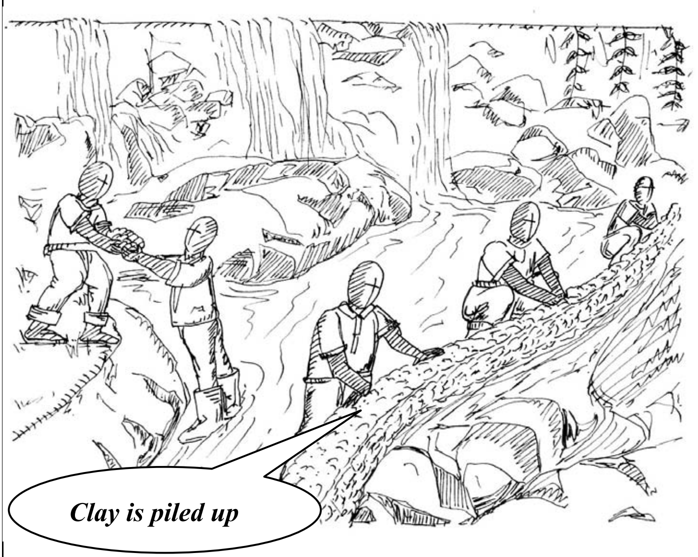
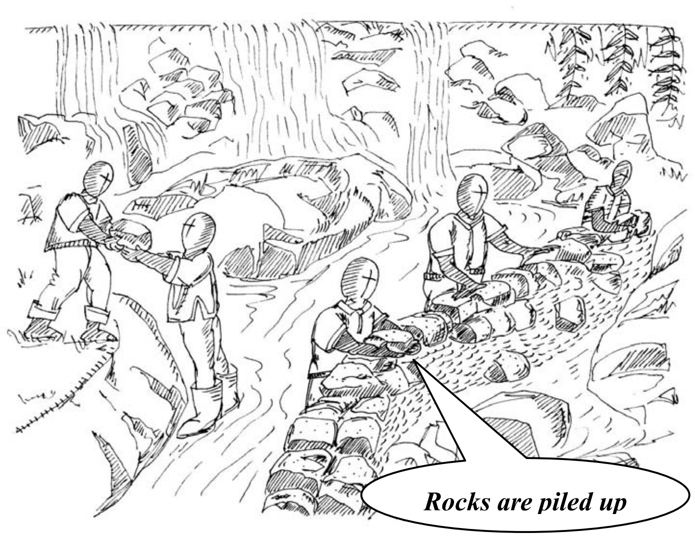
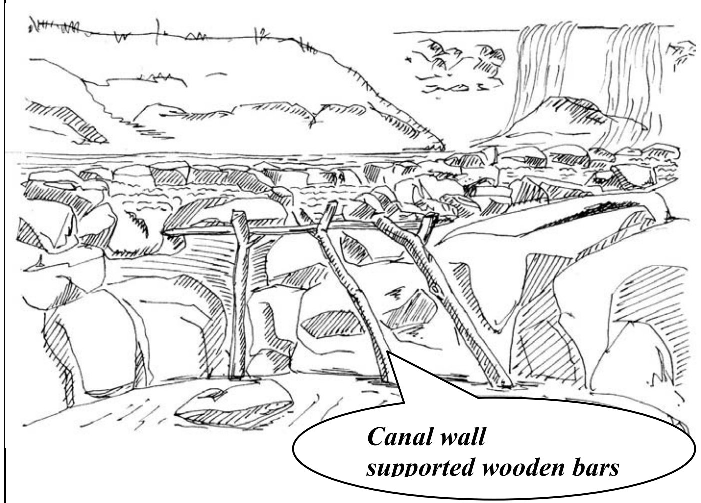
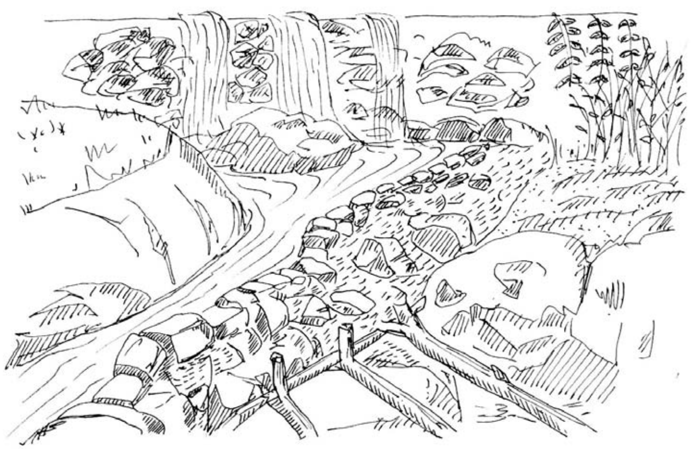
5. Construction of Diversion Weir made of Rock & Clay (Type-E)

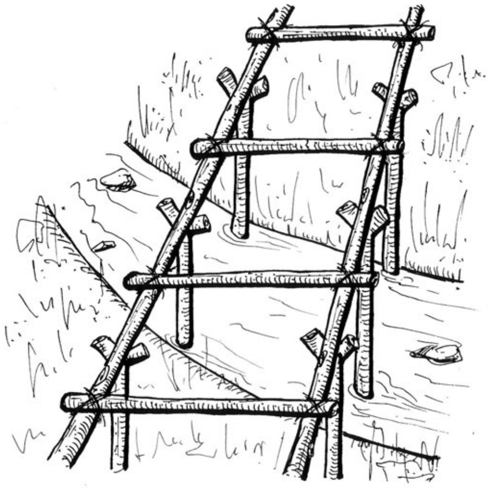
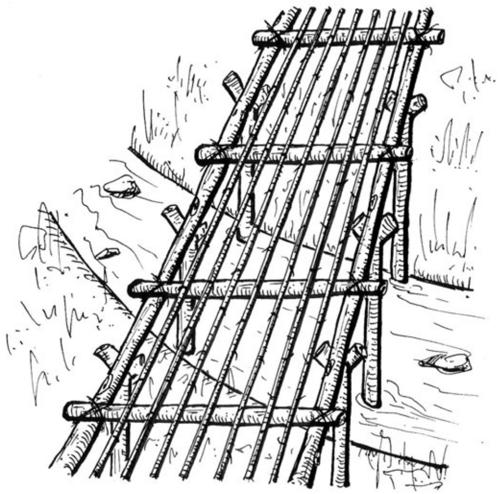
Step	*Process*	*Description*	*Remarks*
1		***Collect and Gather Rocks and Clay Soil;*** *Rock and clay are piled up at the diversion point in the direction of canal.* *As first step, clay is piled up in order to make the basement.*	*If the bed material of stream is mainly composed of rock/stone, this type of weir that is made of rock and clay can be applied to intake the stream water. Rock and clay are piled up mutually, like sandwiches, at diversion point.*
2		***Rocks are piled up;*** *Good clay soils should be the one to be used. When constructing this weir, clay acts as mortar with a perfect water tight bond.* *Rocks are piled up on the clay.*	*A masonry wall is built across the stream in the necessary direction so as to easily intake the stream water into the canal.* *The wall height is dependent on site conditions and the designed tapping depth.*

