A Technical Brief for Springbox Construction

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CE 5993 *Field Engineering in the Developing World*

by

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Midway through a current springbox construction project

(photo provided by current Peace Corps Volunteer, Master's International student, **Lauren Fry)**

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1.0 Abstract

Springboxes provide one solution to communities that consume unsafe water and/or have an inadequate supply. The purpose of this report is to present a detailed briefing of the construction of a springbox for an audience with little construction experience and a limited science background. Through the use of this report and a motivated and invested community, one will be able to build a functional springbox, should the technology be appropriate for the sight. The paper also addresses the science behind springs, the reasons for building and not building springboxes, and the evaluation of different types of springboxes. The author recommends the complete reading of the following report for the most sustainable springbox solution regarding a particular sight.

2.0 Introduction

2.1 Water, Sanitation, and Health

The World Health Organization (WHO) reports that as of the year 2000, one-sixth of the world's population is without access to safe water, while two-fifths of the global population lacks access to basic sanitation. Poor water and sanitation are directly related to human health causing diarrhea, cholera, intestinal worms, schistosomiasis, trachoma, and so forth. Over 2.2 million deaths (mostly children) occur each year from the annual 4 billion cases of diarrhoea alone (WHO, 2000).

The WHO has documented that simple improvements in water, sanitation, and hygiene can reduce diarrhoeal disease by one-quarter to one-third on average, and reduce the general infection rate by 25%. Partially due to development programs, global access to clean water increased from 79% (4.1 billion) in 1990 to 82% (4.9 billion) in 2000, while basic sanitation rose from 55% (2.9 billion) to 60% (3.6 billion).

2.2 Springs as a Water Source

Springs occur where the natural flow of ground water emerges at the earth's surface, usually at hillsides or low-lying areas (Hanson, 1985). The water that flows from springs is usually safe from contaminants, due to the fact that groundwater is naturally filtered as it flows through the earth. Therefore, spring water is generally safe for human consumption, requiring little to know treatment. This makes springs a relatively inexpensive, yet safe water source.

3.0 Evaluation of Spring

3.1 Types of Springs

There are many types of springs that occur in nature. Artesian springs are confined by two layers of impervious material, and are best described as a no-leak pipe that carries water to the point of release (the spring). The water from Artesian springs is likely to have been sufficiently filtered naturally through the ground, and typically has little to no chance of being contaminated with seeping water from the local community (Montana, 2002).

Gravity springs rest on a single impervious layer, and can be thought of as an underground river. The unconfined aquifer will accrue many "tributaries" or input from local water and rain that seeps into the ground. Any contaminated water that flows into the ground will only have the short flow distance before reaching the spring, giving the input water much less time to be filtered naturally (Montana, 2002).

Seepage springs occur where water simply seeps out of sand, gravel, and other porous material. Opposed to artesian and gravity springs where flow is directed to one point, seepage springs result from a somewhat unconfined aquifer, where an underground reservoir simply leaches out in different places. This gives seepage springs the highest susceptibility to contamination; therefore, they are generally discouraged as water sources in the U.S. (Montana, 2002).

3.2 Survey the Area

Observe the geology and the activity at the spring site (Hanson, 1985). If the soil is rocky, it will have a very high infiltration rate, and contaminants will not likely be filtered out. If the soil is mostly sand, the water will infiltrate, but will be filtered to some degree depending on the depth of the aquifer. If the soil contains a high degree of clay, contaminated water will have a difficult time infiltrating the aquifer and the spring should be relatively safe.

Combine these observations with how the land is used (Hanson, 1985). If there is any human or agriculture activity, it increases the possibility of contamination. Observe if there are any animal or human droppings. Also note any agro-chemical usage. These conditions would discourage the use of a nearby spring, especially if the spring was unconfined and the soil was rocky, and also if the spring was shallow and the soil was sandy.

Finally, note the accessibility of the spring (Hanson, 1985). Answer the question, how easy will it be to transport people/materials to the sight? Think about the distribution of the water as well. What will transmission line construction and maintenance cost? Can the community afford the project and will they maintain the spring?

3.3 Determining Spring Reliability, Quality, & Flow

It is also necessary to determine the reliability, quality, and the average/minimum flow of the spring (Hanson, 1985; Montana, 2002). Ask the local residents of the history of the spring. Determine if the spring is seasonal or if it is fairly constant year round. Many authors stress the importance of determining the seasonal variation (Svadlenka, 2001).

To the best ability, determine the quality of the spring water. If there are local standards, there may be local testing apparatus. If no equipment exists, try to observe physical characteristics such as smell and clarity. If there is a strong odor, or the water is very turbid (has a lot of suspended sediment), it probably warrants additional treatment than the standard spring water, such as settling, filtering, and disinfecting. If there are no negative physical observations, make a judgment based on the survey of the area. If the conditions/use of the land are suspect, it may still be necessary to at least disinfect the water before consumption.

Finally, determine the flow of the spring. This can be done by constructing a temporary dike to retain the spring flow. Insert a pipe through the clay dike, and time how long it takes to fill a container with a known volume (Hanson, 1985; Skinner).

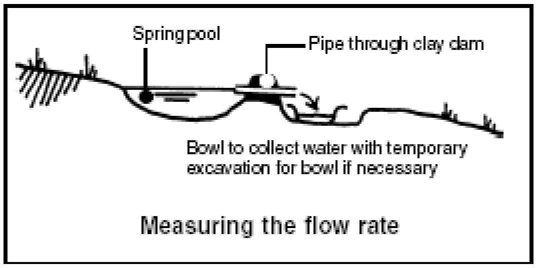


Figure 3.1- Measuring Spring Flow (Skinner)

It is best to perform this test multiple times, and at least once during the dry season. The goal is to determine average and minimum flows in order to predict if the spring will be sufficient for the needs of the community.

4.0 Evaluation of Springboxes and Alternatives

4.1 An Alternative to Springboxes

Springboxes are an excellent choice when appropriate, but they do come with a cost. All of the necessary materials and labor may not be necessary if conditions are right for a less expensive alternative. If the flow rate is sufficient enough that no storage is needed, a springbox may not be necessary. As long as the water can still be protected and collected, and the quality requires no sedimentation, the reader should evaluate another approach: Well Technical Brief 34:"Protecting springs-an alternative to spring boxes", by Skinner and Shaw. The report is available at:
http://www.lboro.ac.uk/well/resources/technical-briefs/34-protecting-springs.pdf
Svadlenka also mentions the simpler alternative, calling the structure an "infiltration gallery."

