No.

The Republic of Malawi

Ministry of Irrigation and Water Development
Ministry of Agriculture and Food Security

THE STUDY ON THE CAPACITY DEVELOPMENT OF SMALLHOLDER FARMERS FOR THE MANAGEMENT OF SELF-HELP IRRIGATION SCHEMES (MEDIUM-SCALE) IN THE REPUBLIC OF MALAWI

FINAL REPORT

ANNEX 2

Technical Manuals

August 2009

JAPAN INTERNATIONAL COOPERATION AGENCY
SANYU CONSULTANTS INC.

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Technical Manuals (Final Report)

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1-1 River Diversion Weir System

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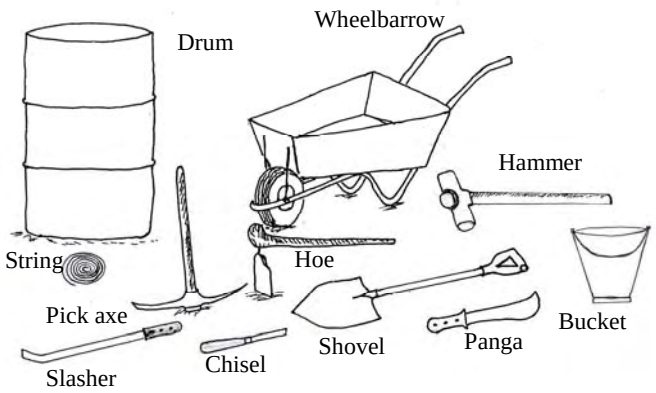
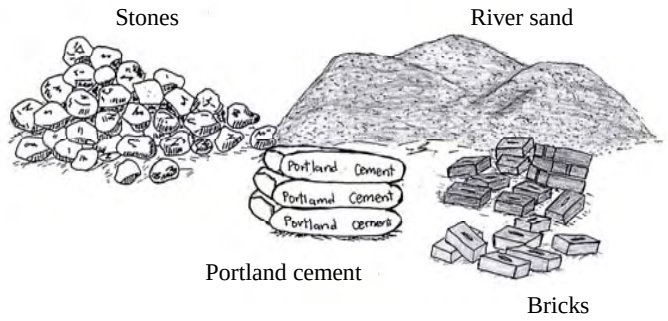
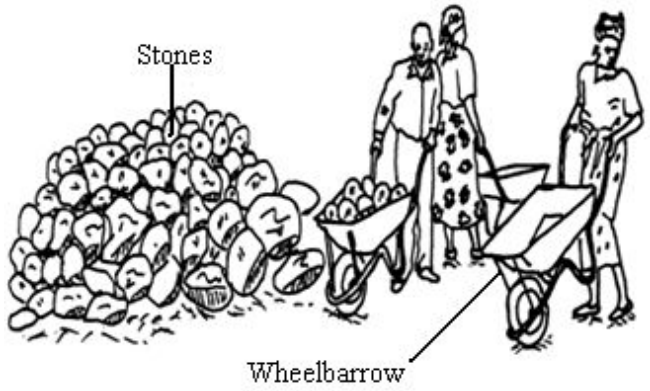
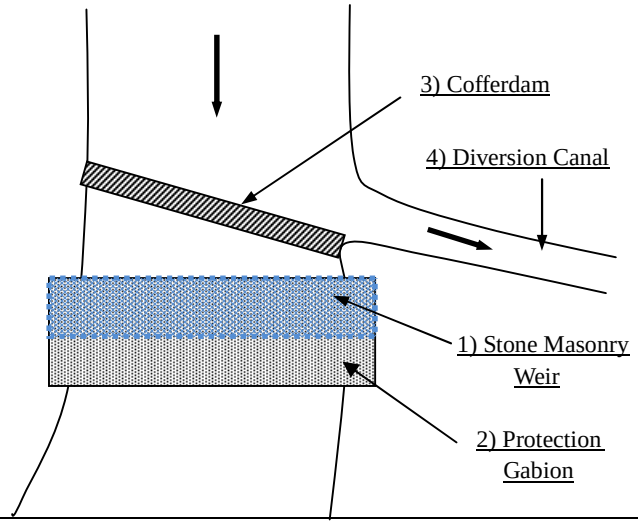
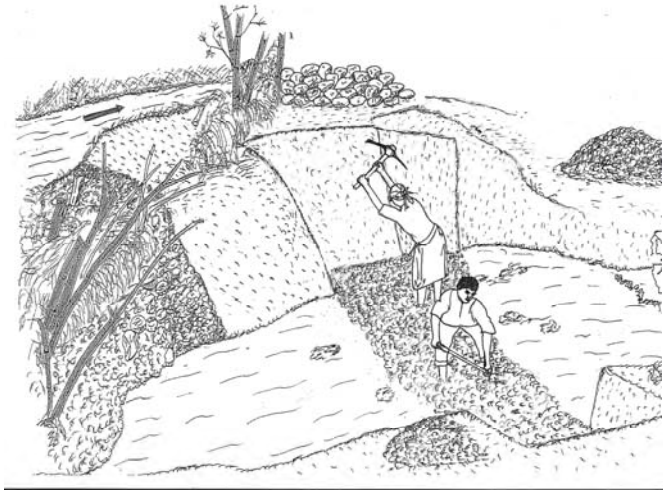
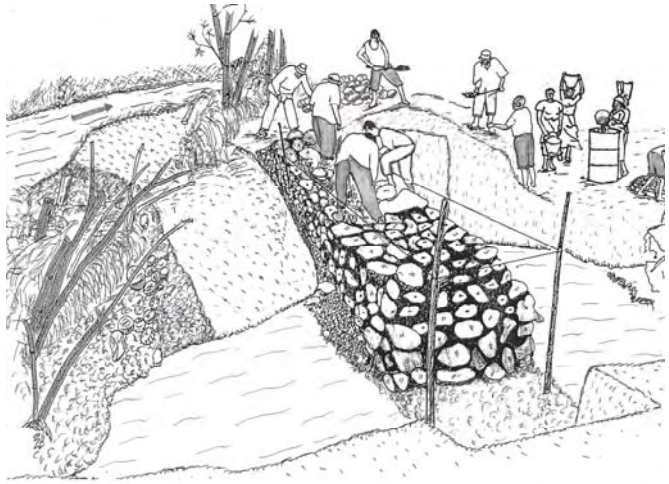
Step	***Process***	***Description***	***Remarks***
1a		***Tools Required*** *Wheelbarrows, hoes, shovels, panga knives, pickaxes, strings, chisels, slashers, hammers, drum, buckets.*	
1b		***Materials Required*** *Portland cement, stones, river sand, bricks.*	