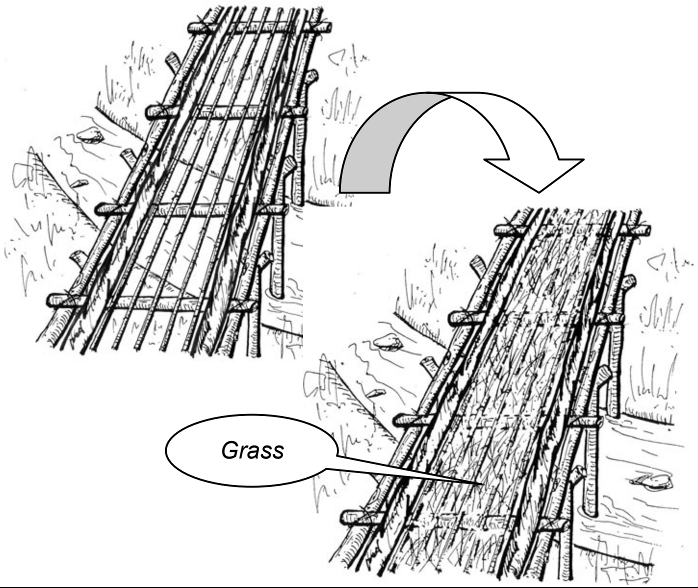
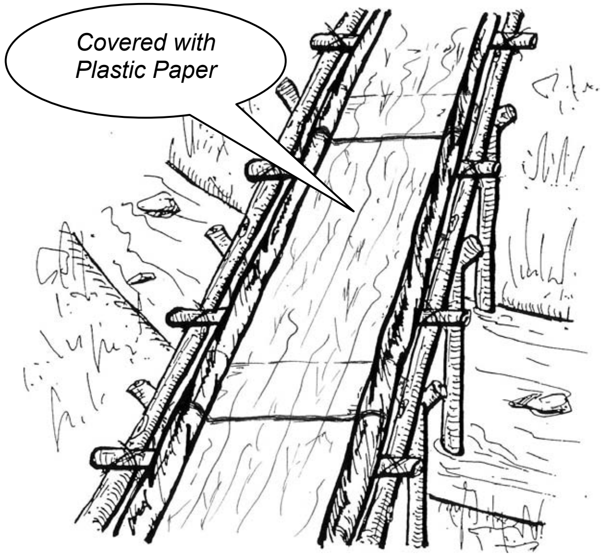
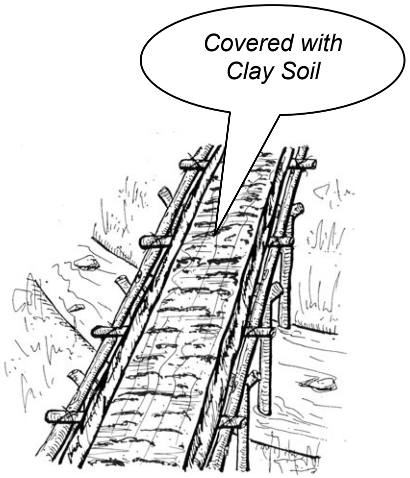
Step	Process	Description	Remarks
3		***<u>Erect / Stand Supporting bars for Canal Wall Reinforcement (if necessary);</u>*** *According to site condition, to support the canal wall wooden bars are used for reinforcement.*	*To prevent water leakage from canal wall, wooden bars are positioned to support the canal wall according to the site situation. Also, in case of this site, some sand bags are used together with rock and clay.* *Very good clay soil is used as mortar to bind the rocks thus making it water tight.*
		*<u>Refer to the Illustration</u>* *Setting out of a place where to construct a wall.*	*Clean the place where the wall will pass and if possible, the wall should be as straight as possible but of course this wall depend on the site condition such as the lay-out of the rock foundation which the wall will rest.*

Step	Process	Description	Remarks
4		**Completion of Construction;** *The masonry diversion weir made of local materials is then completed and the water gets backed up in the upstream weir before flowing into the canal until Eventually the water is conveyed into the dug canal.*	*The dimensions of the weir constructed in Dedza district are as follows;* *-Length of the weir: 7.0m* *-Height of the weir: 0.35m*
		**Note; Maintaining the Weir** *During operation of the irrigated farming, the diversion weir should be maintained carefully. For instance,if a hole is found atv the weir ,seal it with clay/ordinary soil. This process will restore the weir its former good shape.*	

Step	Process	Description
5	**Keeping the Materials (Rocks, Stones)** 	**Note; Dismantling the Weir and Set Aside the Main Materials** *This type of weir is 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 such as the diversion weir becomes an obstruction for safety flow of floods, and this situation will occur inundation to the farm land. Then, the main materials and tools such rocks and stones as construction materials, while wheelbarrows and shovels as tools, are set aside at a suitable place in the village, if properly stored, these materials will be reused for few years to come.*

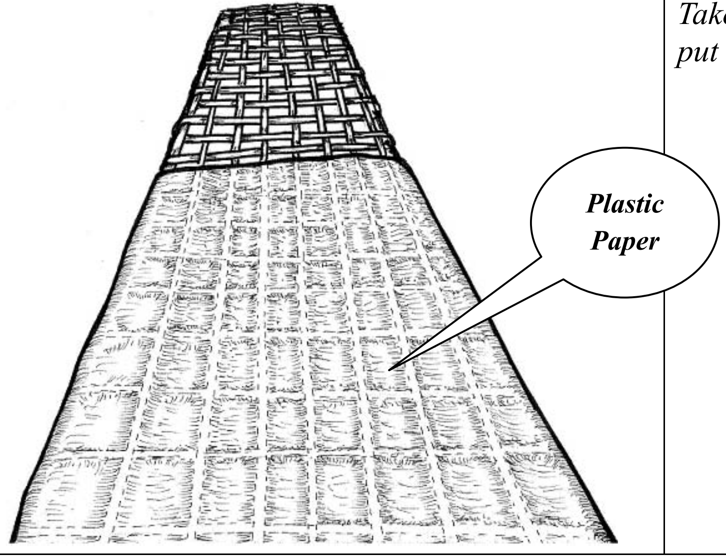
6. Construction of Canal Bridge (Section 1; Crossing Gullies)

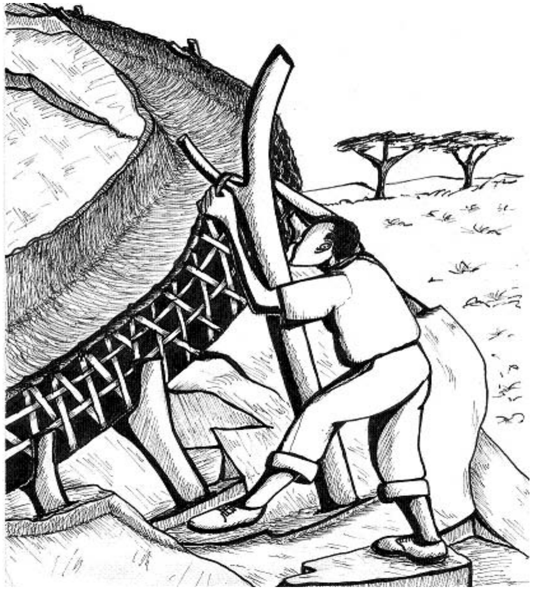
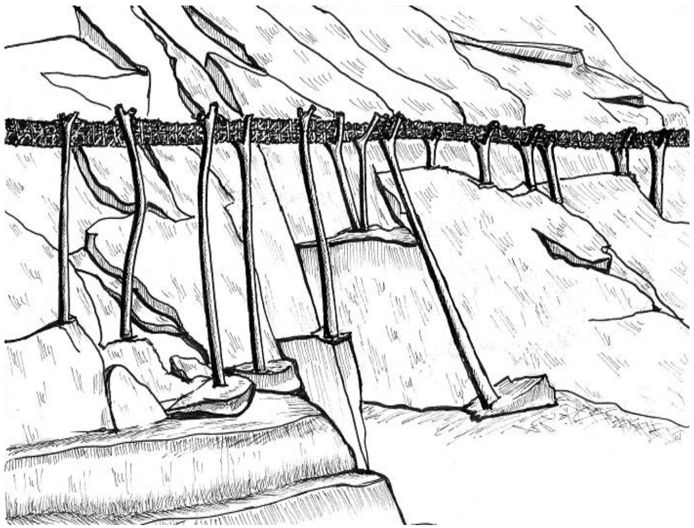
Step	*Process*	*Description*	*Remarks*
1		*Put supporting bars across the stream (or gully).*	*Take trees (about 15-20cm in diameter), with appropriate branch gap and fix two lines across the obstruction in parallel, depending on the width of the canal. Take bamboo or good-sized trees and place them along the branched tree gap and tie them tightly. Across these two lines, place horizontal members (at good interval) and tie them tightly together with the longitudinal members.*
2		*Put elephant grass (or twigs) on the skeleton so formed.*	*Take elephant grass and put them across the horizontal members and tie them together with the horizontal members. Then take ordinary grass and spread them tightly and evenly on top of the elephant grass along and across the whole width of the frame.*

Step	*Process*	*Description*	*Remarks*
3		*Make a canal gap, by putting a bunch of grass at both edge of the frame*	*Make two bunch of grass about 20cm in diameter (of-course depending on the depth and freeboard we intend to set the canal). Place the bunch of grass at each edge of the frame (structure water bridge). In case of deep canal, make several of these bunches, and place them one on top of another that is at the edge of the frame.*
4		*Cover the water bridge with plastic paper (or clay soil)* 	*Take a good sized plastic paper without holes and place it within the hole which has been created by the placement of the grass bunch, and it should overlap these bunches across the whole width of the water bridge. Make sure that when connecting the paper (plastic), the one connected should be below the finished one, to the direction of the flow.*

