worksheet A will help determine the amount of materials needed. Use the worksheet in making the following calculations.

1. Calculate the volume of mixed concrete needed (length x width x thickness; Worksheet A, Lines 1-5).

2. Multiply this number by 1.5 to get the total volume of dry loose material (cement, sand and gravel) needed (Worksheet A, Line 6).

3. Add the numbers in the proportion in order to find the fraction of the total needed for each material (1:2:3 = 6, so 1/6 of the mixture should be cement, 2/6 sand, and 3/6 gravel. In decimals, this is 0.167 cement, 0.33 sand, and 0.50 gravel).

4. Determine the amount of each material needed by multiplying the volume of dry mix from step 2 by the proportional amount for each material (1/6 x volume of dry mix = total amount of cement needed; Worksheet A, Line 7).

5. Divide the volume of cement needed by $.033m^3$ (33 liters), the amount of cement in a 50kg bag, to find the number of bags of cement required. When determining the amount of cement, figure to the largest whole number (Worksheet A, Line 8).

6. An extra quantity of cement should be figured into the total for use in grouting and sealing areas around the outlet pipes.

7. Calculate the amount of water needed to mix the concrete (28 liters of water per bag of cement; Worksheet A, Line 9).

8. Extra gravel will be needed for backfill of areas behind springs. Graded gravel is preferable, but local materials can be used if necessary. Calculate the volume of the area to be backfilled by taking length x width x height of area.

Reinforced Concrete. Concrete can be reinforced to give it extra strength This is best done with wire mesh or specially made steel rods. Reinforced concrete sections must be at least 0.10cm thick. Reinforced concrete should be used for all spring box covers and for the walls of seep structures. If wire mesh is used, the quantity needed will be approximately equal to the area of the slab being constructed. If steel bars (rerod) ar[e] used, they should be placed in the wooden form before the concrete is poured. 10mm diameter rods should be used.

The reinforcing rod should be located as follows:

- So that the rods are at least 25m[m] (0.25m) from the form in all places;
- So that the rebar rests in the lower part of the cover; two-thirds th[e] distance from the top or .70mm from th[e] top of a 100mm slab;
- So that a 150mm (0.15m) space lie[s] between a parallel rods in a grid pattern as shown in Figure 9.

Where the reinforcing rods cross, they should be tied together with wire at the point of intersection.

To determine the number of reinforcing bars, divide the total length or width of the spring box cover by 0.15m (distance between bars). For example, $\frac{1.2m}{0.15m} = 8$ bars.

To determine the length of each bar subtract 0.05m (0.025m each side) from the total length or width of the cover For example, 1.2m - 0.05m = 1.15m.

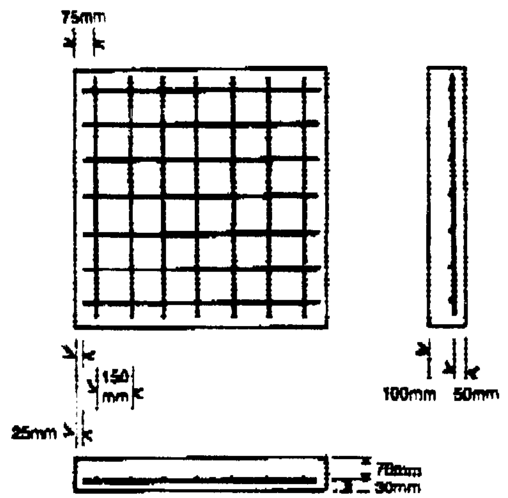

Figure 9. Placement of Rebar in Concrete Slab

Pipes. Outlet pipes can be of galvanized steel, or plastic depending on what is available. Galvanized steel is preferable because of its strength. Steel pipe lasts longer and does not shatter like plastic pipe. Intake pipes should be either clay, perforated plastic open-joint cement or in some cases, bamboo. The choice again will depend on availability of materials and cost. The pipe should have a minimum diameter of 50mm to be sure that an adequate supply of water enters the collection system. All pipes must be laid at a uniform grade to prevent air lock in the system.

When labor requirements, materials, and tools have been decided on, prepar a materials list similar to Table 1 an give it to the construction supervisor

Important Considerations

Spring protection should ensure tha the source is always protected from contamination. Before attempting to develop a spring, conduct a sanitary survey as described in "Conducting Sanitary Surveys to Determine Acceptable Surface Water Sources," RWS.1.P.2. Follow the guidelines for measuring the quantity of available water present in "Selecting a Source c Surface Water," RWS.1.P.3, to be sure that the source will meet community needs. The preliminary work described in these technical notes should be dor before designing a protective structure.

The choice of the structure for spring protection depends on the geologic conditions of the area, the type of spring, the materials available, ar the skill level of available labor. Spring boxes are easy to design and require little construction expertise, although workers should have some construction experience. Driven horizontal wells are also easy and inexpensive to develop although some expertise is needed to complete a successful well.

Structures for seeps are more difficult to design and require that workers have a much higher level of construction experience. The cost of developing a seep may be very high depending on the length of the retaining wall and the amount of pipe needed for intakes.