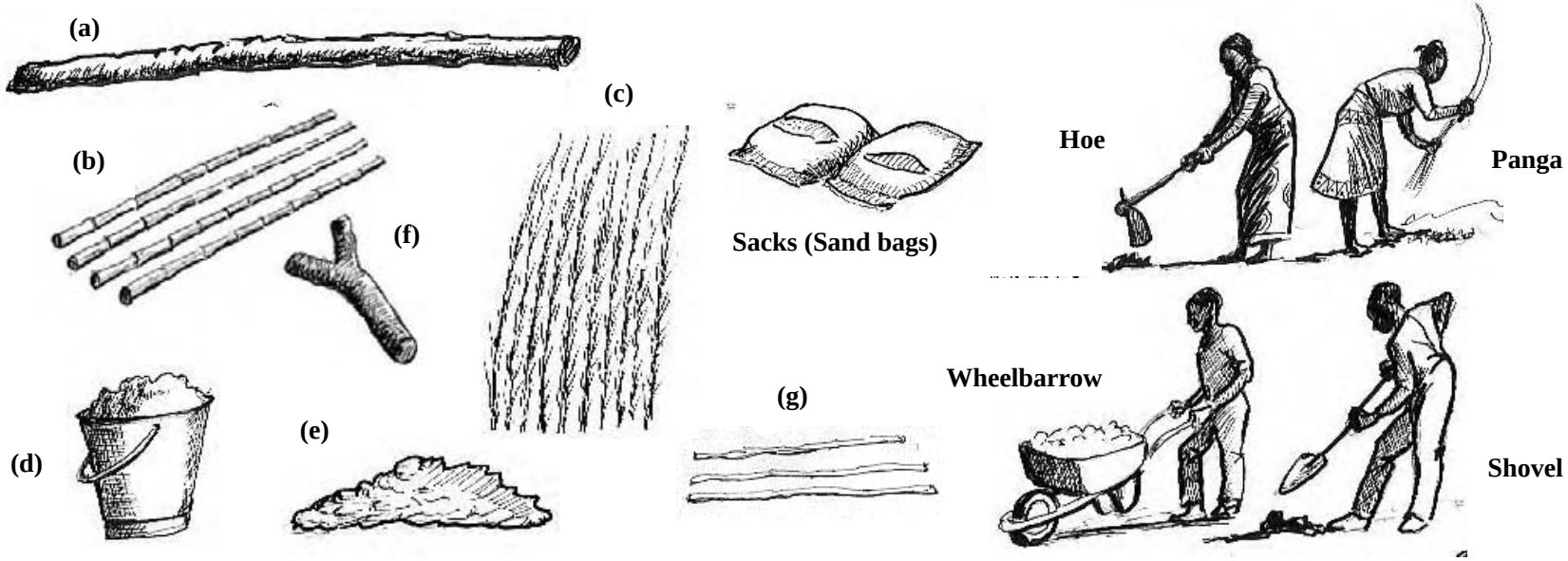
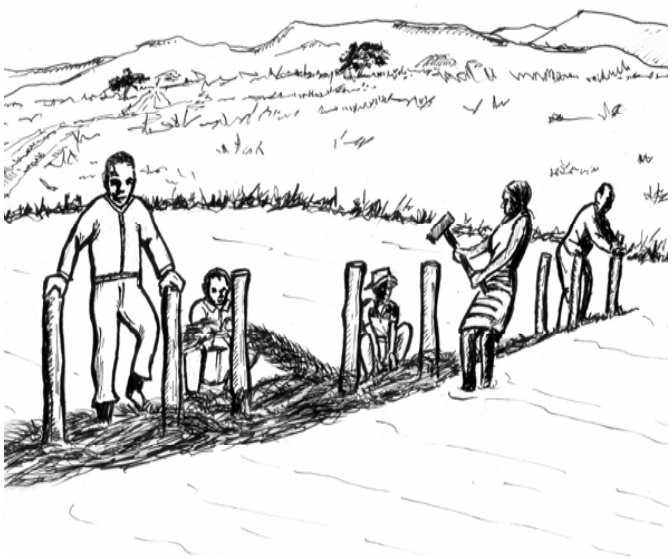
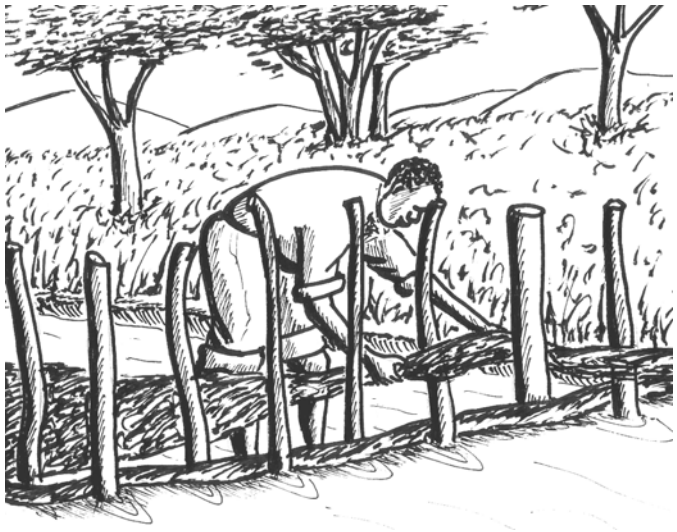
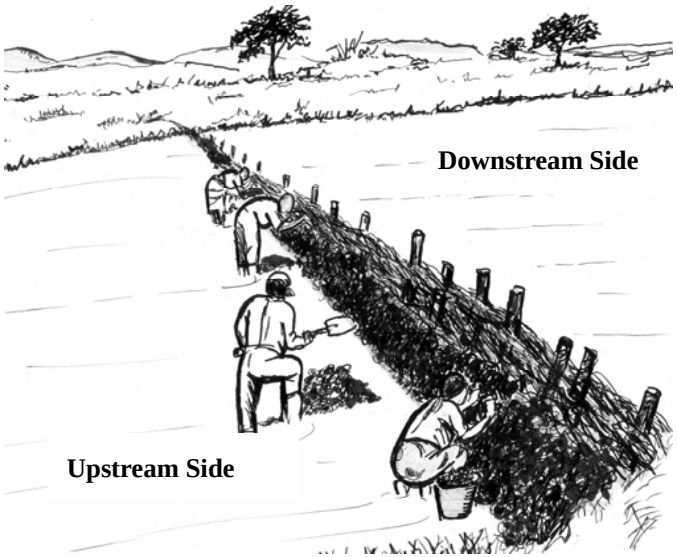
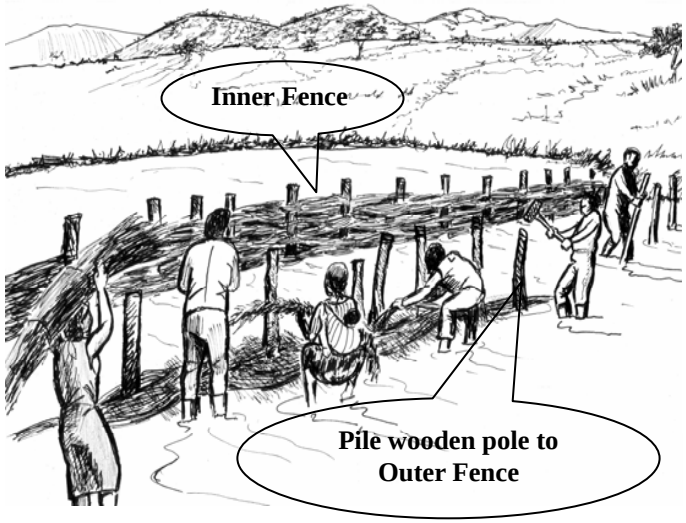
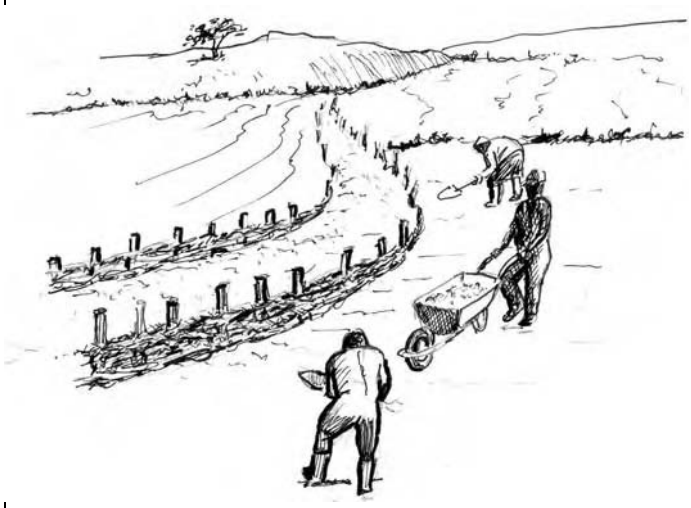