Step	***Process***	***Description***	***Remarks***
2		***<u>Resource Mobilisation (Stones)</u>*** *1. Site identification for stones.* *2. Gather 10 to 30 cm stones using wheel barrows at quarry site and from the field.* *3. Transport and heap the stones to the construction site using oxcart, tractor trailer or truck.*	- *Site should be as close to the construction site as possible (to minimize transportation costs).* - *Large stones should be broken down into suitable size by hammers and chisels (for easy transportation).* - *Stones should be hard rock.* - *Stones in the riverbed should not be used.*
3		***<u>Resource Mobilisation (Sand)</u>*** *1. Site Identification for sand.* *2. Gather the river sand at the identified pit.* *3. Transfer the sand to the construction site using oxcart, tractor trailer or truck.* *4. Before use, allow the sand to dry naturally at the project site.*	- *Site should be as close to the construction site as possible (to minimize transportation costs).* - *Sand should be clean from; debris, salts or other organic foreign matter.*

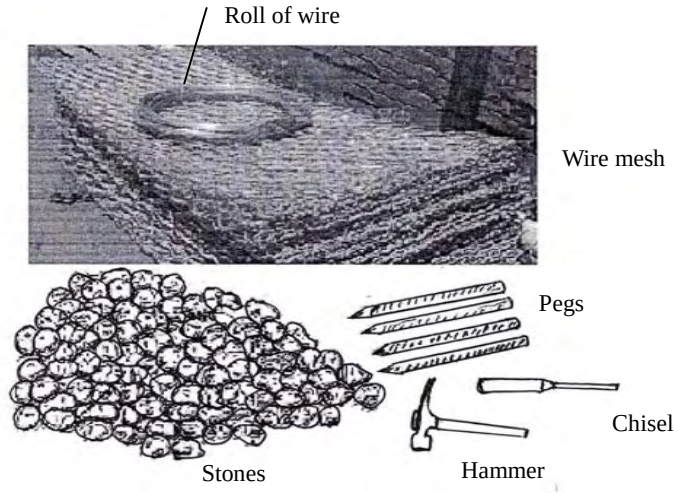
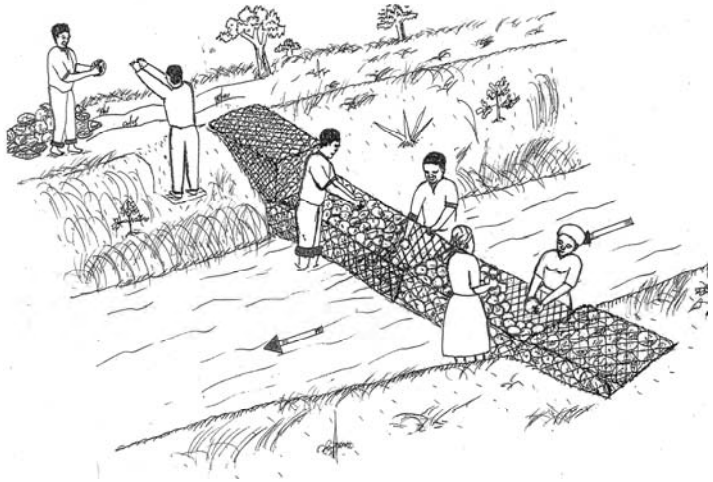
Step	***Process***	***Description***	***Remarks***
4		***System Lay-out*** 1. *Stone masonry weir* 2. *Protection gabion (See 1-1-4)* 3. *Cofferdam (See **Section 1-1-3**)* 4. *Diversion canal*	- *Cofferdam diverts water away from the working area.*
5		***Excavation for Weir*** *1. The foundation is excavated to bedrock at least 50 cm depth from riverbed.* *2. Abutment is excavated 1m horizontal direction into river bank.* *3. The line of upstream end, downstream end and abutment should be indicated with pegs and strings.*	- *If soft or unsuitable soil is found at the excavated depth, additional excavation should be carried out.* ***Precaution(>1.5m excavation)*** - *Maximum safety against land sliding should be ensured when excavating an abutment.*