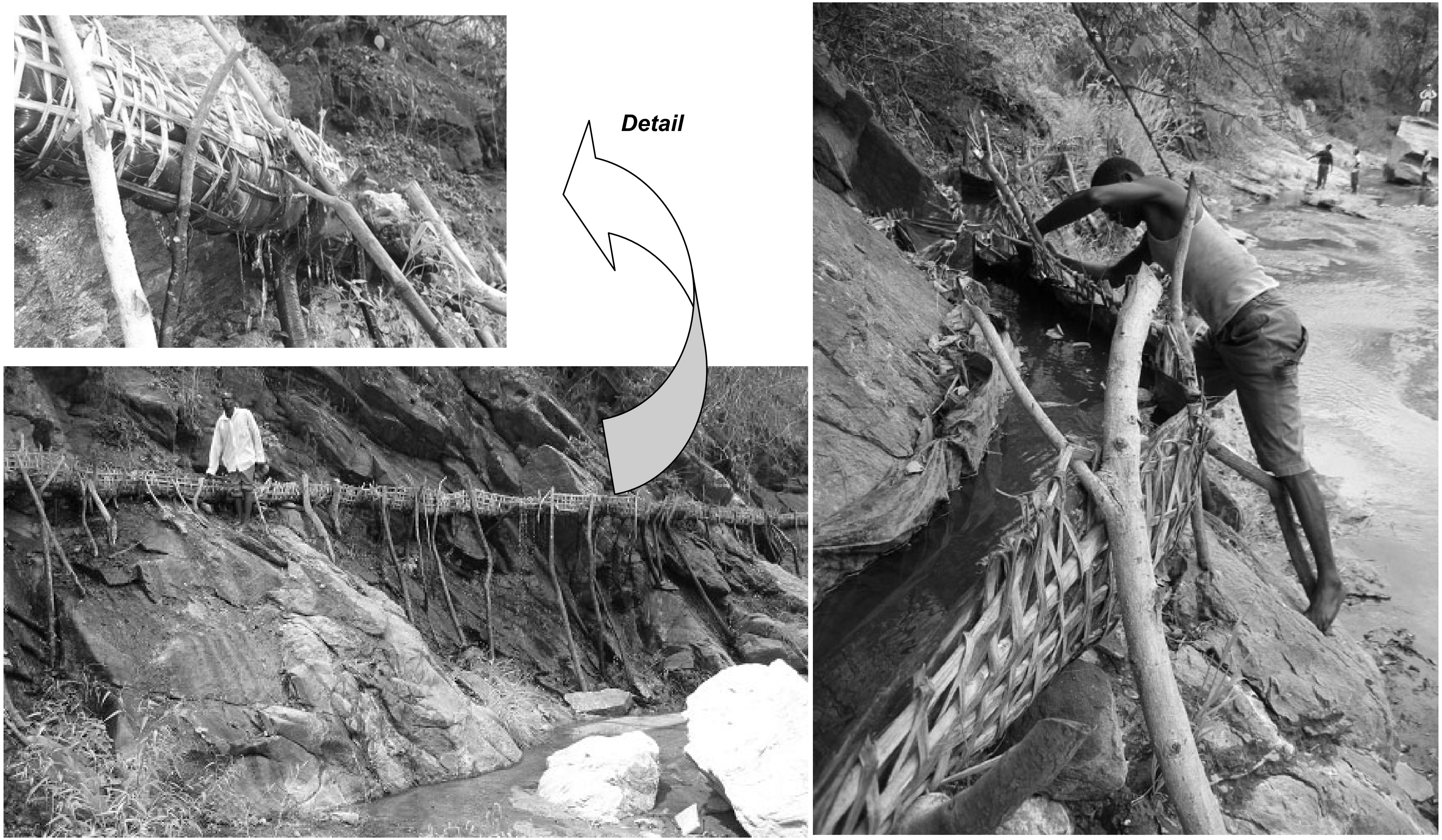
The Exterior of Canal Bridge

Construction of Canal Bridge (Section 2; Running on a Cliff)

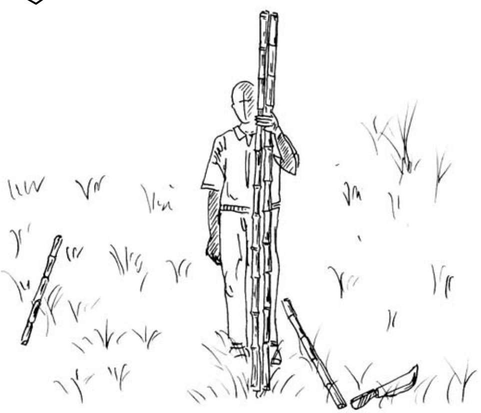
Step	***Process***	***Description***	***Remarks***
1		*Weaving of bamboo strips into a rectangular mat to make a canal bridge.*	*Take good thin strips of bamboo which has been cut by the panga and weave them, as is done when weaving the traditional basket. Depending on the availability of bamboo, it can be closely packed like a basket (dengu) or thin space can be left out. In the process of making the mat, it should be twisted so that a hollow formation, which should be rectangular like in shape, is formed.*
2		*Take a good size plastic paper and put it inside.*	*Take a good plastic without holes in it, and wrap around and inside the weaved structure. Since the structure is rectangular in shape, make sure the paper inside is well placed at the edge of this structure. On the outer edge, use sisal or good strings to tie it together with this structure.*

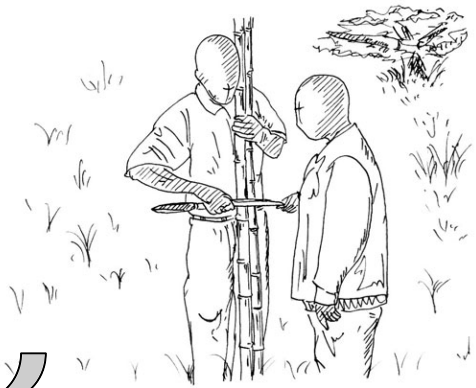
Step	***Process***	***Description***	***Remarks***
3		*Fixing of the canal bridge on the cliff.*	*Fix the weaved bridge on the cliff by putting it on its required position. Put supporting structures below it, e.g a two-branched tree log as seen on the picture. Also, one side of the two-branched tree can be inserted in one of the edge holes so that the weaved bridge can be well suspended. After properly fixing it, plastic paper should be put in order. Follow the same procedure as in step 2 which is explained above for the fixing of the plastic paper.*
4		*Visual outlook of the weaved canal bridge running on the cliff.*	*If the place where the canal bridge is to cross is very long and straight, a canal bridge made from weaving can be made as one structure. But in case where the place is very twisted,, the bridge can be made in pieces and then connected when fixing it in its position.*

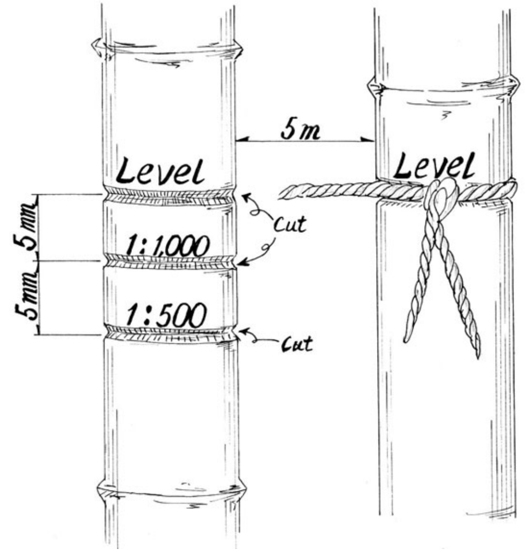
The Exterior of Canal Bridge



7. Canal Alignment using Line-level (Section 1; Assemble Line-level)

Step	***Process***	***Description***	***Remarks***
1		***<u>Adjust the Sticks;</u>*** *Two (2) poles are cut with the same length.*	*Local materials such as bamboo/wooden poles are used. The lengths of sticks are adjusted to the height of stick holders. Usually, the sticks are about 1.7m to 2.0m in height. The poles should have a sizable diameter so that they are easy to hold, bigger poles with bigger diameters would be difficult to hold when in use.*
		*<u>Refer to the Illustrations</u>* 	*In this site, we can see bamboos as local material so that farmers selected these materials and besides the poles are durable.*

Step	Process	Description	Remarks
2		***Make Grove on the Sticks (to know level or slope on field);*** *To know level point or sloping point on field and tie up the string tightly, the circular groves are made on the sticks.*	*The position of the strings is decided according to the height of a person who is going to read the spirit level (level reader). Usually, the height of cut is marked with 1.0m to 1.3m of height from bottom of the sticks. To get the level point on field, the groves (cut) are marked on each pole with same height. On the other hand, these cuts are put on a different height to know the sloping point of canal and/or field. The table (on the next page) shows an example about the position of making grove on each stick.*
		*Refer to the Illustrations* 	*Panga is very useful. Farmers use this to cut the bamboo on step No.1 and to make the cuts on step No.2.* *If a panga is not available, a knife could also be used for making a grove on the pole.*