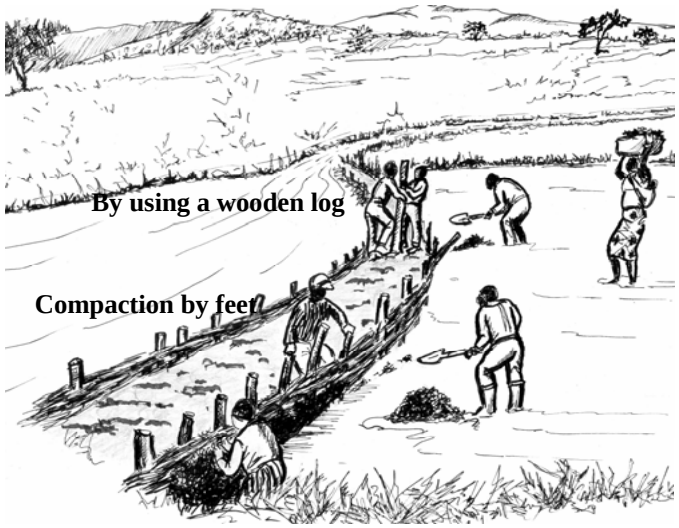
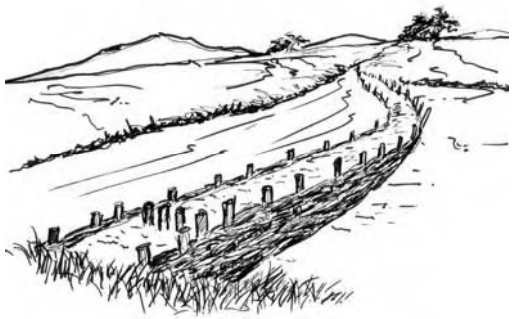
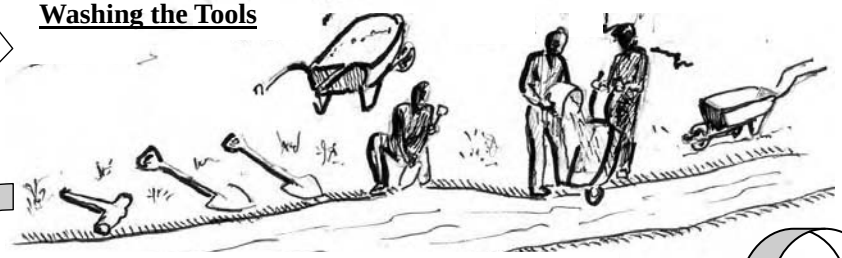
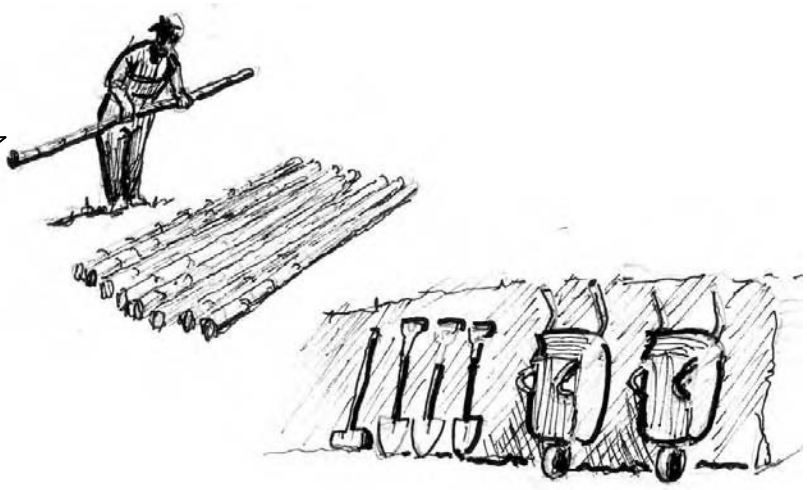
3. Construction of A Simple Weir: Double-line Wall Type (best suited at wider streams whose foundations are not rock)