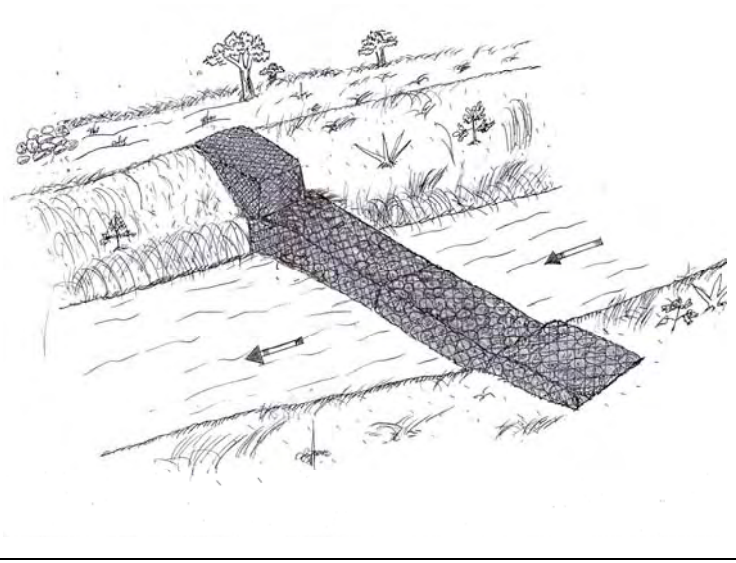
Step	***Process***	***Description***	***Remarks***
6		***De-watering*** *1. During the construction of the base, ensure that foundations are dry by dewatering using buckets.*	- *If there is a lot of ground water, dewatering should be carried out continuously with buckets. Drain ditch and drain pit are required to be arranged.* - *Drainage pumps or treadle pumps may be used when buckets are not sufficient.*
7		***Mortar Mixing Place Preparation*** *1. Excavate a curved surface on a flat place (1.7m diameter).* *2. Compact the surface with rammers or stones.* *3. Lay bricks around the curved surface.* *4. Place mortar in spaces between the bricks.*	- *The mixing place should be as close to the construction place.* - *Compaction seals off all voids.* - *The Place can also be used for future rehabilitation.*
		Water for Mortar *1. Prepare drum(s) of water for mortar at the site on the day of construction.* *2. Water should be clean water.*	- *Number of drums depends on the pace and amount of work to be done.*

Step	***Process***	***Description***	***Remarks***
8		***Stages of Mortar Mixing*** *1. Standard mixing proportion of cement: sand is;* ***1:3*** *2. Measure one 50kg bag of Cement and three wheelbarrows of sand.*	- *If the sand is dry, 20 litre of water is poured and mixed first. Then additional water is sprayed and mixed to the proper consistency.* - *1 bag of cement will be used with sand at the standard mortar mixing place at the same time.*
9		***Weir Construction*** *1. Make sure that the closed one half of the river is dry, if not keep on dewatering.* *2. Wash stones before used for construction.* *3. Line the stones with the flat surface facing outside the structure (use a builders' level when constructing).* *4. Mortar is pushed into the interstices and spaces between the stones.* *5. Stones are placed layer by layer.*	- *Washing removes all debris thereby increasing the bond strength.* - *Voids should be filled with mortar completely so that leakage may not happen and strength is secured.*

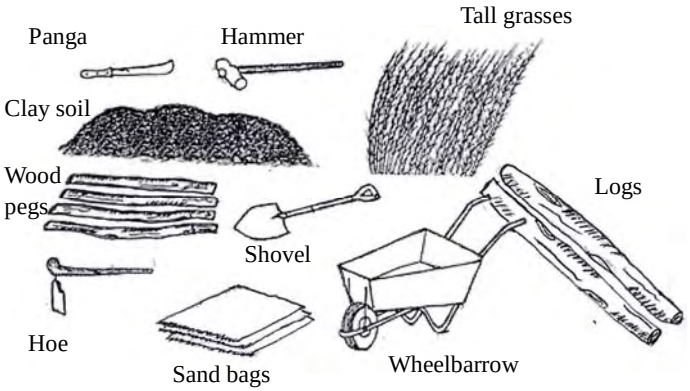
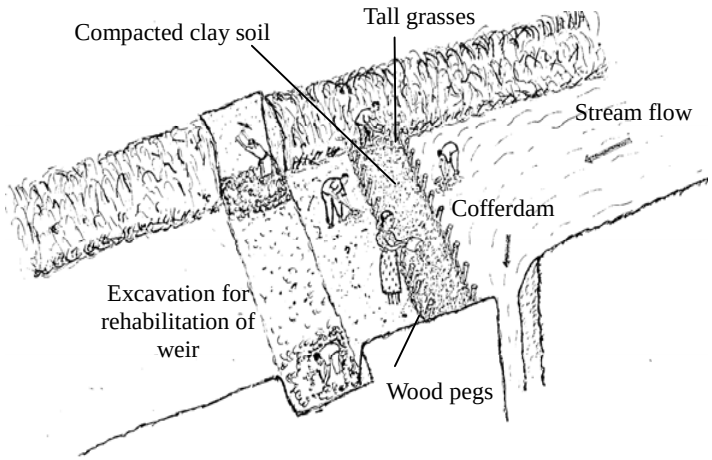
Step	***Process***	***Description***	***Remarks***
10		***<u>Finishing and Curing</u>*** *1. The face surface of stone needs to be left exposed.* *2. The surface of stone masonry needs to be finished neatly and smoothly.* *3. After completion of stone masonry, it needs to be covered with grasses or straw mats for curing mortar.*	