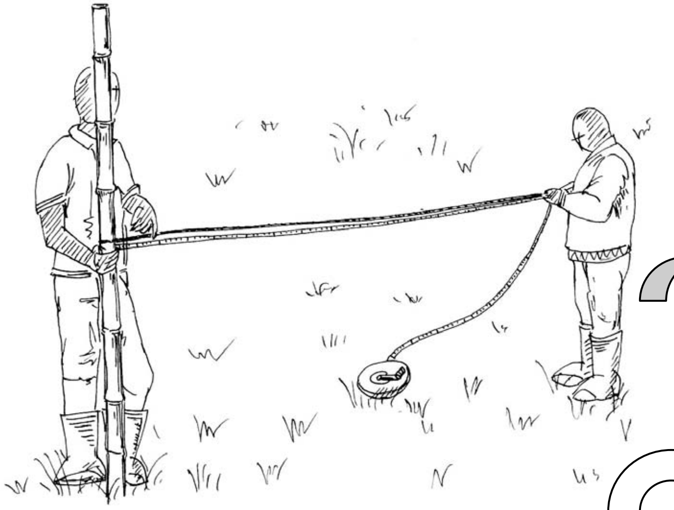
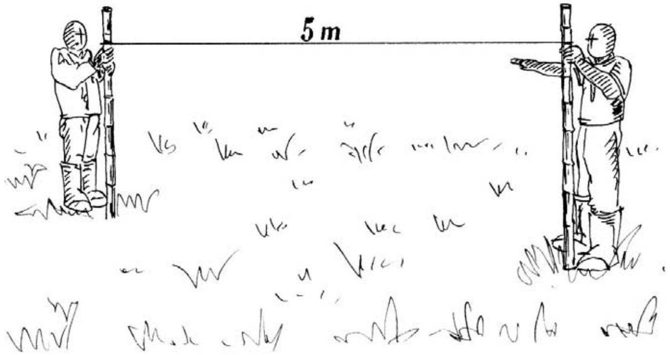
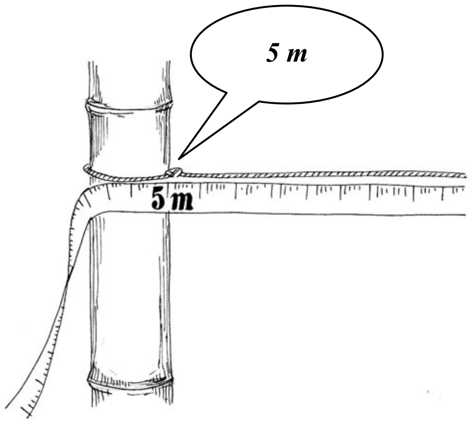
Step	*Process*	*Description*	*Remarks*
2		*Making Groves on the Stick;*	*One needs to know the slope of field/canal, so that these groves are made on the stick with different height. The illustration shown at the left shows the cuts which are made at different height to know the slope of field/canal. The pole showing at the right side has a cut fixed at 1.3m from bottom of the pole. On the other hand, the pole standing at the left hand side has three (3) groves. These groves indicate the level line, 1/500 of slope and 1/100 of slope respectively.*

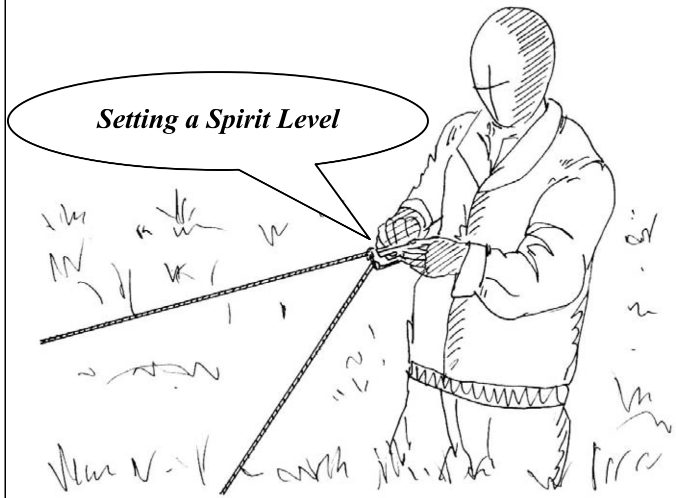
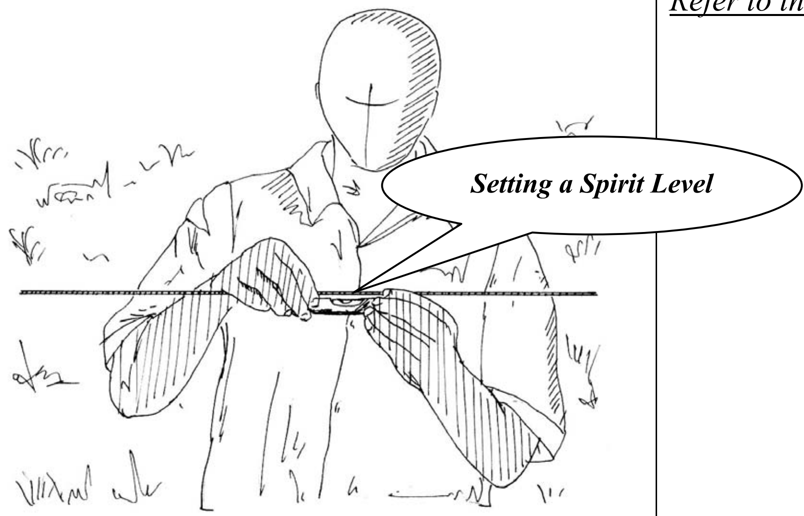
A slope of canal/field to be known	*The position of groves (=tying level of string) on the sticks (In case of 5m strings used)*		*Difference of positioning cuts to be marked between the sticks*
	Stick-(A) (e.g. 1.3m fixed)	*Stick-(B)*	
1/1,000	*1.3 m*	*1.2950 m*	*5.0 mm*
1/500	*1.3 m*	*1.2900 m*	*10.0 mm*
1/400	*1.3 m*	*1.2875 m*	*12.5 mm*
1/300	*1.3 m*	*1.2833 m*	*16.7 mm*
1/250	*1.3 m*	*1.2800 m*	*20.0 mm*
1/200	*1.3 m*	*1.2750 m*	*25.0 mm*
1/100	*1.3 m*	*1.2500 m*	*50.0 mm*

The illustration indicated at the upper left shows that a string is tied at 10mm below from level position to get 1/500 of slope with 5m of string spun.

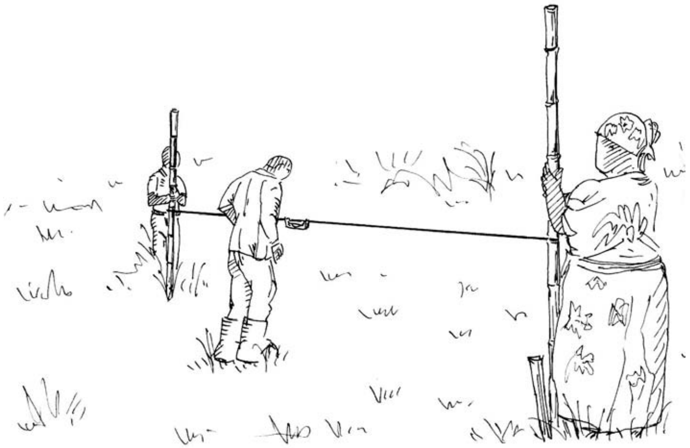
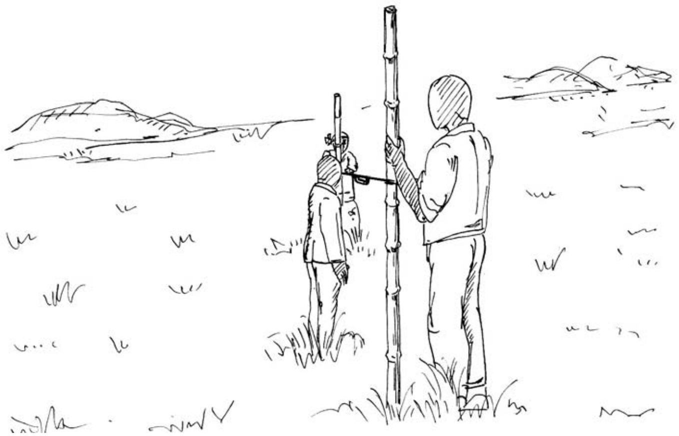
The table shown on the left gives an example for the position of groves (tying string) to know the slope of field/canal.