Step	Materials to be collected
0	**Collect all the following materials**; (a) Log/Bamboo/Twigs: to make the fence both inner and outer (Quantity: 30-35nos. per 10 meter length of the dam, Refer to Step-1 & 5) (b) Grasses (Elephant grass): to weave into the fences (Quantity: depend on the size of the dam, Refer to Step-2 & 6) (c) Clay soil: to patch in front of inner fence (upstream side) and stuff into the opening of the fences (Quantity: depend on the size of the dam, Refer to Step-4 & 7) (d) Ordinary soil: purpose is same as clay soil **Implements;** Hoe, Shovel, Panga knife, Wheelbarrow, Hammer (Quantity of these implements depends on the number of participants for construction of the dam)
	

Step	Process	Description	Remarks
1		**<u>Pile Wooden Poles to the Inner Fence (Upstream Side);</u>** To make the inner fence, the wooden poles such as log, bamboo and twigs are piled every 30-50cm interval on the line crossing the stream. When the poles are properly positioned, they are driven into the streambed by a hammer.	In fact, this process of putting inner fence is just same as that of single-line weir construction. As single-line weir may hardly be able to stop water due to the leakage through the weir body, this double-line weir was devised. Therefore, one may say this weir is best suited at a site whose width is relatively wider, so that it is impossible to construct inclined type weir, whose foundation is formed with soil (not rock), so that we can drive poles into the foundation, and where we need to minimize water leakage probably due to a fact that there is little water flowing in the stream.
2		**<u>Weave Grasses into the Inner Fence;</u>** To tap the stream flow, grasses (elephant grass etc.) are woven horizontally into the inner poles following Step-1. Then, the grasses woven are compacted by feet. The moment any grass is weaved between the poles, press it tightly with feet. Continue doing this until a required height of this weir is obtained. The weaving of grass should be done to both fences, so that a space is left in between the parallel fences.	The grasses are bundled and woven horizontally between the wooden poles. A good chunk of grass twisted is taken and finally it is woven between poles. When the bundle has reached the end, the next bundle should not start at the very ending of the last bundle but it should start at midway in order to minimize creating gaps. The bundled grasses which are woven between the poles are treaded layer by layer so as to compact it in order to achieve a water tight situation.

Step	Process	Description	Remarks
3		**<u>Put Clay/Ordinary Soil on the Inner Fence;</u>** Furthermore, clay/ordinary soils are put on the upstream side of inner fence to prevent water from passing through the weir body as leakage. To protect water leakage through the gap of grass fence and boiling due to sand bed material of the stream, the clay soils are put on the upstream side of inner fence and the bottom of stream up to a certain level.	The above Steps-1, 2 and 3 are exactly same as those of single-line weir construction. There may be a difference from the single-line weir; that is the interval of the poles. Since this is to be a double-line weir, a wider interval than that of single-line weir may be accepted, say 50 to even as wide as 70cm interval.
4		**<u>Pile Wooden Poles to the Outer Fence (Downstream Side);</u>** The outer fence is constructed following the Step-3. As first step of making the outer fence, the wooden poles are piled on the line of outer fence such as that of Step-1, preferably 50cm to 1m downstream from the inner fence. Then, being same as Step-2, grasses (elephant grass etc.) are woven horizontally into the outer poles. The grasses should, of course, be compacted by feet/ or using a log in order to achieve a water tight situation.	The poles are hammered into the ground with double lines (namely at outside of inner fence). The whole essence of hammering is to make the structure strong, and to make the poles go beyond sand deposits. The interval between the poles can be 50cm – 70cm, a little wider than that of single-line weir.

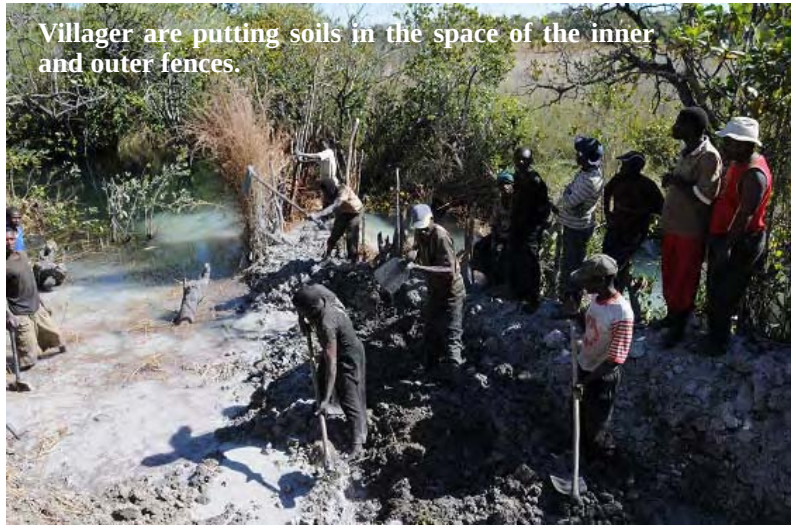
Step	Process	Description	Remarks
5		**<u>Stuff Clay/Ordinary Soils;</u>** Put the soil which exist around the site into the opening between the inner fence and outer fence. To prevent water leakage from the grass fences, clay/ordinary soils are put into the space between the inner fence and outer fence. The clay soil and ordinary soil can be collected around the diversion site.	It should be noted that the wider the space between inner and outer fences, the more soils should be prepared and put into. The wider the space, the less leakage we can expect but the harder the job of putting soils in between becomes.
6		**<u>Compact the Soils;</u>** The clay and soil ordinary soil thrown into the space between the inner and outer fences should be compacted heavily by feet or with a wooden log. After all the process above is followed, the weir is now completed and water starts backing up on the upstream of the weir, then the water starts getting into the diversion canal to flow.	Completion ! 