1-1-2 Gabion Weir Rehabilitation

Step	***Process***	***Description***	***Remark***
1		***<u>Tools and Materials Required</u>*** *10-15cm stones* *Chisels / hammers* *Wire mesh (mesh size: 80mm – 100mm)* *Roll of wire for binding (D=2.2mm, zinc coated)* *Pegs (length: 1.0 m)*	
2		***<u>Construction of Gabion Weir</u>*** *1. Prepare stones at the construction site.* *2. Fabricate and align the gabion wire across the downstream of the intake.* *3. The gabion should be pegged 50cm into the soil for anchoring.* *4. Fill the gabion wire with the assembled stones.* *5. Cover the gabion with another wire mesh.*	

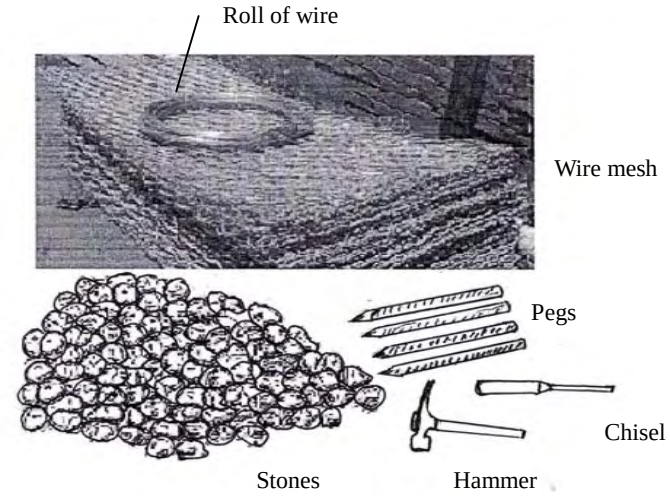
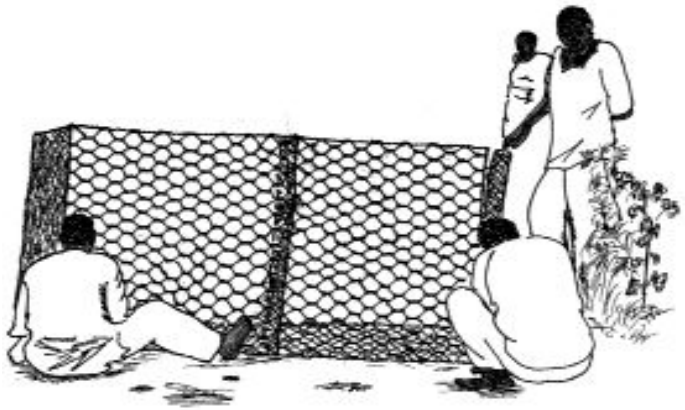
Step	***Process***	***Description***	***Remark***
3		***<u>Completed Gabion Weir</u>***	

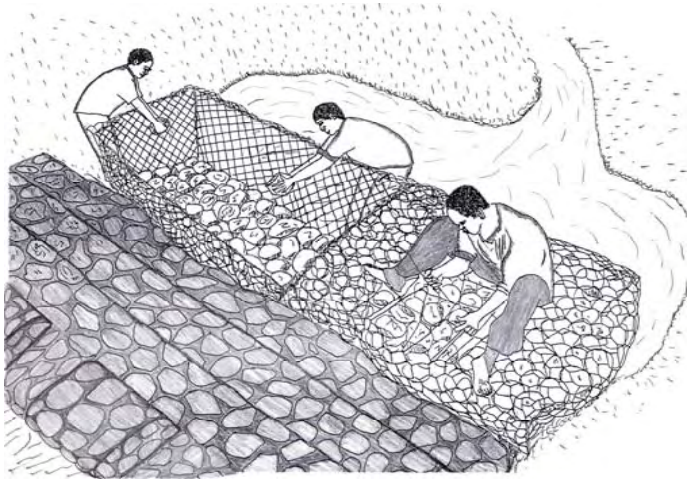
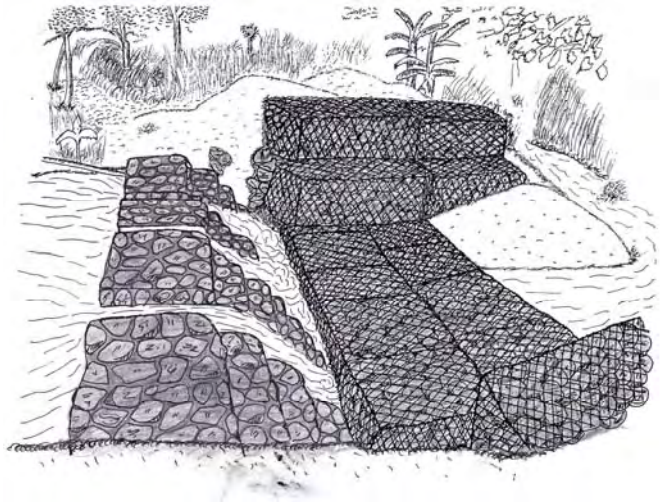
1-1-3 Cofferdam Making