The finished spring may look something like Figure 4.1. Notice that the design shows no storage of the spring water, only a constant flow.

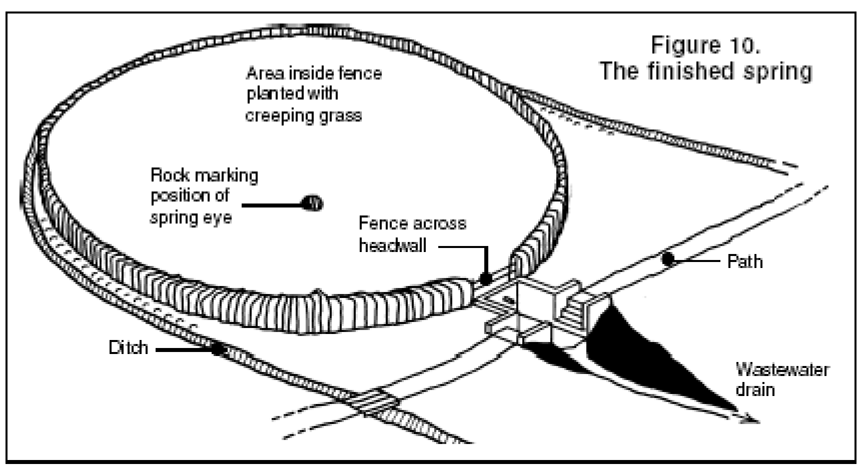


Figure 4.1- An Alternative Design to Springboxes (Skinner)

4.2 Benefits of Springboxes

Constructing a springbox has many benefits. They protect the spring water from contamination by surface runoff, and contact with humans and animals (Water for World, RWS.1.C.1). They also provide a permanent point of collection. But their most distinguished advantage to the alternative mentioned above is their storage of water. If a spring has a low flow, it might still be sufficient for the needs of a community if allowed to accumulate over the coarse of a night, and other time periods when not in use. This allows a spring to serve many more people then it otherwise could.

Yet another advantage is that springboxes may also act as settling basins, to assist in the removal of suspended sediment from the water. This is a distinct health advantage because bacteria and other organisms that cause harmful effects are generally attached to soil particles in the water.

5.0 Types of Springboxes

The type of springbox that should be built is most directly determined by the type of spring at the sight and the available resources in the community.

5.1 Springbox Type- Related to type of spring

Both the type of spring and its location are essential in determining the type of springbox that should be built. If the spring is naturally occurring on relatively flat ground, it is likely to be qualified as an artesian spring, described in Section 3.1. Water flows vertically out of the ground due to the pressure that is accumulated within the confined aquifer. This can be thought of as a fire hydrant tapped into a water main; when the water pressure is high enough, it can overcome the force of gravity and flow vertically.

Therefore, in the case of an artesian spring, a springbox with an open bottom may be placed over the water source, and the naturally occurring pressure will force water into the springbox (Montana, 2002). This would lead to a design similar to the one presented in Figure 5.1.

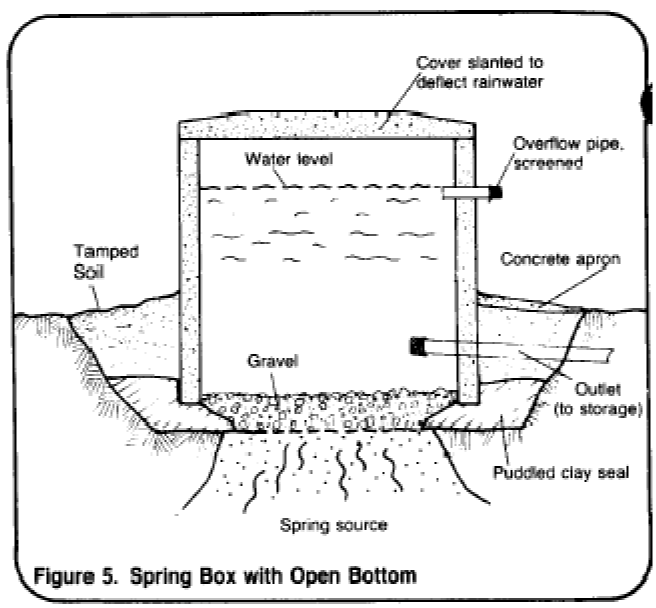


Figure 5.1- Springbox with an Open Bottom (Water for the World RWS.1.C.1)

If the spring occurs at the base of a slope or hillside, the flow is likely to be gravity driven. As mentioned in Section 3.1, opposed to an artesian spring, a gravity spring will most likely have just one impermeable layer (on the bottom). In this case, much less pressure will exist in the system.

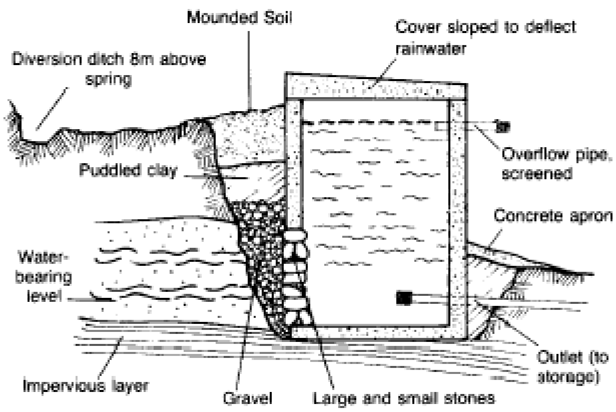


Figure 4. Spring Box with Open Side

<u>Figure 5.2</u>- Springbox with a Side Entrance (WW-1.C.1)

Due to the nature of the horizontal flow, and low water pressure, a gravity spring in a hillside will require a springbox with a side entrance for the water. The design will most likely be similar to the structure presented in Figure 5.2.