Step	Process	Description
7	**Dismantling the Weir**  **Washing the Tools**  **Transporting Materials and Tools to the village** 	**Note; Dismantling the Weir and Set Aside the Main Materials** These types of weirs are constructed as temporary facilities for the intake of stream water for irrigation farming in dry season. Therefore, the weir should be dismantled before the start of the rainy season because such kind of structures are constructed across the river/stream and as such, the diversion weir becomes an obstruction for safety flow of floods. Main materials such as logs, bamboos and twigs are then set aside at a suitable place in the village. If properly stored, these materials will be reused for few years to come. **Setting aside the Materials & Tools** 

Examples of Double-line Weir (Mansa District (Left), Luapula Provicne, Mungwi District (Right), Northern Province)

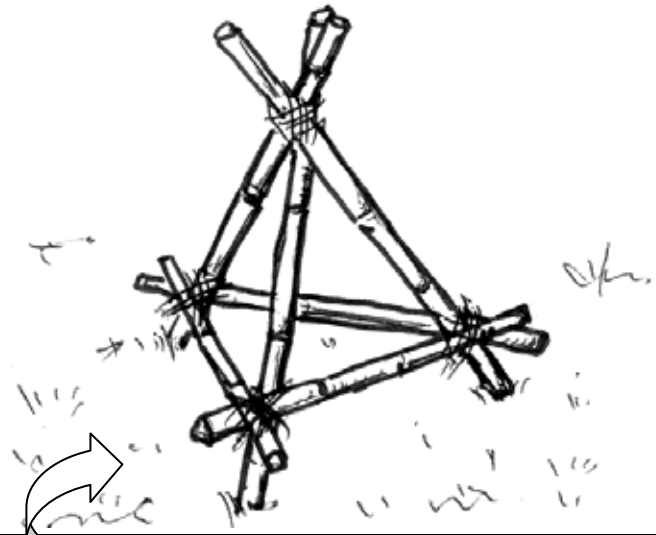
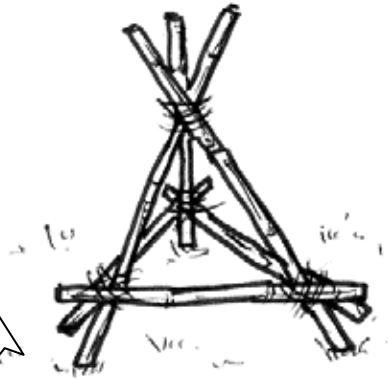
A double-lien weir which works village road as well.

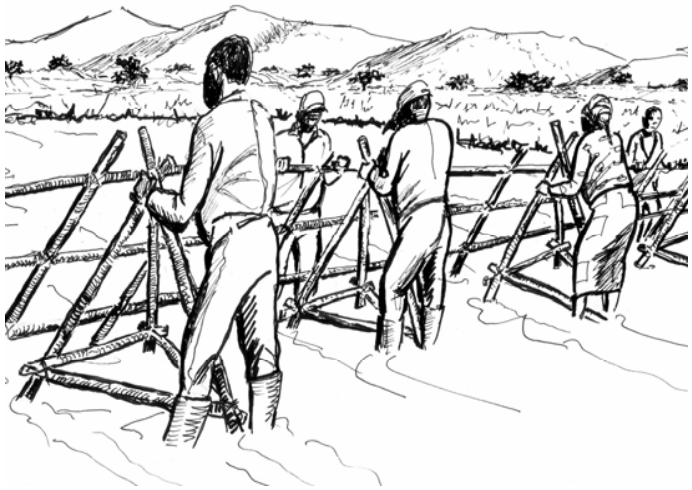
The frame of the inner and outer fences are not put up.



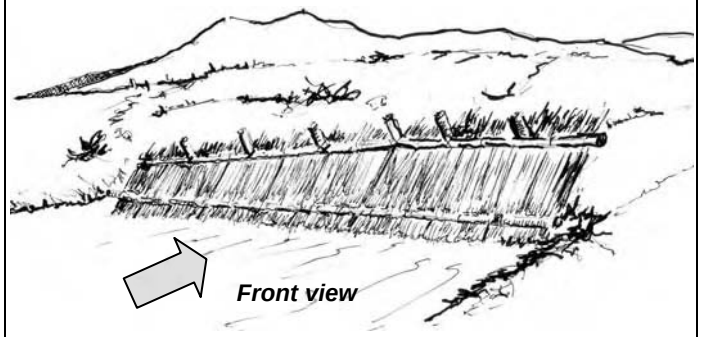
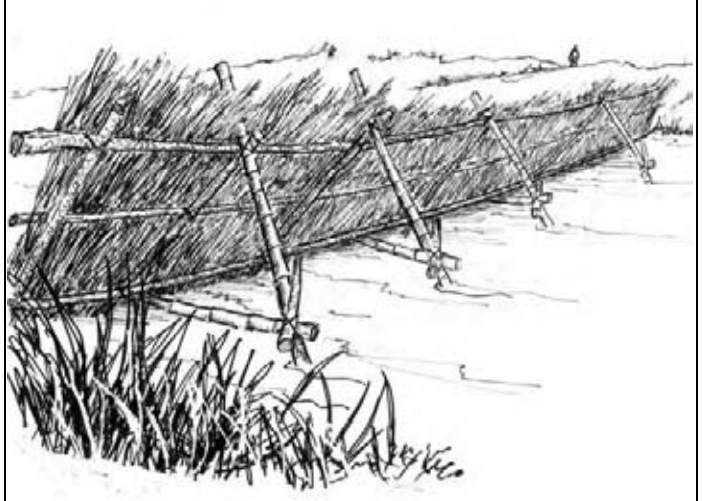
Villager are putting soils in the space of the inner and outer fences.