Step	***Process***	***Description***	***Remark***
1		***Tools and Materials Required*** *Wheelbarrows, hammers, panga knives, hoes, shovels, wooden pegs, tall grasses like elephant grass, clay soil, logs, sand bags, wheelbarrows.*	
2		***Cofferdam Construction*** *(a) Cofferdam with soils* *- Position wooden poles at the diversion point* *- Weave grass fence to tap the stream flow* *- Put clay soil on the grass fence* *- Compact the soil using logs* *(b) Cofferdam with sand bags* *- To fill sand bags with soils* *- To place sand bags tight each other at diversion point.*	*- Cofferdam is constructed to close the river (upstream of the construction site) so that the weir point is dry throughout the construction.* *- Rammers may be used for the compaction when available.*

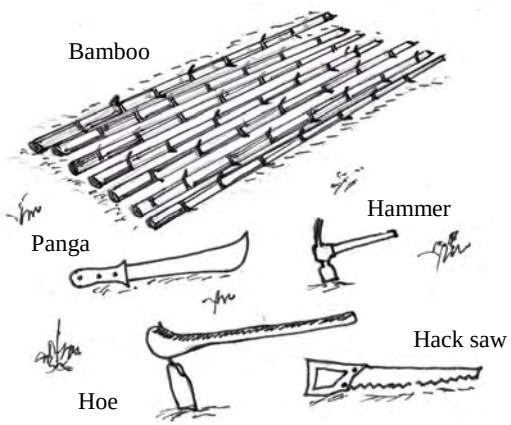
1-1-4 Protection Gabion Construction

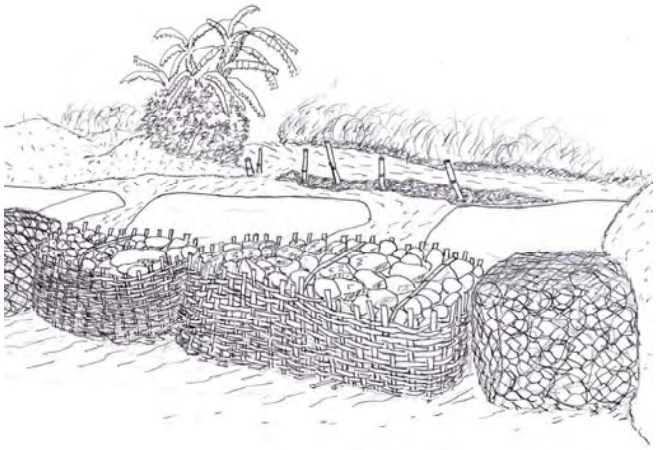
(a) Wire Gabion

Step	***Process***	***Description***	***Remark***
1		***Tools and Materials Required*** *10-15cm stones,* *Chisels / hammers,* *Wire mesh (mesh size: 80mm – 100mm),* *Role of Wire for binding (D=2.2mm, zinc coated),* *Pegs (length: 1.0 m).*	
2		***Preparation of Gabion*** *1. Stones are heaped by the site.* *2. Gabion wire mesh is fabricated at the site.* *3. Excavation is made to the required shape and depth.*	- *Stones are generally uniformly graded in sizes ranging from 100 mm to 150 mm.*

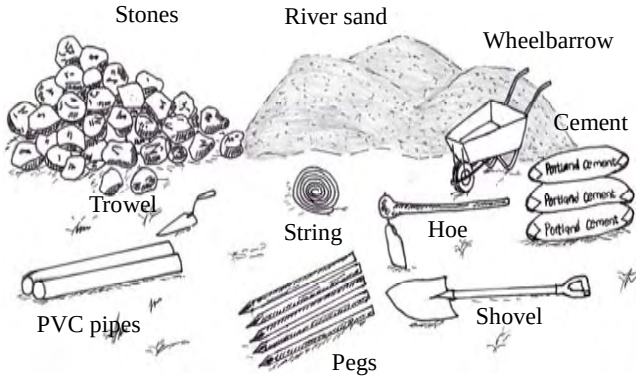
Step	***Process***	***Description***	***Remark***
3		***Construction of Wire Gabion*** *1. In case the foundation is soil, gabions are pegged down for anchoring. The length of peg is about 1m and drive into the ground more than 50cm.* *2. The gabions are filled with stones carefully placed by hand to ensure good alignment and avoid bulges with minimum voids.*	
4		***Constructed Wire and Gabion***	