In the case of a seepage spring, water will likely be flowing from more than one point. Similar to gravity springs, the flow will result from the force of gravity, and therefore exist almost always at hillsides or the bottom of a slope. Although seepage springs are discouraged as sources of drinking water in the U.S. (Montana, 2002), they may still be appropriate in the developing world. Seepage springs have the highest susceptibility for contamination; however, if risk of contamination is low, they may still be used as a water source. They may simply require additional protection from contamination.

A springbox for a seepage spring may be constructed in two ways, depending on the spring characteristics. The ideal design is to dig far enough back into the hill to reach the single source of all of the spring flow. In this case, the seepage spring would simply be a gravity spring covered by a small amount of porous media. If a single line of water flow cannot be found, one may still be able to dig far enough back to ensure all of the water flows into the side opening of the springbox, detailed in Figure 5.2.

However, if the lines of spring flow are too separated and cannot be channeled into one springbox structure, the designer should take a different approach. Rather than a springbox, one should construct what is known as a Seep Collection System. A detailed method of how this construction should take place is presented in the Water for the World brief-RWS.1.C.1, p.8-10, and can be found at http://www.lifewater.org/wfw/rws1/rws1c1.pdf. The final design of such a system is presented in Figure 5.3.

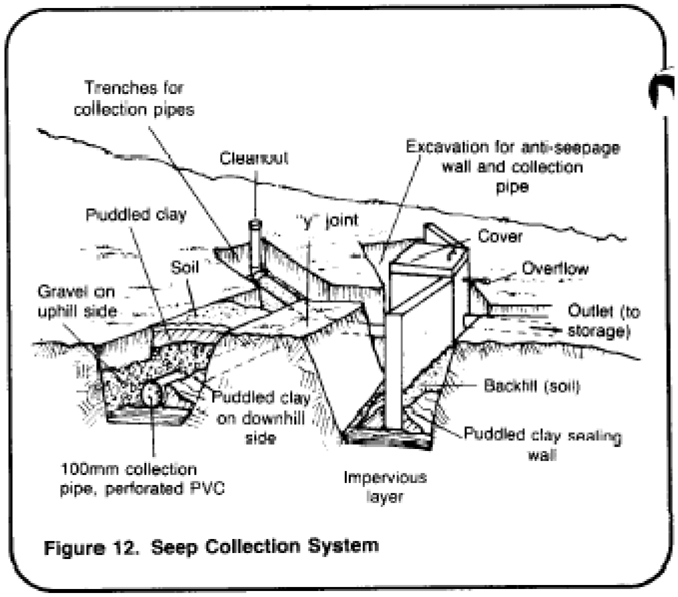


Figure 5.3- Seep Collection System (WW-1.C.1)

5.2 Springbox Type- Related to building material

The project and community resources may greatly affect the materials that can be used to construct the springbox. The importance of using local materials is mentioned frequently in developing world projects, and in two of the references to this report, specific to springbox construction (Svadlenka, 2001; Jennings, 1983).

Historically, a reinforced concrete structure is the most effective and has the longest design life. Although local gravel and sand may be used, this type of springbox requires a relatively large supply of expensive material that must be purchased including rebar, concrete, and wood for forms. The construction of a reinforced concrete springbox also requires the most skill and precision by the workers.

A masonry springbox will likely be less expensive, requiring no rebar and less overall concrete. Half bricks and broken bricks are generally discounted or possibly even free, which can save a large amount of the local resources. If such bricks are available in or near the community, the author recommends the construction of a circular, springbox with mortar and bricks. A diagram of a masonry springbox is presented in Figure 5.4, and details of the construction are presented in Section 8.0.

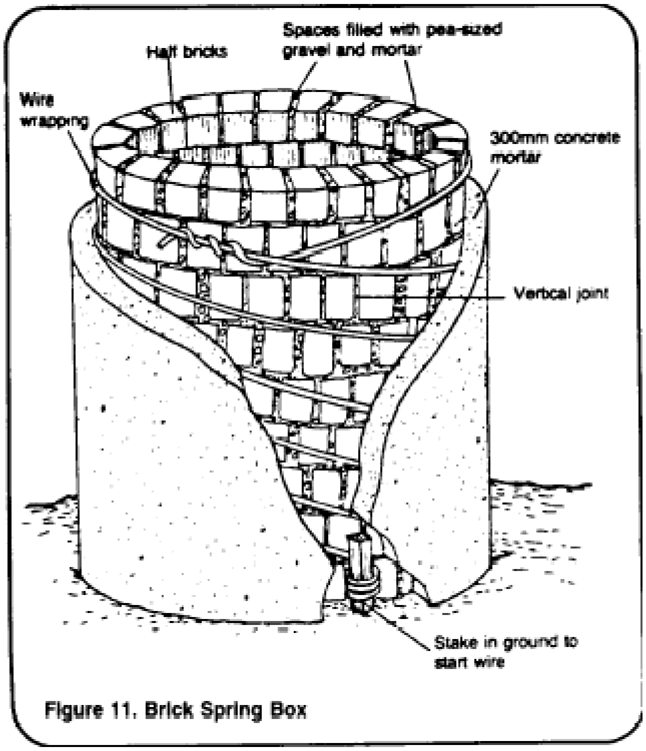


Figure 5.4- Masonry Springbox (WW-1.C.1)

6.0 Springbox Design

Based on all of the information one has gathered up to this point, it is necessary to come up with the springbox design. Depending on the conditions and the type of springbox desired, there are many possible designs. From the figures presented in Section 5, one can gather a general idea of the relative designs for each springbox type.

A few calculations are necessary in order to design an appropriately sized springbox. First, it is necessary to determine the needed water storage based on the required daily flow to the community. It is generally best to design with a factor of safety to account for dry seasons and population growth.

If the desired flow to the community is greater than the average and/or minimum spring flow, then a springbox is justified (opposed to the alternative mentioned in Section 4.1). Based on the difference between the two flows, one can calculate the needed storage volume of the springbox. The required storage volume can be determined by using Equation 6.1.

$$V = (Q_{out} - Q_{in}) * t$$ Equation 6.1- Required Storage Volume

V equals the storage volume in cubic feet or cubic meters, Q_{out} equals the predicted flow needed for the community in cubic feet per second (cfs) or cubic meters per second (m^3/s), Q_{in} equals the average or minimum spring flow in cfs or m^3/s (depending on how much safety one wants to factor into the design), and t equals the total time it will be used over the course of one day, converted to seconds to be dimensionally correct.