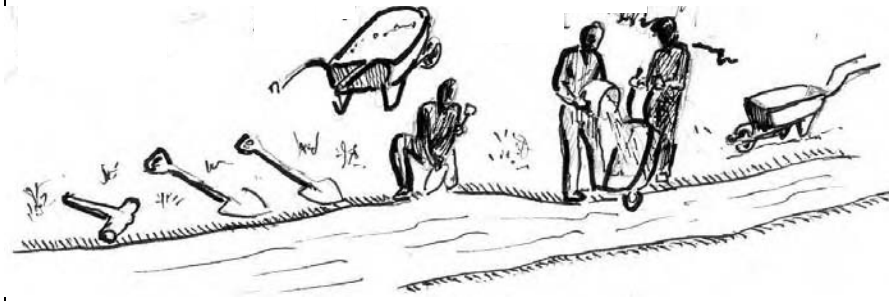
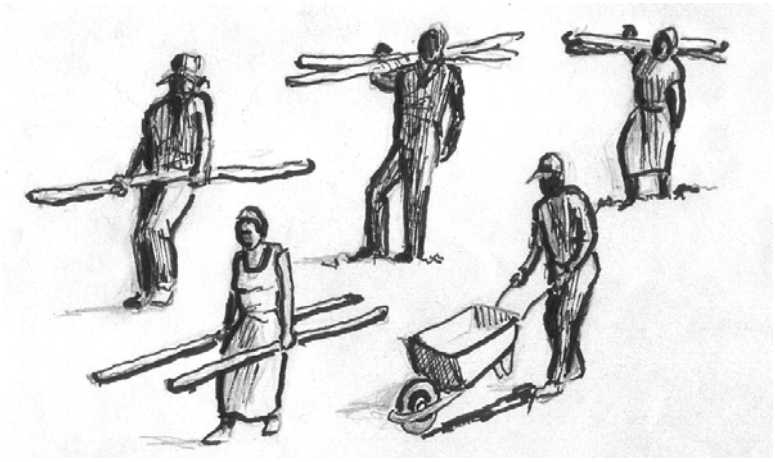
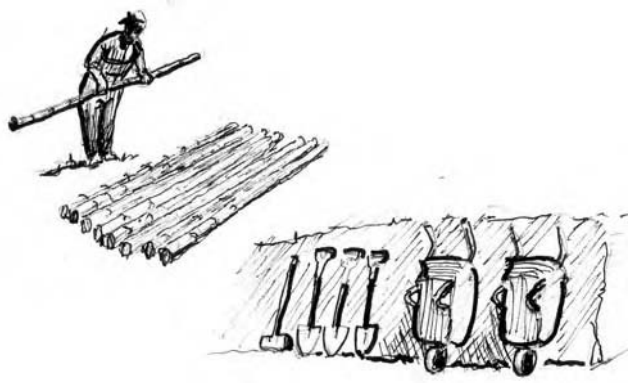
4. Construction of A Simple Weir: Trigonal Supported Wall Type (can be installed on a rock foundation where wooden logs can't be driven)

Step	Process	Description	Remarks
1		**<u>Assemble the Trigonal Prop (Standing Structure);</u>** To support the brush dam made of grasses/clay soil, the trigonal prop standing structures are assembled as shown in the left illustration.	The trigonal prop can be made of log/bamboo. The size of this structure is adjusted depending on the site condition with reference to the design tapping water level. As an example, each member is cut with a length of 1.3m for 0.5m of tapping water depth design. The diameter can be of the log's/bamboo's one for the trigonal prop; around 7cm - 15cm each. The front of this structure, namely the upstream side, has an inclination to act as support for the fence made of logs, bamboos and grasses with clay soil, and lastly, to stand against the water pressure.
		<u>Refer to the Illustrations</u> Cutting of trigonal prop members and assembling of this structure. 	An angle of inclination of the front face is around 70 - 80 degrees. To tie the members to each other, local materials such as runners/grass/sisal can be used. The horizontal 3 members of the prop, forming the horizontal triangular, should be placed outside of the inclined members, so that it can stand more against water pressure.

Step	Process	Description	Remarks
2		**<u>Set up the Trigonal Props across the Stream;</u>** The trigonal props are set at the diversion point across the stream. Then, horizontal members are fixed to the trigonal props to keep them in place and in line to each other. At least, 3 horizontal members i.e. upper, middle and lower members should be fixed on the trigonal props. As a result, all of the trigonal props are connected by the horizontal members and will withstand the water pressure as one structure.	The trigonal props are placed at a proper interval in order to prevent this structure from falling down by water pressure. In case of a site in Mungwi district, the width of the stream at the diversion point was about 15m, and 10 trigonal props were set up giving an interval of 1.5m apart. The diameter of fixed horizontal members can be around 3cm - 10cm each. The materials can be wooden poles and bomboos.
3		**<u>Place the Grasses on the Trigonals;</u>** To tap the stream flow, the grasses are placed vertically in front of the trigonal props touching the bed level of the stream.	To reduce the water leakage, it is better to put the grasses very closely. In particular, at the bottom portion of stream, a lot of grasses should be used and should be placed tightly. The horizontal member to be fastened on the top of the grass is the bottom one. Then the second and finally third on top. This helps to keep the grass very tight to the trigonal prop and indeed reinforces the trigonal prop.

Step	Process	Description	Remarks
4		**<u>Tie the Standing Grasses to the Trigonal Structure;</u>** To prevent swelling out of the standing grasses, these grasses should be pressed against the trigonal prop by using horizontal members again tied with runners. Three horizontally parallel members, at the bottom, at the middle and at the top, are finally fastened with the props or otherwise with the horizontal members already set behind the grasses. The grasses are thus sandwiched by those horizontal members set in front and behind.	To press down the grasses on the trigonal prop, another layer of horizontal members are put in front of grasses which are made to run parallel with the first horizontal members already placed at beginning but at a specified interval between each other and these are tightly tied to the first layers of horizontal members. In so doing, grass is tightly sandwiched between horizontal members. The number of layers of horizontal members is dependent on the height of the trigonal weir. In general, 3 lines of horizontal members are placed.
5		**<u>Put the Clay Soil on the Grass Fence;</u>** Clay soil is placed on the grass fence starting from the foundation or streambed level. To prevent water leakage, the clay soil is patched on the grass fence. The clay soil is put not only on the grasses as a part of brush dam but also on the gap between the bottom edge of the grass fence and the natural ground/exposed rock foundation.	Putting of clay soil should be started at the bottom, and much attention should be put at this stage. This is because this area is very critical in reducing water leakage and thus where the water pressure is the highest. A lot of clay soil should be placed at the bottom in order to make it water tight as much as possible to prevent leakage.