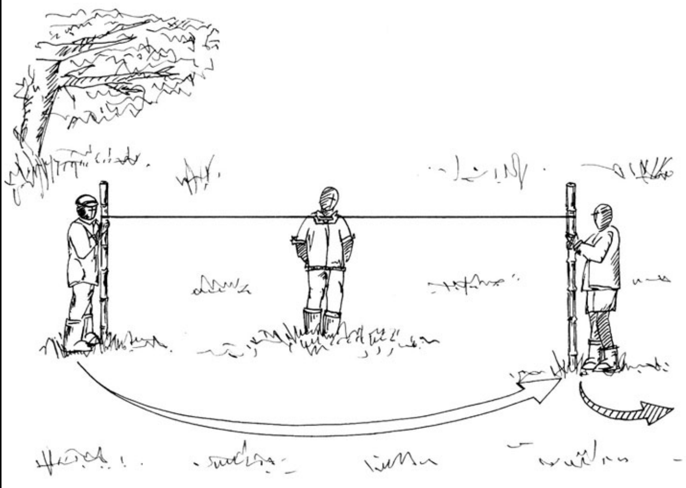
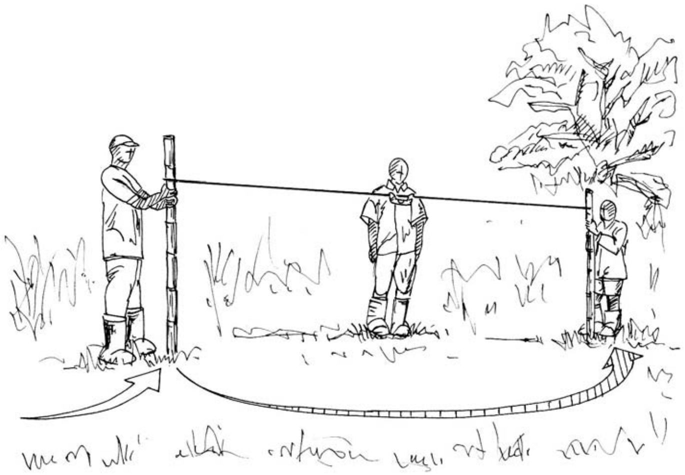
On a gentle topography, 1/1,000 is recommended while on a relatively steep slope, 1/500 or steeper slope is recommended.

Step	Process	Description	Remarks
3		***Fix the String;*** *Tie the string on a grove marked on step No.2.* 	*The length of string is adjusted to the site condition. With no big obstructions at the site for survey, long length of string, say 10m, might be adopted. Usually, 5m length of string is ideal in the site.*
		*Refer to the Illustrations* *Testing the line-level.* 	*Usually, the length of string is set on 5 m length.*

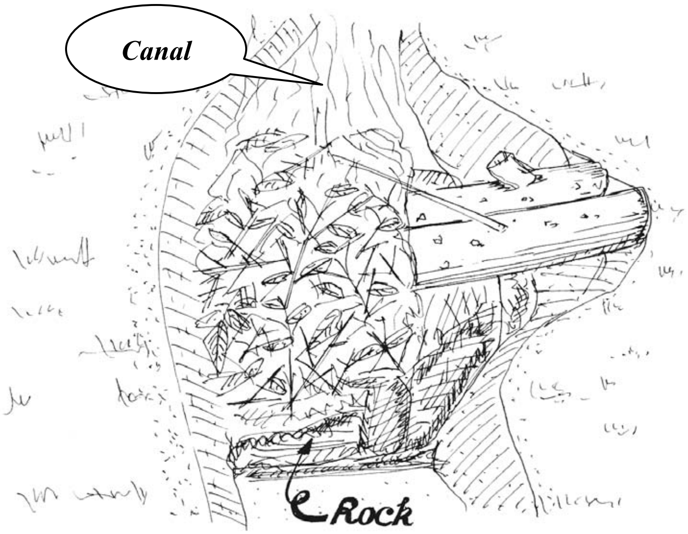
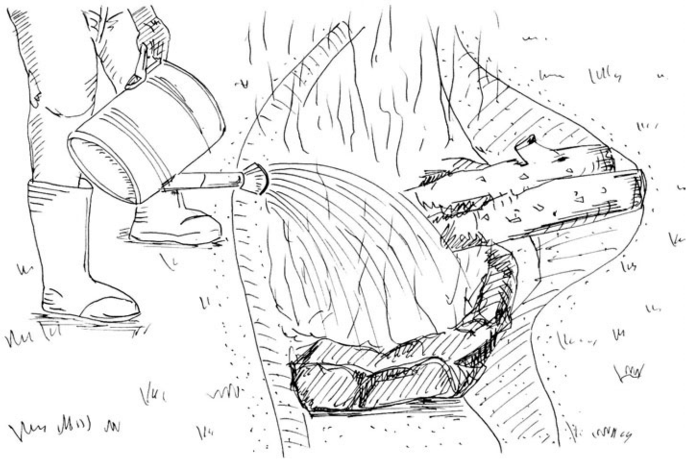
Step	Process	Description	Remarks
4		***Set a Spirit Level (completion of assembling the line-level);*** *Set a spirit level on the string.* *After the required spun between the poles is set, the spirit level is set or put on the string.*	*A spirit level is set on the string. The position where the spirit level is fixed is the center of string, e.g. 2.5m point with 5m of string.*
		*Refer to the Illustration*	

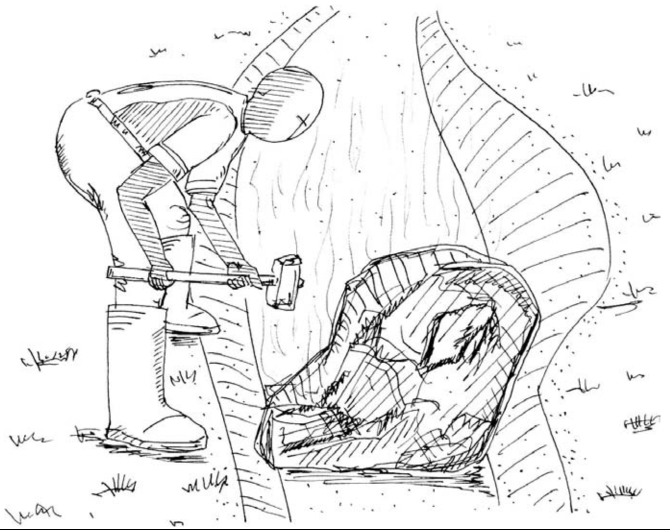
Canal Alignment using Line-level (Section 2; Canal Alignment)

Step	**Process**	**Description**	**Remarks**
0		*The line-level can be used to know level points or sloping point on the field. To survey that, three persons are needed at least, namely two (2) pole holders and a level reader.*	*According to the kind of survey, namely surveying the level point or sloping point, operation of the line level is different. To align canal which has suitable slope, surveying sloping point is required.* *The operations of the line which can know the sloping point is indicated from next page.*
		*<u>Refer to the Illustration</u>*	

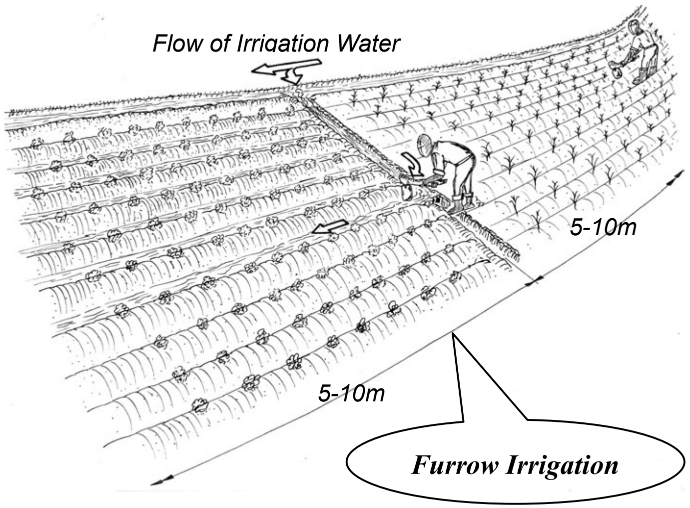
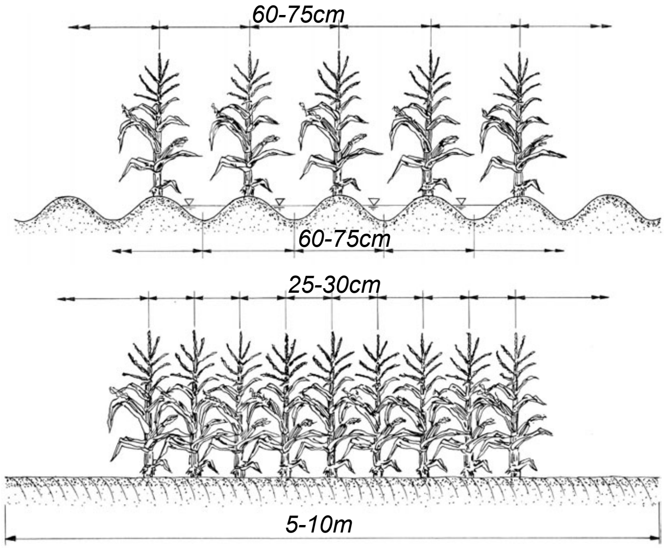
Step	*Process*	*Description*	*Remarks*
1		***Surveying sloping point on the field;*** *The persons who are holding the sticks and a level reader is the minimum number required, to survey sloping point by using line-level.* *The stick holders stand should stand at intervals of 5 meters. At this time, a stick holder who has the stick that has a string which is tied at a lower position than the other stick, should stand at a higher position (He/she stands on the left side as shown in the illustration).*	*The other one who has the stick that has a string which is tied at fixed position, should stand at a lower place to know the slope of field.* *A level reader checks whether the bubble in the spirit level is at center or not.* *One of the stick holders who stands at lower position will move to the point where the bubble in the spirit level is read at the center.*
2		*Refer to the Illustration* *Moving to the next level point.*	*After the sloping point is made sure, the stick holders will forward to the next point respectively at the same time. One of the stick holders who stands at higher point will move the point where the other one has stood.* *After this, the same procedure is repeated until the required distance is achieved.* *The points where the pole holders stand act as bench marks where the pegs have to be driven.* *Upon completion of leveling smoothing of some pegs is done to ensure a smooth canal alignment.*