From the storage volume, one can design the dimensions of the tank, being sure to remember that the water will only occupy the volume inside the tank up to the overflow pipe. It is best to first determine dimensions for an appropriate base size, and then vary the height of the design based on the needed volume. If the calculated height seems unreasonably tall then it is appropriate to increase the length and width as well to find a good relationship. The useful storage volume for a rectangular springbox can be calculated through using Equation 6.2.

$$V = l * w * h$$ Equation 6.2- Volume of a rectangular springbox

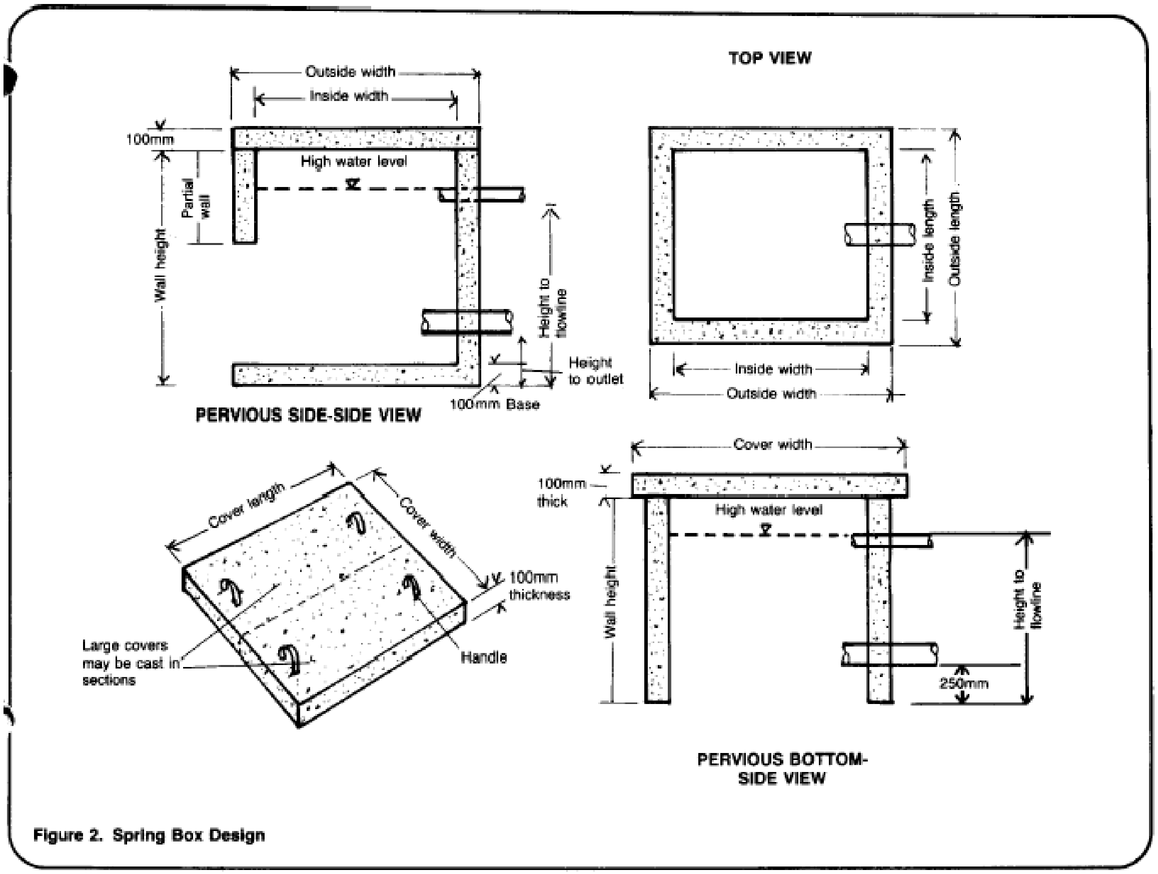
l equals the inside length, w equals the inside width, and h equals the inside height to the high water level. All the values should be measure with consistent units in feet (ft) or meters (m).

The same strategy is applied for a circular tank made from masonry. The useful storage of a cylindrical springbox can be determined by using Equation 6.3.

$$V = \pi * \frac{d^2}{4} * h$$ Equation 6.3- Volume of a cylindrical springbox

d is the inside diameter in ft or m, h equals the inside height to the high water level, and π equals 3.142.

Finally, the outside dimensions can be determined by adding the desired thickness of the walls. Typically a thickness of 100-mm is sufficient. See Figure 6.1 for a typical design of a rectangular springbox with a pervious side and the design for a pervious bottom.



<u>Figure 6.1</u>- Typical Design for Rectangular Springbox for both hillside and level ground (WW-1.C.1)

7.0 Springbox Construction

This section presents a detailed procedure for the construction of a reinforced concrete springbox. Many of the general construction steps for a masonry springbox are the same for reinforced concrete. However, the differences between the two are acknowledged in Section 8.0 Construction of a Masonry Springbox.

7.1 Advanced Planning

Once all the information has been gathered and the design is ready, it is necessary to plan the construction of the springbox to ensure its successful completion. Calculating and ordering materials, deciding on the order of construction, determining work schedules, assigning duties, and soliciting the appropriate help from the community are all essential.

A Washington Field Report for USAID documented the importance of advanced planning, especially regarding the materials, tools, and skilled labor force required (Jennings, 1983). Water for the World agreed, noting that inadequate quantities of materials can lead to delays during construction (WW-1.C.1)

Jennings stressed extra importance for skilled labor. The suggestion was to spend additional time with the skilled labor before their work is needed on the project

(Jennings, 1983). This was for two reasons: first to build a relationship with them, and second, to predict how they will actually perform. Their direct relationship to the overall project success warrants extra investigation, if possible, of their work ethic and former work. However, it is important to do this without making them suspect or offended.

7.2 Materials

As previously noted, the use of local materials is highly recommended for all springbox construction, as long as the materials will fulfill the needs of the community. In many cases, stones, gravel, sand, and even cement can be found or purchased on a local level. Generally, things done at the local level will save community resources, and possibly boost local economy. As such, the availability of local materials should go hand in hand with the design.