Step	Process	Description	Remarks
6	 *Diversion Weir in a Wide Stream: Rock Foundation*	**<u>Completion of Construction;</u>** <u>The front / Upstream of the Weir</u> Water finally backs up at the upstream of the weir and the duration of backing up depends on the stream width. The weir is finally completed. 	With this trigonal supported weir, water depth stored could reach over 1.0 m or even more than 1.5 m. However, the higher the water level is, the riskier it is and therefore it may fall down. Therefore, it is not recommended to store water over 1.0m.
		<u>The back / Downstream of the Weir</u> 	Check the inclination of the weir. The bamboos supporting the trigonal prop, which is at an inclined angle, is clearly seen / shown in the pictures with its horizontal support. The water level in the downstream is lower than the upper stream of the weir. The trigonal props also help resisting the water pressure which is greater at the bottom, hence the unique design the trigonal prop.

Step	Process	Description
7	**Dismantling the Weir** **Washing the Tools**  **Transporting Materials & Tools to the village** 	**Note; Maintaining the Weir** During operation of the irrigated farming, the diversion weir should be maintained carefully. For instance, if a hole is found on the weir, it should be immediately sealed with clay/ordinary soil. This process will restore the weir its original good shape. **Note; Dismantling the Weir and Set Aside the Main Materials** These types of weirs are constructed as temporary facility for the intake of stream water for irrigation farming in dry season. Therefore, the weir should be dismantled before the start of the rainy season because such kind of structures are constructed across the river/stream and as such, the diversion weir becomes an obstruction for safety flow of floods. Main materials such as logs, bamboos and twigs are then set aside at a suitable place in the village. If properly stored, these materials will be reused for few years to come. **Setting Aside the Materials & Tools** 

Examples of Trigonal Supprted Wall Type (Mungwi and Mpila Districts, Northern Province)

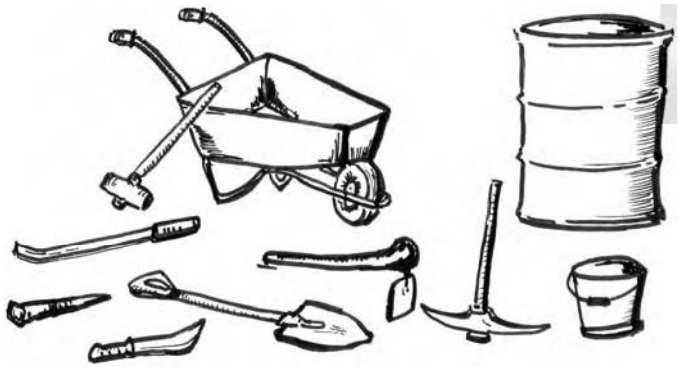
Assembling trigonal stand structure

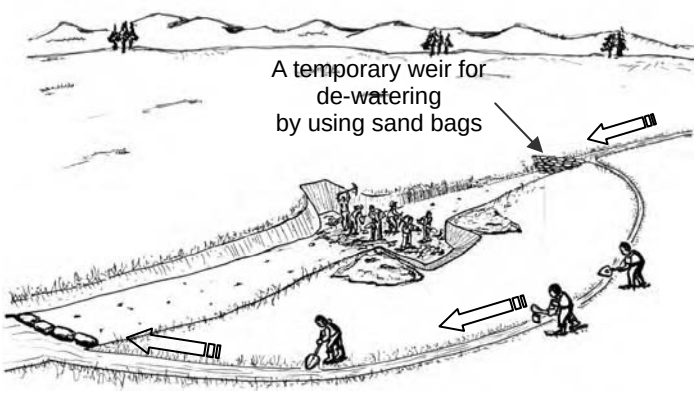
Placing the grasses with horizontal members