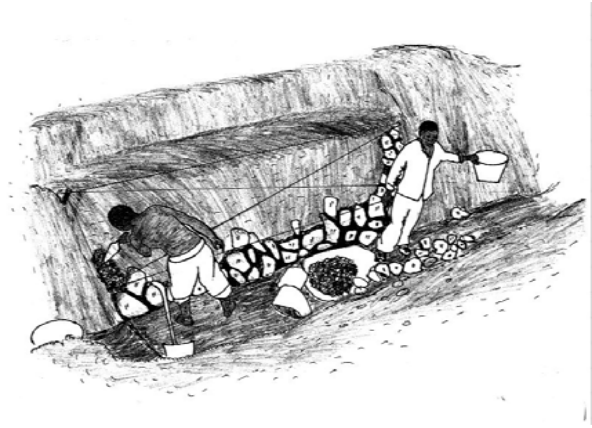
(b) Bamboo Gabion

Step	***Process***	***Description***	***Remark***
1		***Tools and Materials Required*** *Matured bamboos,* *Hammers,* *Panga knives,* *Hack saw,* *Hoes.*	
2		***Bamboo Gabion Basket Fabrication*** *1. Cut 2 cm thickness bamboo.* *2. Prepare a place where the basket is to be installed. Excavate 1.0 m x 1.0 m by 50cm depth.* *3. Drive pegs of bamboo or poles into the soil using the hammer* *4. Weave bamboo strips into rectangular / square baskets.* *5. Fill in the baskets with gathered stones* *6. Weave the top of the basket with the bamboo.*	***Dimensions*** - *The length and width of bamboo gabion more than 1m but less than 0.5m height.* - *Vertical member space should not be more than 10cm.* - *Horizontal member space should not be more than 5cm.* - *One bamboo gabion (1.0m x 1.0m x 0.5m) requires about 10 fully grown and matured bamboos.*

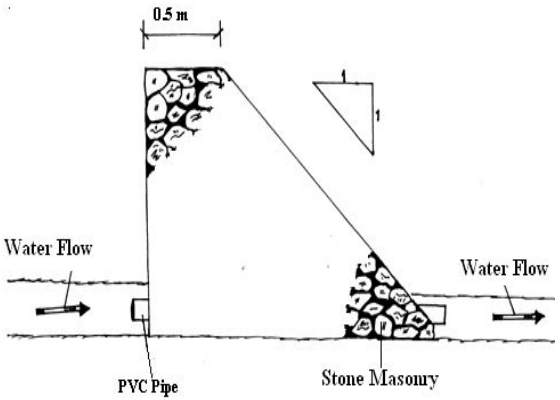
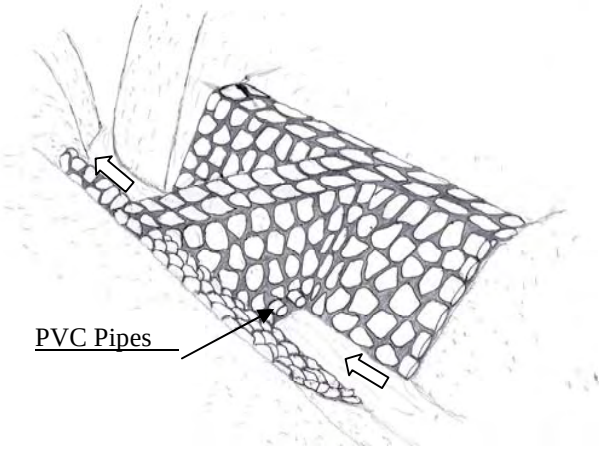
Step	***Process***	***Description***	***Remark***
3		***Constructed Bamboo Gabion***	

1-1-5 Stone Masonry Intake Rehabilitation

Step	***Process***	***Description***	***Remark***
1		***Tools and Materials Required*** *Wheelbarrows, hoes, shovels, PVC pipes, strings, builder knives (trowel), Portland cement, stones, river sand, pegs.*	- *Stones and sands need to be heaped by the site.*
2		***Excavation*** *1. Mud and loose soils of foundation and side wall should be removed.*	- *The length of upstream and downstream stone masonry canal should be 1.0m.*

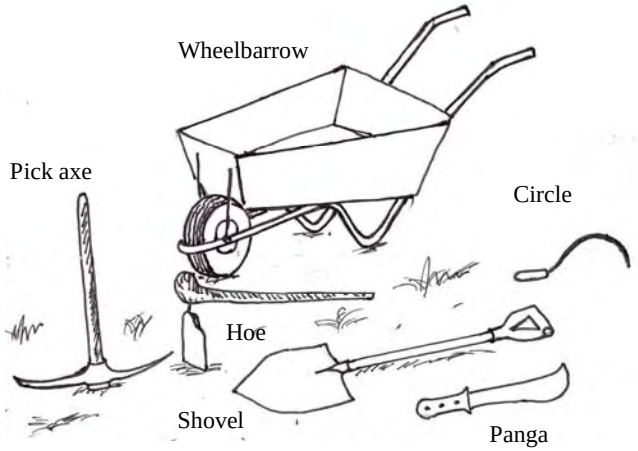
<table>
<tr><th>Step</th><th>Process</th><th>Description</th><th>Remarks</th></tr>
<tr><td>3</td><td>  </td><td><u>Construction of Base and Wall</u>
1. Strings are used to indicate the dimension.
2. Stones are placed on stable and compacted ground. The voids among stones are filled with mortar completely.</td><td>- The thickness of stone masonry should be 20cm. However the size of stone ranges from 10 to 30cm.
<u>Precaution</u>
- Stones should be properly aligned on top of each other to avoid any falling which can lead to accidents.</td></tr>
<tr><td>4</td><td>  </td><td><u>Installation of Pipes</u>
1. The bottom elevations of pipes are 20cm from canal bed.
2. Intake water level elevations are required to be above that of the top of pipes.
3. The slope of pipes are 0.2% to 0.3%
4. Pipes are surrounded by mortar more than 2cm thickness. Stones are placed spacing from the pipes more than 2cm.