Once the design is final, the required materials should immediately be determined. Any outside material should be ordered, and the gathering of local material begun. A sample materials list is presented in Table 7.1. Although substitutions may be made, this table provides a fairly accurate "general list" for springbox construction. The user of this report will need to modify the list for their individual project. Be sure it includes an adequate supply of every material required for all aspects of the project.

Table 7.1- Sample Materials List for Springbox Construction (WW-1.C.1)

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 (rebar)	-	-
	Galvanized steel or plastic pipe (for outlets, overflow, and collectors)	-	-
	Screening (for pipes)	-	-
	Boards and plywood (for forms)	-	-
	Lubricant for oiling forms (motor or vegetable oil)	-	-
	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	-

7.3 Site Work

Site work will likely be required before, during, and after construction of the springbox.

7.3.1 Fence

A fence is needed around the spring site to prevent contamination from local animals. It should be high enough and sturdy enough to prevent the entrance of any animals common to the area. Construction of the fence may take place before the pouring of the springbox; however a sufficient opening should be left so that the materials can be easily delivered to the sight. People will also need adequate space to maneuver during the placement of the springbox.

Fence construction may be a good activity for the work crew during the curing of the concrete. Yet, whenever one chooses to construct the fence, it should be completed before the use of the spring water. After the fence is finished, one should scout the site for any remaining fecal matter from animal/human presence. The sight should be completely clean of such wastes well before the consumption of the spring water.

The recommended standards for fence dimensions vary significantly. Montana standards specify 100-ft (30-m) in all directions, while Water for the World only requires a 9-m clearance. Remember, the fence should serve the simple purpose of preventing fecal matter from entering the spring water. If the geology of the area is sufficient for contamination prevention, the fence may only need to have the minimum 9-m clearance. If there are no surrounding animals and the community is responsible enough to keep contaminants out of the spring sight, no fence may be necessary. Yet, one can never predict the future livestock conditions and other factors. As a result, fence construction is a relatively inexpensive precautionary measure to prevent contamination for years to come.

7.3.2 Diversion Ditch

All sources found in the writing of this paper call for a diversion ditch to protect against contamination from surface water. The function of the ditch is to simply catch and divert surface water away from the spring sight. Therefore, the ditch should be up gradient of the spring and then slope downhill and away from the spring. Water for the World recommends the ditch be a distance of 8-m away from the spring, providing sufficient clearance, while sitting within the protection of the fence.

Hanson's Peace Corps Manual states more of the science behind the diversion ditch. He states that if the surface water at the ditch infiltrates into the ground, it should have to travel a minimum of three vertical feet through the soil before coming in contact with the spring water. To verify this specification, a three-ft stick can be held upright at the spring, and used to sight what horizontal location up the slope equals a three-ft change in vertical position (Hanson, 1985).

While the writer acknowledges that Hanson's approach should provide sufficient filtration, it may be excessive in some cases. On steep slopes, a 3-ft vertical clearance seems reasonable; however, on gentle slopes, a horizontal distance of 10-15 meters should provide reasonable safety.

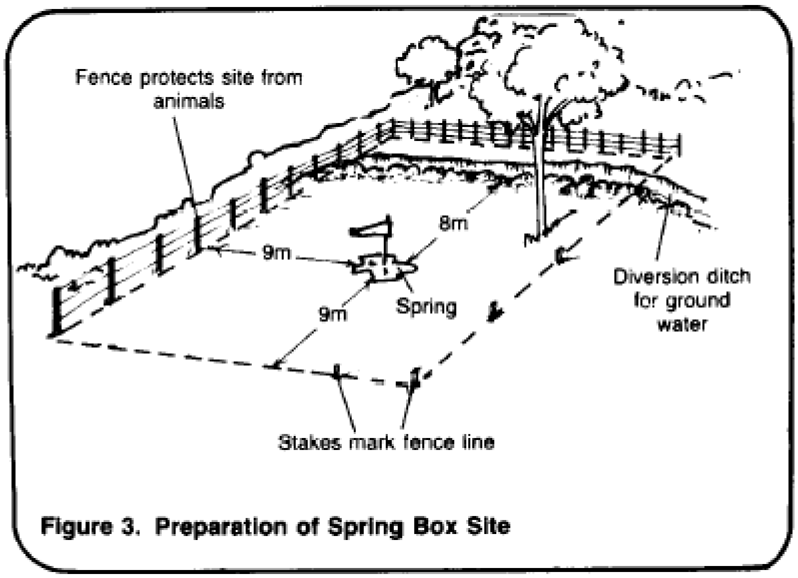


Figure 3. Preparation of Spring Box Site

<u>Figure 7.1</u>- Potential Fence and Ditch Design (WW-1.C.1)

Figure 7.1 diagrams a design for both the diversion ditch and the fence. The size of the ditch should be relative to the amount of overland flow it will need to intercept; however, in a well-vegetated area, even on a slope, the runoff will not require a very wide channel. Hanson's Peace Corps manual recommends a normal depth of about six-inches (Hanson, 1985). Another suggestion is to line the channel with stones to prevent erosion. Once the project is completed, one should inspect the ditch during a normal rain event and verify that it is large enough to divert the flow. If the ditch is insufficient, it may always be dug wider.

7.3.3 Spring Preparation

Work will also be required on the spring itself before the placing of the springbox. Although, this work too may be saved for the curing time of the springbox, some of this same work may be needed in determining the type of spring in question, and as a result, the type of springbox required.

The first recommendation is to be sure to dig far enough into the hillside that all of the spring water will be channeled into the springbox as discussed in Section 5.1. One should also dig downward until they hit an impermeable layer of clay or rock (Hanson, 1985). This is best for the collection of water into the structure, and also provides for a good foundation. If digging becomes messy, it may be necessary to divert the water for construction. This can be done by building a small dam, digging a temporary ditch, or using one of the pipes that is to be used in the completed springbox, and is demonstrated in Figure7.2.

A final note is if on a hillside, be sure to dig slightly upstream of the visible spring outflow so that the springbox can be somewhat set into the hill.