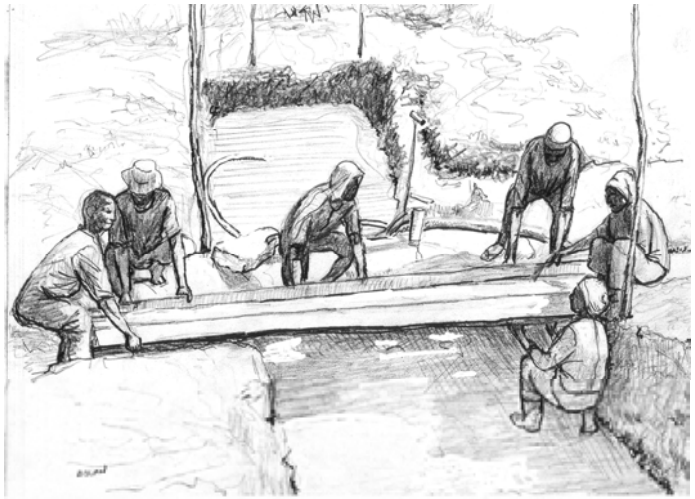
Aligning trigonals across the stream

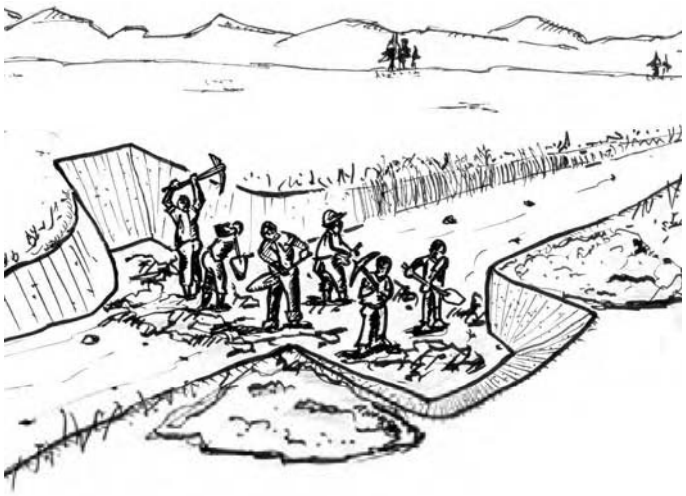
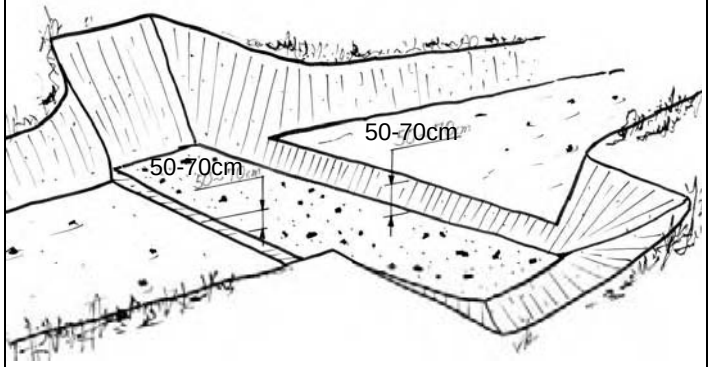
Since flow in the stream is too much, right side of the weir is intentionally left opened.

5. Construction of Permanent Weir: Wet Masonry Wall Type

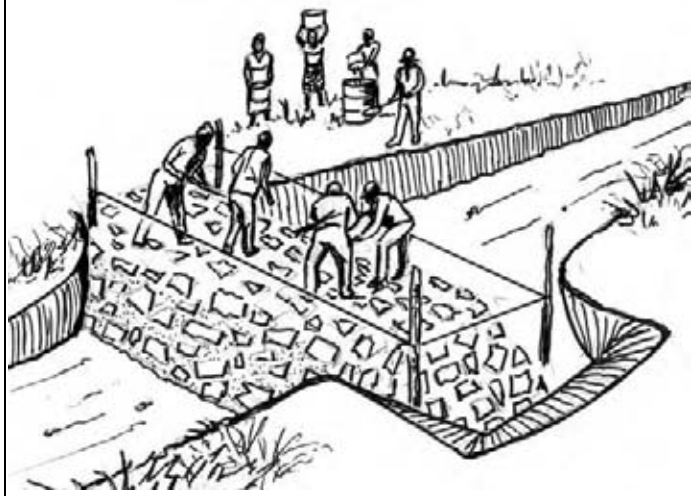
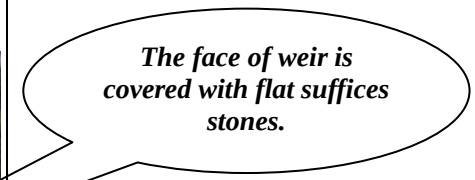
Step	Process	Description	Remarks
1		**<u>Tools Required:</u>** For the construction of permanent weir, the major tools required are: - Wheelbarrows - Hoes - Panga knives - Pickaxes - Chisels - Hammers - Buckets - Drum - Slashers - Shovels - Trowel	
2		**<u>Materials Required:</u>** For the construction of permanent weir, the major materials required are: - Cement - Stones - River sand	

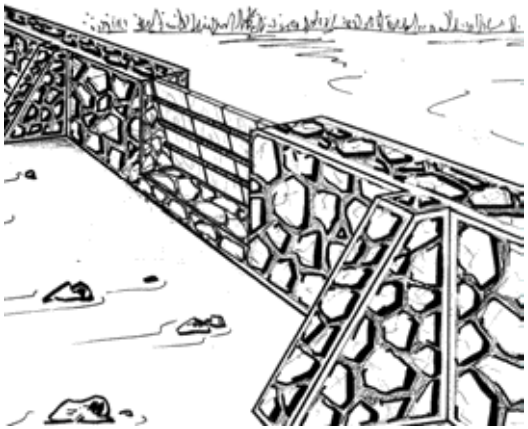
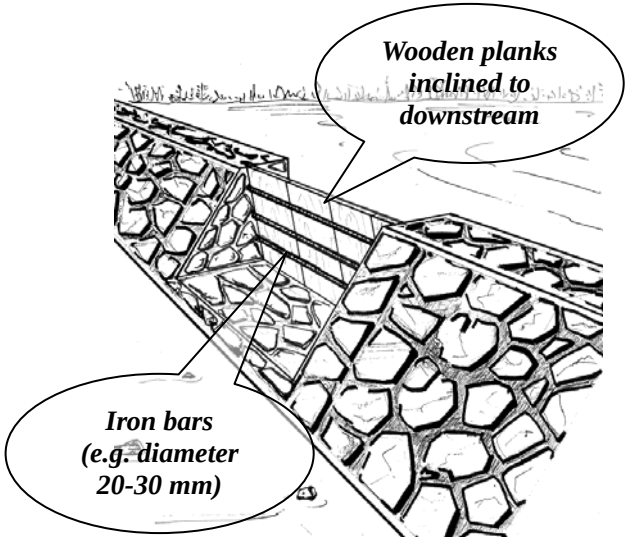
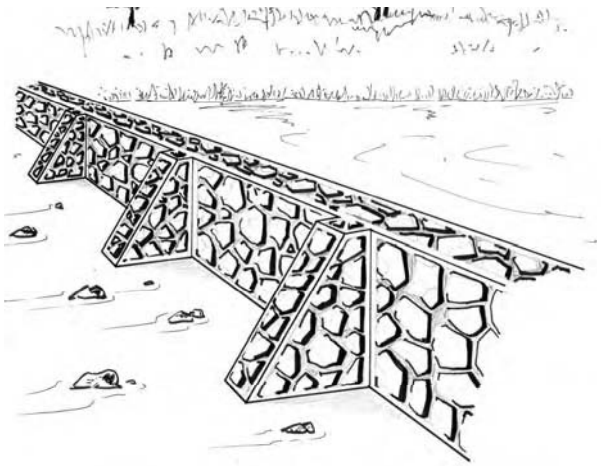
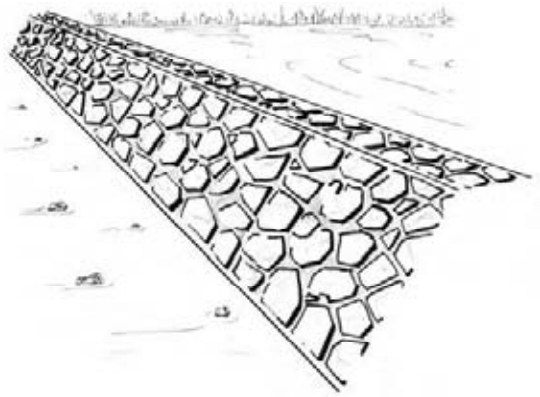
Step	Process	Description	Remarks
3		**<u>De-watering by Bypass Channel:</u>** During the construction of weir, it is necessary to keep the foundation of construction site dry. To this end, de-water the site by making a bypass channel, a sort of detour channel to divert the stream water. Dig the bypass channel as shown in the left illustration to divert the river/stream water to the downstream of the construction site. Then, pile sandbags or construct temporary diversion weir out of locally available materials to stop the stream water and divert it into the bypass channel.	If you see a plenty of seepage at the construction site, dewatering should be carried out continuously with buckets in addition to diverting the stream water into the channel. Drain ditch and drain pit may be required to do the dewatering in this case. Drainage pumps or treadle pumps may have to be used when buckets are not sufficient to drain out the seepage and make the foundation dry.
4		**<u>Material for Temporal Weir:</u>** For setting up the temporal weir to divert stream/river water, sandbags are the most appropriate.	