8. Rock Breaking

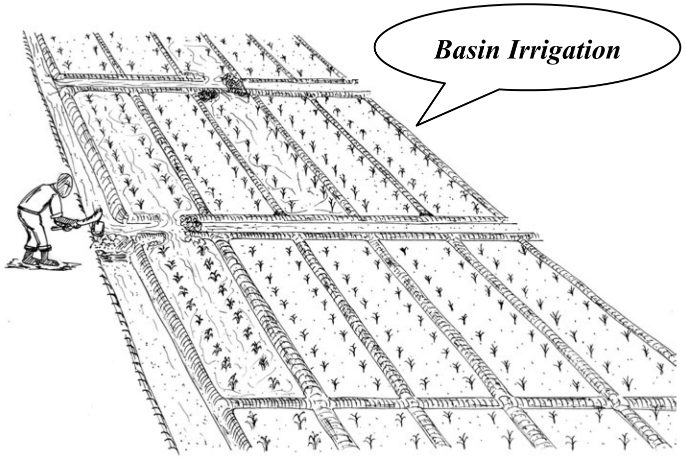
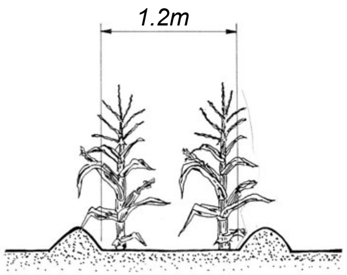
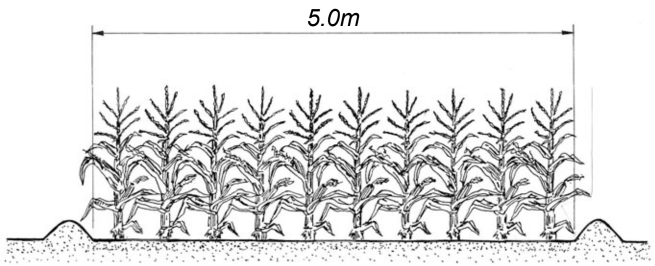
Step	Process	Description	Remarks
1		**Burn the Rock;** The rock is burnt. When there are rocks in the canal that become an obstruction for construction of canal, the rocks have t be burnt. 	This works on the principle of expansion and contraction. When the rock is heated, it expands. So the whole purpose of heating is to make all the rock minerals forming a rock to expand.
2		**Cool the Rock;** Sprinkle cold water on the rock. 	Water is poured on the heated rock very fast. This makes the rock to contract. The rock minerals making the rock starts to contract at different rates thus in the process cracking the rock.

Step	***Process***	***Description***	***Remarks***
3		***<u>Crush the Rock;</u>*** *The rock is crushed upon hammering.* 	*After cooling the rock by watering, the rock is easy to break because of the cracks which have just been created by heating and cooling due to the different expansion and cooling rates of minerals with the rock.*
		*<u>Refer to the photo</u>* *A farmer breaking the rock. The photo on the left had side shows a canal with a rock which has been removed.*	*As already explained, it is easier to break the rock after exposing the rock to the heating and cooling process. As you can see from the illustrations, the farmers were now able to break the rock which they had earlier failed to break before it had undergone this process.*

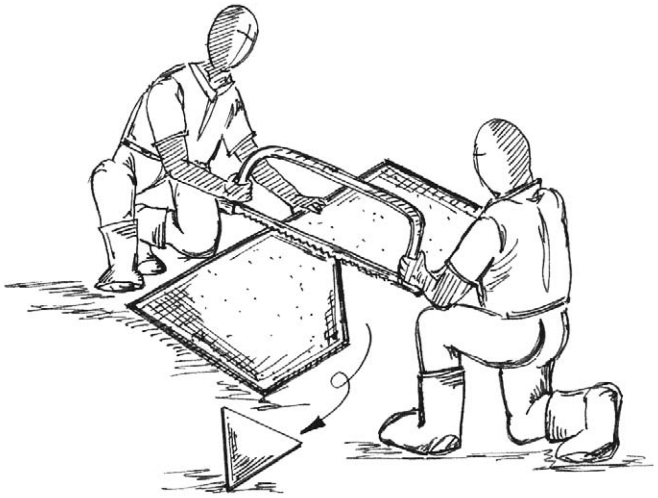
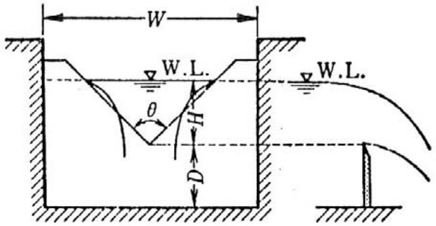
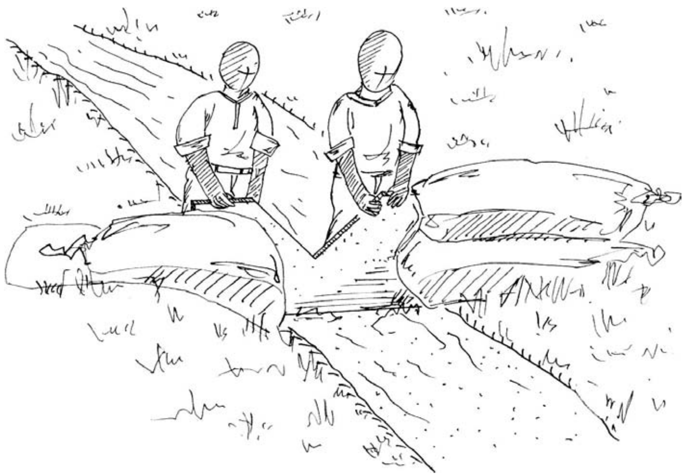
9. On-farm Irrigation Method (Section 1; Furrow Irrigation)

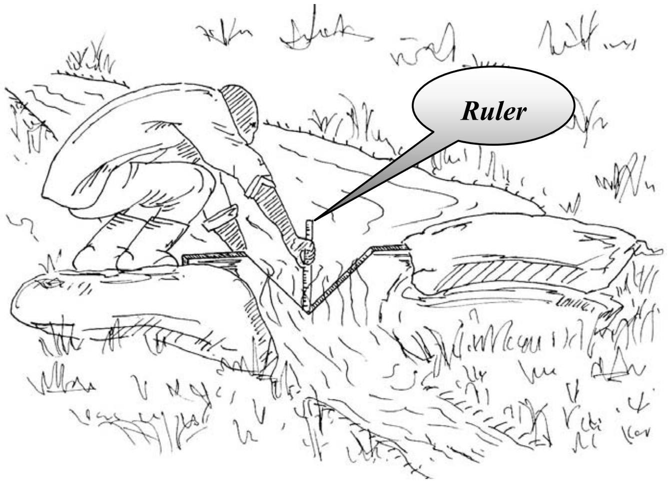
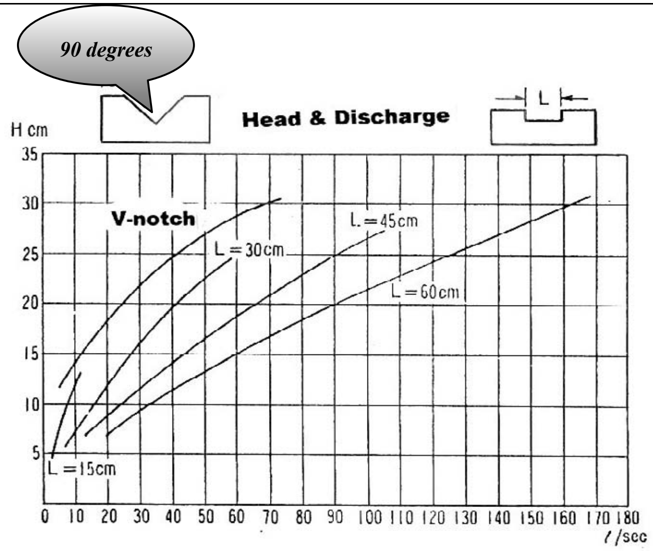
Step	*Process*	*Description*	*Remarks*
1		***Making the ridges and furrows;*** *Furrows are generally used on farms having large uniform fields where long furrows can be formed. This irrigation method is not appropriate for the place where farmers' plots are irregular in shape.*	*Under furrow irrigation water is taken to the plant through long, narrow channels (furrows) formed in the soil at regular intervals, between the crop rows (ridges). The length of the furrow is normally 5 - 10 m but depends on the type of soil and the land slope.*
2		*Refer to the Illustrations* *Water is gradually absorbed into the bottom and sides of the long furrow wetting the soil. Crops are usually grown on top of or half way down the ridges between furrows.*	*It is important to use the right shape of furrow, furrow spacing and length. And, good water management is important for the method to work well. The interval of ridge is usually 60 – 75 cm. And also, cops are planted at intervals of 25 –30 cm on top of or half way down the ridges.*