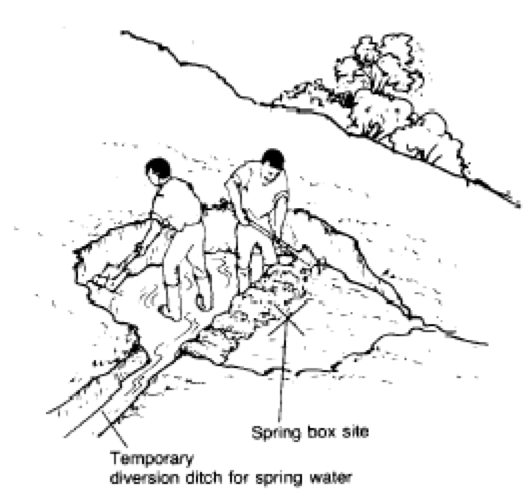


Figure 8. Excavating Spring Site

Figure 7.2- Spring Preparation (WW-1.C.1)

7.4 Form Construction

Formwork should be done on a level surface. The wood should be cut to the appropriate sizes according to the design. Nails and wire braces may be used to keep the inside 100-mm away from the outside form. For side entrance springboxes with a concrete bottom, the inside form will have to be nailed to the outside form in order to accurately suspend it such that the floor is 100-mm thick (WW-1.C.1). Place actual pieces of the appropriate pipe size in the locations designed for pipes to ensure that the pipe holes in the springbox are the correct sizes.

Little reinforcement in the springbox walls is necessary. Water for the World suggests that 4 rebars tied together in a square and placed along the perimeter of the form should be sufficient to prevent cracking (WW-1.C.1).

The springbox cover should be poured separately and reinforced with rebar to increase its tensile capacity. The rebar should be tied together with wire in a parallel grid at 150-mm on center. See Figure 7.3 for a detailed design.

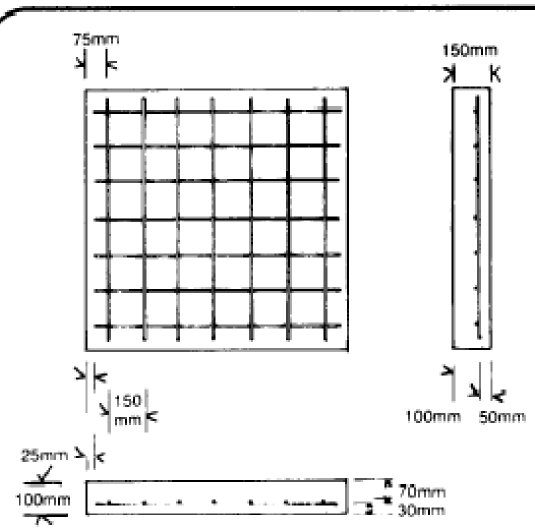


Figure 9. Placement of Rebar in Concrete Slab

Figure 7.3- Detail of Springbox Cover (WW-1.C.1)

7.5 Form Bracing

Bracing is essential in the construction of a springbox. Concrete is very heavy and can separate the forms if not adequately braced (WW-1.C.1). Outside bracing can possibly be done with leftover wood. Another suggestion is to drill small holes in the forms securing wire through them. The wire can be tightened by twisting it with a small but strong wood scrap. This will help hold the forms together at the appropriate 100-mm thickness. Figure 7.4 depicts a well-reinforced form with twisted wire braces.

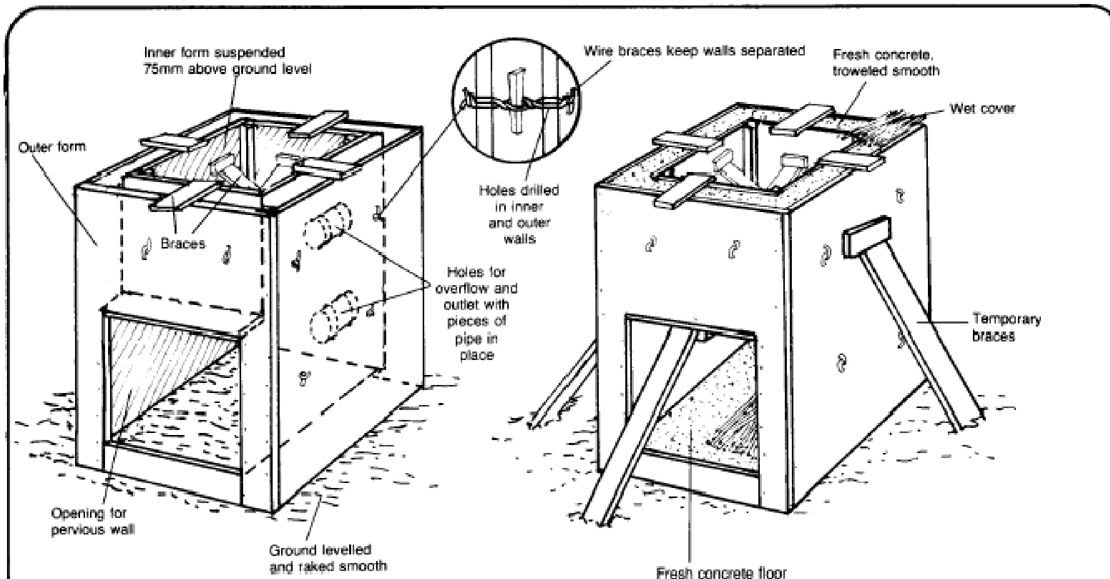


Figure 6. Forms for Spring Box with Open Side

Figure 7.4- Well-Reinforced Forms for a side entrance Springbox (WW-1.C.1)

7.6 Pouring and Curing

7.6.1 Place the Forms

To begin the pouring process, the form should be placed either at the permanent location of the springbox or close by so that it will not be far to move after it has cured (WW-1.C.1). If poured in place at the permanent site, the spring water will definitely have to be diverted using the methods mentioned in Section 7.3.3. If not at the permanent location, find an area with level ground. Place the form on a piece of building paper, tin sheet, or possibly even a plastic tarp, anything to keep the edge smooth and the concrete from sticking to the ground (Van Dam, 2003).

7.6.2 Oil the Forms

For best results, the forms should be greased before pouring (WW-1.C.1). Use an agent such as old motor oil, vegetable oil, or even spray on cooking oil to keep the concrete from sticking to the forms (Van Dam, 2003).