Step	Process	Description	Remarks
3’		**<u>De-watering by Water Bridge:</u>** In case that the abutment foundation is formed with rock, it is impossible to make diversion channel. In this case, we may introduce water bridge bypassing the stream water over the longitudinal section of the dam to be constructed. Water bridge can be assembled with timbers/planks, and plastic sheet should be placed thereon to prevent seepage.	The dimension of the section of a water bridge should defer from one site to another depending on the flow volume to be diverted. In most cases, width 50 – 150 cm can be recommended. 
4’		**<u>Placing of the Base Concrete:</u>** While diverting the stream water to downstream with the water bridge, base concrete should be placed in the bottom of the foundation where the dam body is to be constructed. The base concrete is placed underneath the water bridge as shown in left.	

Step	Process	Description	Remarks
5		**<u>Excavation of River foundation:</u>** While keeping construction site dry, excavate the river/stream bed of the construction site until all the organic materials deposited therein have been removed and to the depth where hard foundation is found. Abutment should also be excavated at least 2 m to the horizontal direction into river bank on both sides.	
6		**<u>Further Excavation:</u>** Foundation of the diversion weir to be constructed should further be excavated 50 cm to 70 cm in depth unless otherwise there is already rock foundation.	If soft soil or unsuitable soil is exposed, additional excavation should be carried out. **Attention:** To prevent landslide, shape of the wall at abutment should be in slope, if the depth of excavation is expected to be deeper than 1.5m.

Step	Process	Description	Remarks
7		**<u>Chipping Rocky Foundation:</u>** If there is rock on the bottom of river bed, chipping should be done to make concrete to firmly contact with the foundation.	To chip the rocks, you may use hammer, and chisel if you have. Otherwise chip the rock foundation by hammer.
8	 Note: Mortar shall be mixed on a rock foundation, on a steel plate or otherwise at first construct a floor like thin flat concrete base and start mixing mortar thereon.	**<u>Mortar Mixing:</u>** In order to get proper mortar, standard mixing proportion of cement to sand is 1:3 or 1:4 in terms of volume. This automatically means one bag of cement (usually 50 Kg per bag in Zambia) shall be mixed with 3 – 4 bags of sand. In any case, the recommended mortar ratio should never be weaker than 1:4.	Prepare drums of water for mortar mixing at the site on the day of construction. Water should be clean. If the sand is dry, pour 1 jerrican (20 liter) of water and mix it in advance. Then, additional water should be sprayed and mixed to keep proper consistency of the mortar. The mixing should be carried out on an exposed rock foundation or floor like thin concrete base, otherwise soil could be mixed up, making the concrete quality poor.

Step	Process	Description	Remarks
9	 Wet masonry weir supported by continuous buttress	**Weir Construction:** Wash and wet the stones in advance to pile them up. Place mortar first and pitch stones into a layer, and push mortar into the interstices and gaps in between the stones. Hammering stones lightly may be required to make the contact between the mortar and stones firmly. Repeat this process till the required level.	Unless de-watering is kept continuously, never close the construction site completely. Voids in the weir body should be filled with mortar entirely so that water leakage may not happen and strength of the weir body is secured. Split line level is helpful to see the level of the layer.
10		While repeating the above, layout the flat surface of stones in line facing outside of the weir. 	

Step	Process	Description	Remarks
9	**Installation of Sand Sluiceway:**  		Sand sluice way should be installed in order to pass the sand sedimentation from upstream to downstream and also allow fish to go and come. Standard size is 0.5 – 1.0 m width, not more than one meter in any case from the viewpoint of structural stability, and the depth should be around 2/3 of the height of the wall. The sluiceway can be installed one in every 10-15 m span. There should be several horizontal iron bars across the opening on which wooden planks are placed inclined to downstream to store water.
10	 Wet masonry weir supported by several buttresses  Wet masonry weir supported by continuous buttress (Gravity Type Wet Masonry)		**Finishing:** The surface of stone needs to be exposed to the air and finished neatly and smoothly. Every time after the day's work and also upon completion of the construction, the weir body needs to be covered with wet grasses or wet straw mats for curing mortar. Recommendable type of weir depends on weir height; 1.5m - 2.0m: Continuous buttress type Less than 1.5m: Several buttresses type