<u>Maximum uniform flow quantity of pipes</u>
<table><tr><td>Diameter</td><td>Discharge</td></tr><tr><td>140 mm</td><td>7.9 lit/s</td></tr><tr><td>200 mm</td><td>20.3 lit/s</td></tr></table></td><td></td></tr>
</table>

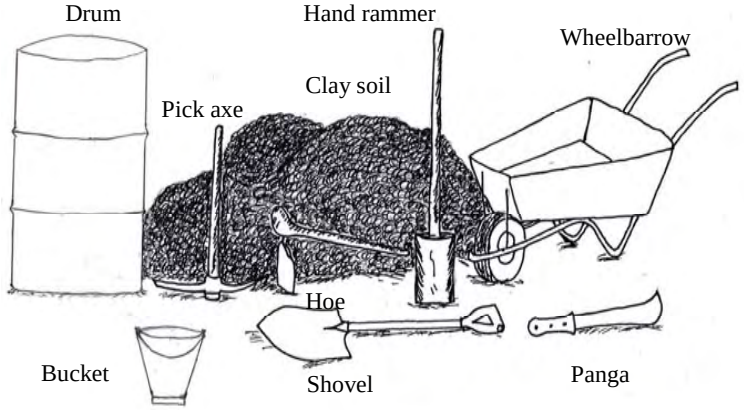
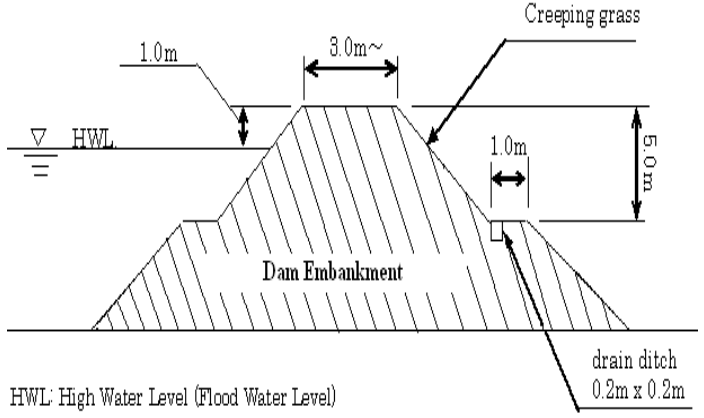
Step	***Process***	***Description***	***Remarks***
5		***<u>Construction of Intake Body</u>*** *1. Top width of intake is 0.5m.* *2. Upstream slope of the intake body need to be vertical and downstream slope 1:1.* *3. Stones are placed on stable and compacted ground. The void among stones should be filled with mortar completely.* *4. After completion of stone masonry, it is covered with grasses or straw mats.*	***<u>Precaution</u>*** - *Stones along the vertical face of the upstream should be properly aligned to avoid any falling which can lead to accidents in the course of construction.* - *In case of big streams or rivers, water inflow control structures will be accommodated such as sluice gates.*
6		***<u>Constructed Stone Masonry Intake</u>***	

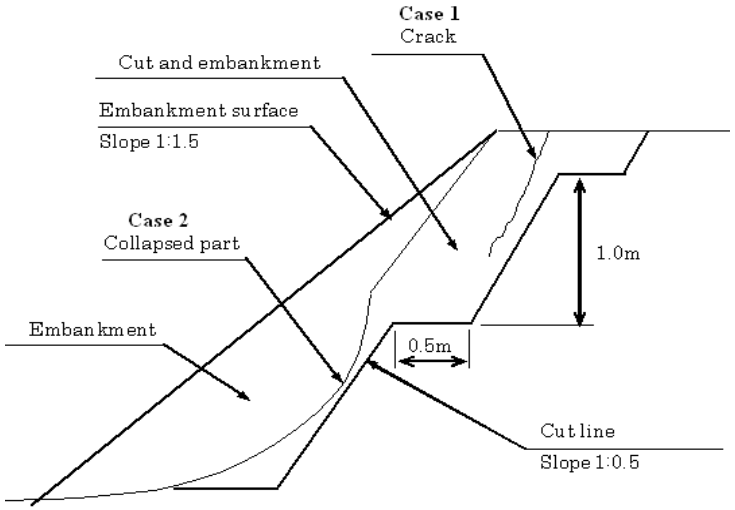
1-2 Water Impounding Dam System

1-2-1 De-siltation of Dam

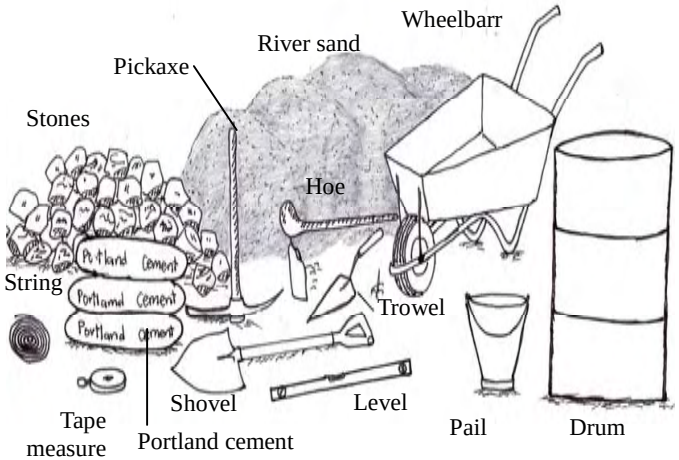
Step	***Process***	***Description***	***Remark***
1		***<u>Tools Required</u>*** *Hoes,* *Shovels,* *Pick axes,* *Wheelbarrows,* *Panga knives,* *Circles.*	
2		***<u>De-silting Work</u>*** *1. Sediments are removed in the dry season using shovels and wheelbarrows.*	- *Sediment accumulates and reduces storage capacity of the reservoir every year little by little.* - *Excavation of slope below emergency spillway should be considered.*