7.6.3 Mix the Concrete

The ideal mixture for portland cement concrete is presented in Figure 7.5. A good rule of thumb is to mix in a ratio of one part cement, to two parts sand, and three parts gravel (WW-1.C.1). It is strongly recommended to only add a small amount of water, just enough for a thick paste. Take note that too much water makes the concrete weak. In an effort to save cement, if the gravel being used is of high quality, the mixing ratio can be increased to 1:2:4 (cement : sand : gravel). Note that large pockets of air are undesired. The 5% ideal volume is only in regions that experience freeze/thaw (Van Dam, 2003)

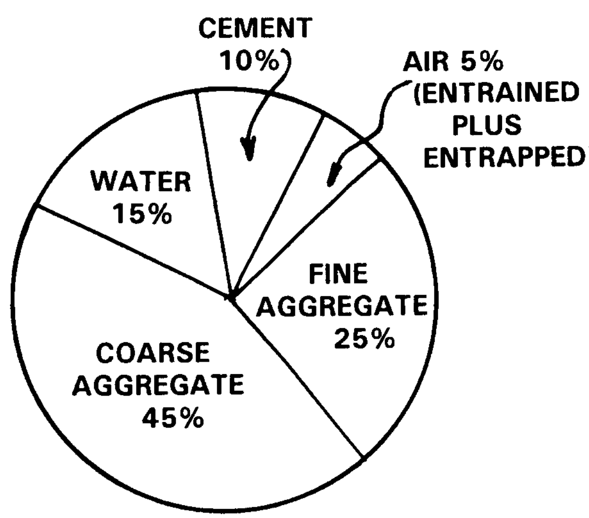


Figure7.5- Ideal Concrete Mixture (Van Dam, 2003)

7.6.4 Place the Concrete

Place the concrete into the forms, filling the forms completely (WW-1.C.1). Large air pockets and voids weaken concrete, and should be removed through tamping. Tamping involves anything from heavy banging and shaking of the form to ramming within the mixture using a steel rod (Van Dam, 2003). One should remove all possible air pockets, while avoiding damage to the form or concrete.

Next, smooth all of the open surfaces with a trowel or an equivalent tool with a flat edge. Take special note to smooth the lid of the springbox concave downward, such that the middle is higher than the edges. This is so no water is permitted to stand on or near the springbox (WW-1.C.1).

7.6.5 Assist in the Curing of the Concrete

The curing process of concrete is not a drying process; rather, it is a chemical reaction that requires water (Van Dam, 2003). If the concrete is allowed to dry, it will lose strength and likely crack. Once the concrete sets, the structure should be kept sufficiently wet. The setting process usually takes 90-minutes to 3-hours, and is verified when pressure from a footprint does not leave an indentation. After setting is verified, too much water is an impossibility, as concrete can even cure under water.

Rather than constantly water the structure, a good practice is to cover the concrete with moist canvas, burlap, empty cement bags, straw, or even plastic (WW-1.C.1). The protection should remain moist (except the plastic) and cover the structure for the duration of the curing process. A good practice is to water the concrete and the cover at least once every day of curing. At a minimum, the concrete should cure for seven days; however, the US standard is 28 days for all concrete except quick curing mixtures (Van Dam, 2003). Concrete continues to gain strength over the life of the structure, but 28 days is accepted as enough time to reach sufficient strength.

7.7 Install the Springbox

The spring box must be installed correctly in order to ensure optimal operation. Be sure the structure sits flat on the impervious base in order to form a seal that prevents the escape of water due to seepage under the springbox.

7.7.1 Place the Springbox

After a minimum of curing for seven days, the forms may be removed, and the structure should be carefully placed into its permanent location. For safe transport, expect this process to require at least six to eight people (WW-1.C.1). Refer to Figures 5.1 and 5.2 to be certain of how the structures should be placed. Note for the hillside structure it is important to place large and small stones in the opening at the back to provide structural support, allow the water to enter, and prevent its caving in to the rest of the backfill.

7.7.2 Seal to Prevent Leakage
It is very important to be certain that the springbox sits on level ground with a solid foundation of impervious media (WW-1.C.1). It is also necessary to seal the connection between the springbox and the ground with leftover concrete or puddled clay. Precise work on this job will prevent the seepage of water under the structure, resulting in the collection of all available springwater.

7.7.3 Backfill
In completing the structure, it is important to force all water entering the spring to first pass through gravel (WW-1.C.1). Next to the gravel layer should come an impervious layer of clay to protect the spring from contamination. The final layer should be a mounded layer of topsoil sloping away from the springbox, so as not to trap surface water and force its seepage into the structure.

7.7.4 Install Pipes
Place the overflow and outflow pipes in their proper locations (WW-1.C.1). Use concrete to seal their connection with the springbox and prevent leakage. Remember to install a screening on the overflow pipe to prevent contamination. Always use copper or plastic screens to prevent rust and securely attach them with wire (Water for the World-RWS.1.O.1). Install a valve on the outflow line, and place a rock or other erosion control underneath the outlets of both the overflow and outflow lines.

7.7.5 Clean the Structure
It is very important to clean and disinfect the springbox before use. The structure is likely to have become contaminated during construction. Make a cleaning solution using a ratio of 1 gallon of liquid chlorine laundry bleach to 10 gallons of water (Montana, 2002). Scrub the interior walls of the springbox wearing plastic gloves and other appropriate clothing, preventing skin contact with the cleaning solution. Cleaning should be performed from the outside of the storage tank because entering the structure during cleaning is dangerous to a person's health.

7.7.6 Disinfect Entire System
After the springbox has been thoroughly cleaned, it is then necessary to disinfect the entire system. Make a disinfecting solution using 3 pints liquid chlorine laundry bleach to 100 gallons of water. This solution should sit in the springbox and the pipes for at least 12 hours (Montana, 2002). If the springbox is connected to a distribution system, the distribution system should be disinfected as well. Otherwise, simply close the outflow valve of the springbox for 12 hours, while leaving the overflow pipe open for safe discharge when the structure is full. After the disinfection period, allow the outflow pipe to flow, and do not drink the water until both the scent and taste of chlorine is gone. Finally, place the cover securely onto the springbox.