On-farm Irrigation Method (Section 2; Basin Irrigation)

Step	***Process***	***Description***	***Remarks***
1		***<u>Making the Sunken Bed;</u>*** *A basin is a leveled area of fields, surrounded by earth embankments, which is totally flooded during irrigation. Basin irrigation is suitable for many crops.*	*In sunken beds the crops grow on the flat surface, which is surrounded by a small earth embankment and are kept wet for a long time when the bed is irrigated. The advantages are (a) the amount of water can be given with a minimum amount of labor if beds are well leveled, (b) water losses can be kept low by minimum run-off, and (c) basins last for a long time once they are constructed.*
2	 	*<u>Refer to the Illustrations</u>* *Basin irrigation needs a good water supply to fill the basin quickly. This in turn requires accurate land leveling and proper land size.*	*The width and length of the sunken bed is normally 1.2m and 5.0m respectively but depends on the type of crops.*

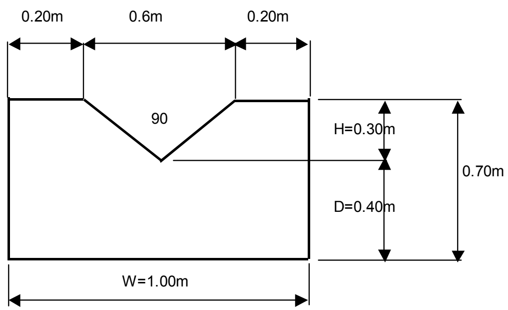
10. Discharge measurement (Section 1; V-notch Method)

Step	***Process***	***Description***	***Remarks***
1		***<u>Making the V-notch;</u>*** *Generally, the v-notch is made of wooden board at an angle of 90 degrees.* 	*If the amount of stream flow is small such as up to 100 lit/sec, v-notch is available to measure the discharge. The application of v-notch is as following (refer to the figure showing the left):* ・ *0.5m<=W<=1.2m* ・ *0.1m<=D<=0.75m* ・ *0.07m<=H<=0.26m* ・ *H<=W/3*
2		***<u>Set V-notch up;</u>*** *The v-notch is set up at suitable site near the place where is planed to be construct the diversion weir.*	*The v-notch must stand perpendicularly to the stream flow. To stabilize the v-notch, sand bags can be used.*

Step	Process	Description	Remarks
3		***Measure the depth of nappe;*** *The stream flow starts overflow.*	*After setting of the v-notch, the stream flow starts overflow through the v-notch. The v-notch will be left as it is. When the nappe will become stable, the depth of nappe will be measured.*
4		***Read the Graph or use Tables;*** *The amount of stream flow can be known by the graph shown on the left side, or refer to the tables on the following table.*	*After measurement of the depth of nappe, the depth is checked against the graph to know the volume of flow. The graph shows the relationship between the depth of nappe and discharge. Or otherwise refer to the table on the following page.* *An exercise in case of V-notch;* *The depth of nappe: 25cm* *The amount of flow: 40 lit/sec*

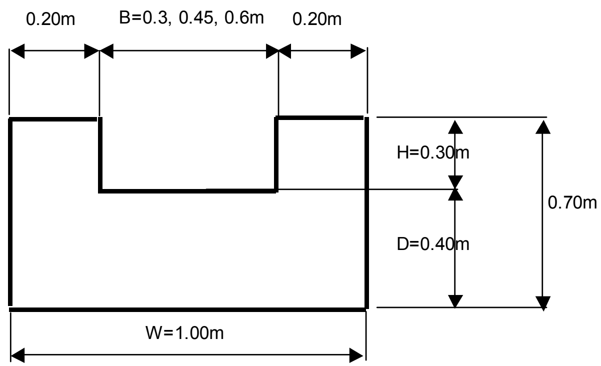
Step	*Table of Discharge against Ovewflow Depth*
4	***In case of V-notch:***

Over flow depth on V-notch	Discharge	
h (m)	Q (m^3/min)	Q (lit/sec)
0.07	0.11	1.83
0.10	0.26	4.41
0.12	0.42	6.92
0.14	0.61	10.14
0.16	0.85	14.14
0.18	1.14	18.96
0.20	1.48	24.67
0.22	1.88	31.31
0.24	2.34	38.95
0.26	2.86	47.63

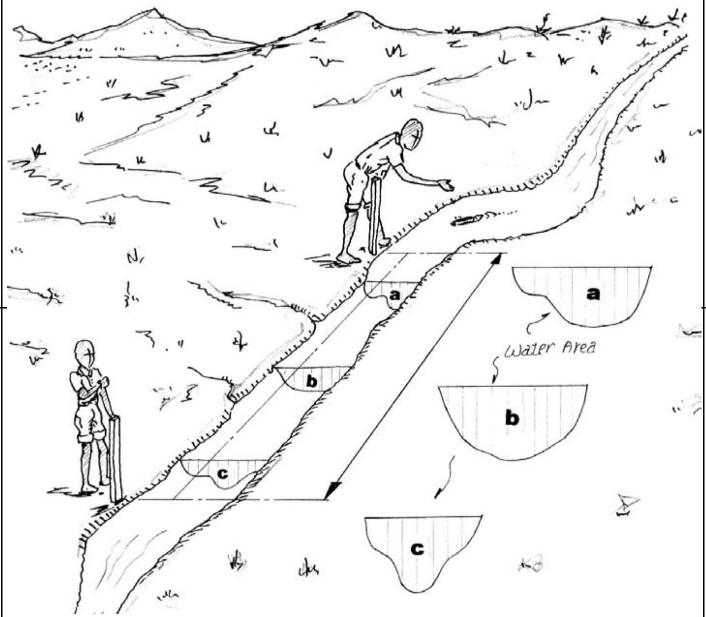


4	***In case of rectangular notch:***

Over flow depth on R-notch h (m)	Discharge		
	B=30cm	B=45cm	B=60cm
	Q (lit/sec)	Q (lit/sec)	Q (lit/sec)
0.10	16.59	25.17	34.00
0.12	21.88	32.93	44.54
0.14	27.72	41.36	56.02
0.16	34.08	50.43	68.37
0.18	40.96	60.09	81.56
0.20	48.35	70.32	95.54
0.22	56.23	81.11	110.29
0.24	64.62	92.43	125.80
0.26	73.51	104.27	142.03
0.28	82.90	116.62	158.98

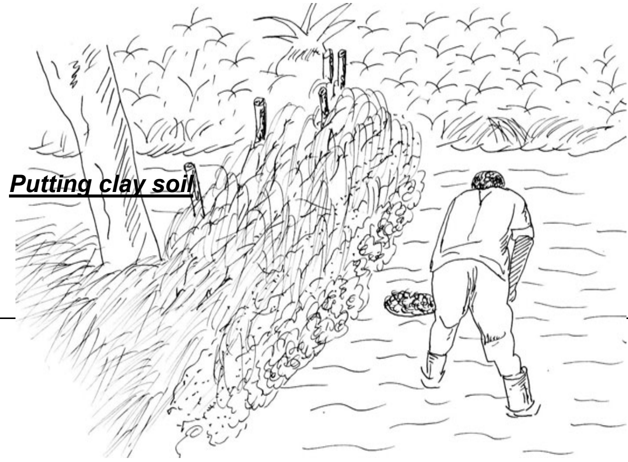
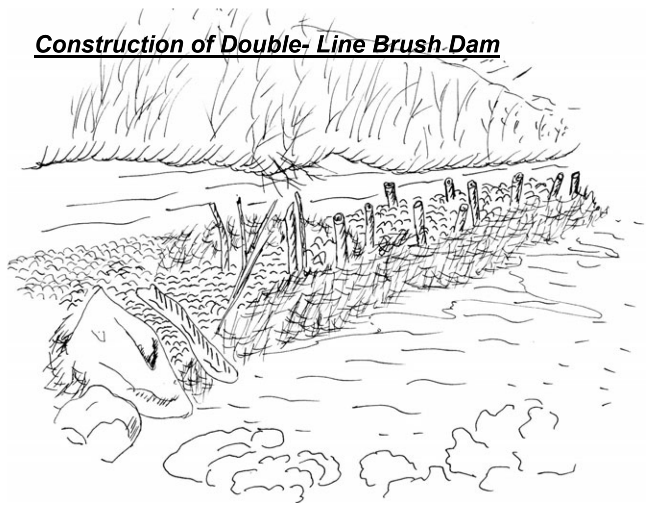