7.7.7 Test the System

If water quality testing equipment is available, test the outflow water for bacteria, fecal, and other contamination. Otherwise, observe if any sickness occurs from consuming the water. Finally, an effective water quality test at no cost is to observe if there is an increase in turbidity after storms (Montana, 2002). This is a simple indicator that runoff is reaching the spring and possibly contaminating the water. If observed it will likely be necessary to use continuous chlorination in the springbox. If this is the case, the required chlorination rate will vary, as it depends on pH, temperature and flow.

8.0 Construction of a Masonry Springbox

The circular masonry springbox is only likely to be applicable on level ground artesian springs. However, if given those conditions, such a structure can save many resources versus the reinforced concrete structure. See Figure 5.4 for a typical design. The simple construction steps are as follows:

8.1 Place Bricks and Mortar

Using the calculated design diameter, place half bricks in a circle surrounding the spring (WW-1.C.1). Fill in the spaces between the bricks with a mortar mix of one part cement to three parts sand. When placing the bricks, be certain the vertical joints do not line up. Make sure to leave two pipe-size holes in the structure for the required water outlets.

8.2 Reinforce the Structure

Once the cylinder has reached the design height, wrap the structure with locally available wire several times, then secure and cut the wire (WW-1.C.1). Cover the entire outside wall with the same mix of mortar, one part cement to three parts sand. At a minimum, the thickness should completely cover the reinforcing wire.

8.3 Build a Circular Cover

A circular cover should be built using the same method presented in Section 7.4. After the lid has cured and the Cleaning and Disinfection steps have been completed, place the cover on the springbox.

9.0 Operation and Maintenance

The completed springbox will have a long life if operated and maintained properly.

9.1 Water Quality Maintenance

If the technology is available, the spring water should be annually tested for bacteria, nitrates, turbidity, and conductivity to determine if there is any contamination from surface water (Montana, 2002). If such tests are not applicable, remember a simple way to observe surface water contamination is if the spring water becomes darker, cloudier, or more turbid following a rainstorm.

Springs are also susceptible to viruses such as giardia and cryptosporidium, as well as other microorganisms that go undetected on standard tests. Special tests for these contaminants should be pursued if people are possibly becoming sick from consuming the springbox water.

Once a year the springbox should also be emptied, disinfected, and the accumulated sediment removed (WW-1.O.1). The spring can be emptied with a bucket and sediment removed with a shovel as depicted in Figures 9.1 and 9.2.

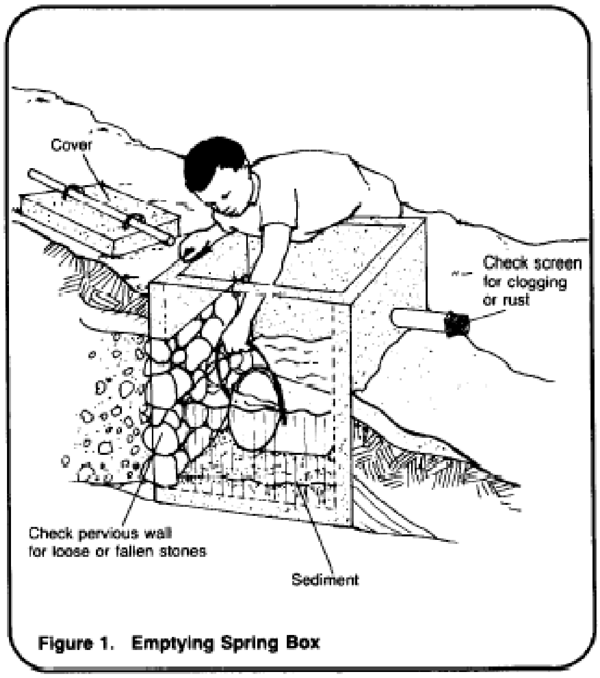


Figure 9.1- Emptying Springbox (WW-1.O.1)

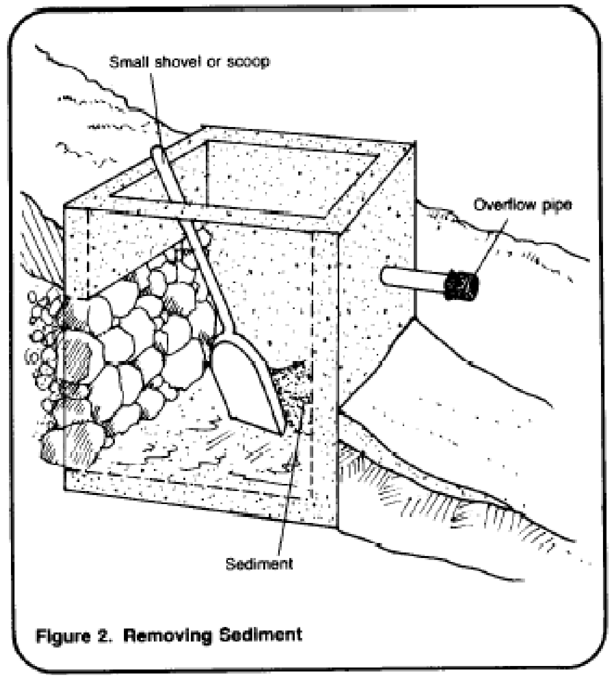


Figure 9.2- Shoveling Springbox (WW-1.O.1)

9.2 General Springbox Observations

Regularly check the cover, making sure that it is not being removed by the users who might dip their hands and buckets into the water, possibly contaminating it (WW-1.O.1:1). Observe the overall structure for any cracks, leaks, or possible failure points. Finally, determine if all of the spring flow is being collected by the structure. Check to see if any water is seeping from the sides, seals, or underneath the springs. Repair any damages.

9.3 General Site Maintenance

Inspect the fence, diversion ditch, and the up-gradient erosion to see if anything should be repaired or upgraded (WW-1.O.1). Is there any evidence of animals inside the fence? Is the ditch adequately draining the surface water? Is there topsoil building up at the back of the springbox? If these problems exist, solutions are relatively simple including: repairing the fence, lining the diversion ditch with stones to increase flow and prevent erosion, and controlling up-gradient erosion with more backfill, plants or stones.

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