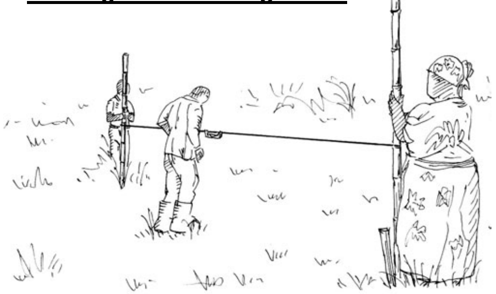
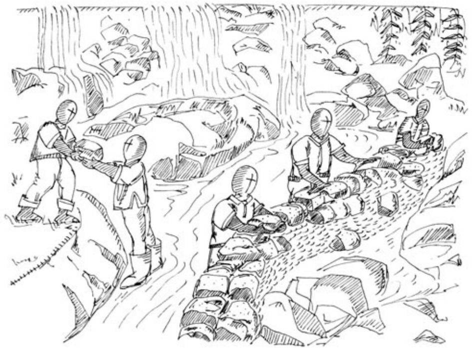
Discharge Measurement (Section 2; Float Method)

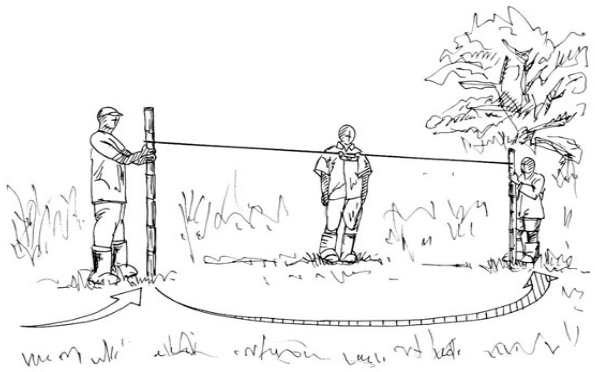
Step	***Process***	***Description***	***Remarks***
1		***<u>Measurement of the Water Area;</u>*** *The float method is available to know a rough estimate of the stream flow. The amount of flow (Q) can be estimated by measuring the size of the stream (A=water area) and the speed (V=velocity) of the water (Q=A*V).*	*The water area f the stream (width multiplied by depth) has to be measured. It is better to select a clean and straight section on the stream, at least 5 – 10m long. Measure the depth at one cross-section for at least 3 points (e.g. at 1/4, 1/2, and 3/4 of total width) and calculate the average depth. Then, after the water area for each cross-section is calculated, the average water area for all cross-sections is calculated.*
2		***<u>Measurement of the velocity;</u>*** *A float (e.g. a piece of wood) is thrown into the water to measure the velocity. Measure the time taken by the float to move between the upstream cross-section point to downstream one. Repeat this measurement at least three times, and calculate the average velocity.*	*The measured velocity at the surface is larger than the velocity along the bottom and sides, therefore, the measured velocity at the surface needs to be corrected as follows:* *-When the water depth<30cm, Velocity=average velocity times 0.7* *-When the water depth>30cm, Velocity=average velocity times 0.85* *Finally, multiply the average water area by the corrected average velocity (A*V). This is the amount of flow (Q=A*V).*

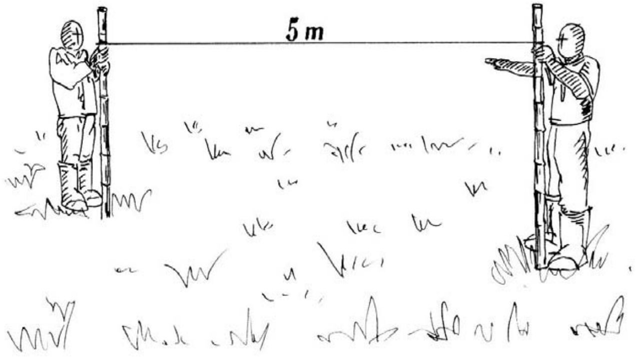
11. Problems and Measures on Construction of Irrigation Facilities

<table>
<tr><th>Problem</th><th colspan="2">Measures</th></tr>
<tr><td colspan="3">During construction, you may face some problems. Following are examples of probable problems and measures taken:

1. Water Leakage from Brush Dam
2. Water Leakage from Canal
3. Water Leakage from around the Brush Dam
4. Dug canal deep
5. Stagnate canal water in the field
6. Difficulty of doing line leveling due to specific topographic condition
7. No good clay, for sealing brush dam, is found

</td></tr>
<tr><td>1. Water Leakage from Brush Dam</td><td>1. Putting clay soil in front of dam (upstream side). Putting clay is useful way to prevent leakage.
2. In cases, plastic paper may be put in front of the dam, and mat woven by reed with clay soil placed thereon can also be tried.
3. As a trial for reduction of water leakage, sand bags on the hole and bottom of stream were put at a site in Kasungu district, however, this was ineffective, because the water leakage came out through the gaps of the sandbags.
3. A double line dam was then made as a counter measure for leakage, and it worked.
4. Dig the canal deeper to reduce the water pressure for brush dam. To reduce the leakage, digging canal some more may be useful according to circumstances. On the other hand, however, the surface point becomes far.</td><td>
</td></tr>
</table>

Problem	Measures	
2. Water Leakage from Canal	*1. Shifting the alignment and/or putting clay on the canal wall. On the canal alignment, passing nearby shrub/banana tree etc. should be avoided. There is possibility the roots zone will cause the leakage. And also, filling canal is difficult to prevent seepage so that alignment of canal having filling portion should be avoided.* *2. Very good clay soil is used as mortar to bind the rocks thus making it water tight.* *3. Farmers use plastic papers to reduce the water leakage from canal. Those plastics are obtained by contribution of each farmers. Some of farmers use the plastic paper as the cover for tobacco shade. Thus, it can easily be concluded that plastics for irrigation facilities is not problem.* *4. In case of a site in Lilongwe district, the canal bridge was repaired by using tree barks on farmer's own idea. Farmers have their own experiences and ideas in their life. Thus there is possibility that farmers will get their own way for construction of the irrigation facilities with just receiving the advices and suggestions from by field officers.*	***Shifting the canal alignment***  ***Putting clay soil to the canal***  ***Using the plastic paper*** 

Problem	***Measures***	
3. Water Leakage from around the Brush Dam	1. *Putting clay into the trench to be dug around the dam can be considered as one of measure.* 2. *In case of a site that has the problem, the nature of the soil is usually very porous. This shows necessity to check the soil condition not only dam site included along the canal but also whole of the area. And also, sounding farmers out should be more detail about the condition of soil around the dam.*	
4. Dug canal deep *5. Stagnate canal water in field*	1. *Canal alignment was inappropriate. Then, re-alignment was done by using the line-level. The line-level is useful not only for the leveling on field but also the surveying of canal alignment.*	***<u>Re-alignment by using the line-level</u>*** 

Problem	*Measures*	
6. There are some places in the field that are difficult to measure the level by line-level such as depressions, gully crossing, ridges existing on farm etc.	*1. If there are bank portion like ridge, to dig up to the point required these places is possible to measure the level point. And also, as one of alternatives, tying position of string can be shifted up to getting level.* *2. If there are depressions or gully crossing, to extend the string is also possible. However, too long string makes judging level difficult due to the difficulty in keeping tension of string.* *3. It seems that the limitation of string length to keep tension when the survey is carried out can be said to be 5m.* *4. And also, from the view of saving time for survey, 5m of length is better than the shorter one.*	***5m of length is appropriate***  ***Good clay is essential, however if not available plastic paler can be used***
7. For construction of diversion weir, supplement of good clay is important thing to prevent the water leakage, although sometimes good clay is not found.	*1. Farmers may buy the plastic paper instead of using clay or construct the permanent structure when they gain benefits from irrigation in future.*