1-2-2 Dam Embankment Rehabilitation

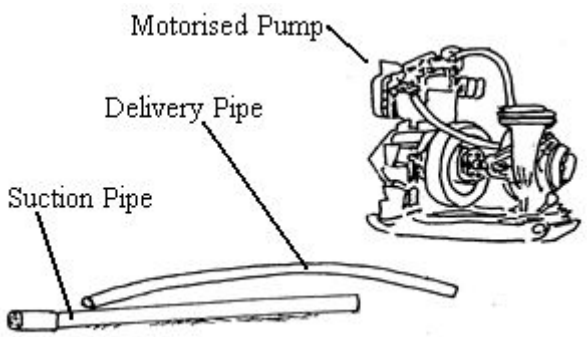
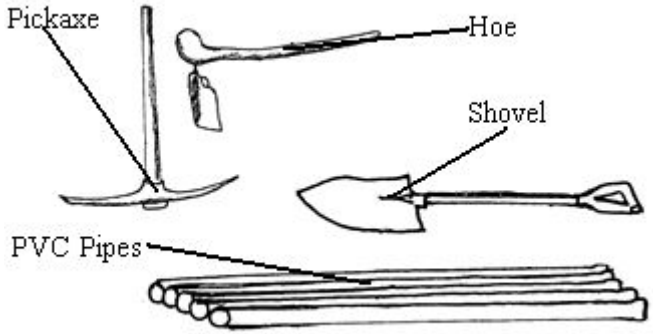
Step	***Process***	***Description***	***Remark***
1		***Tools and Materials Required*** *Hoes,* *Shovels,* *Pick axes,* *Wheelbarrows,* *Hand rammers,* *Panga knives,* *Clay soil,* *Drum for water,* *Buckets.*	- *Pedestrian roller could be used depending on the compaction workload.*
2		***Cross-Section of Dam Body***	

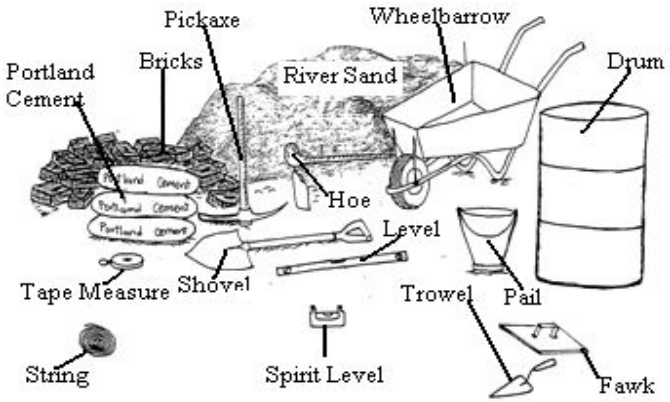
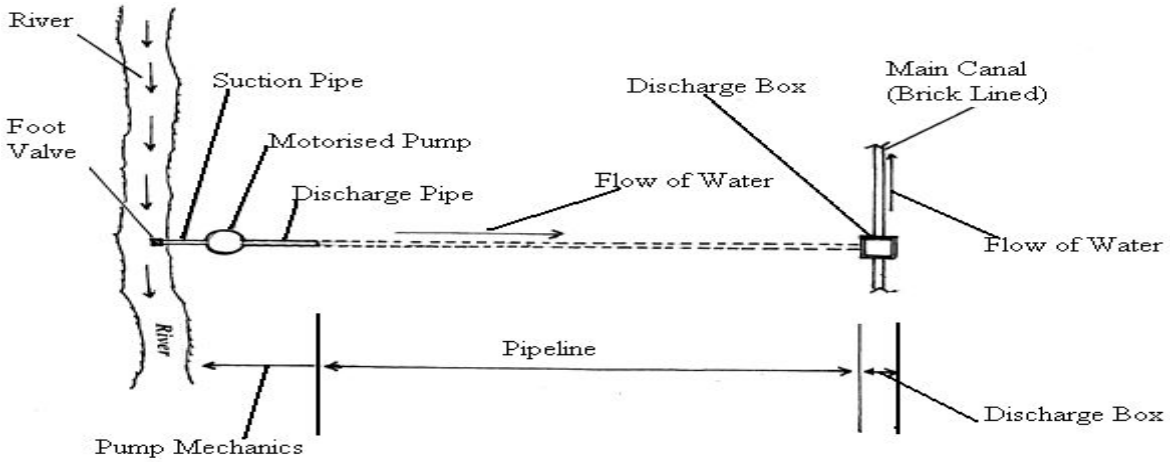
Step	***Process***	***Description***	***Remark***
3		***<u>Dam Embankment Rehabilitation</u>*** *1. Types of damages:* *<u>Case 1;</u> cracks along the embankment.* *<u>Case 2;</u> collapsed or eroded portion of embankment.* *2. Cracked part and collapsed part of embankment should be repaired.* *3. Cracked part and collapsed part are cut tiered 1m height steps.* *4. Embankment material are laid in 30cm thickness each layer and compacted.*	- *Filling materials shall be clay soil and spreading and compaction of clay soil shall be supervised by engineers.*

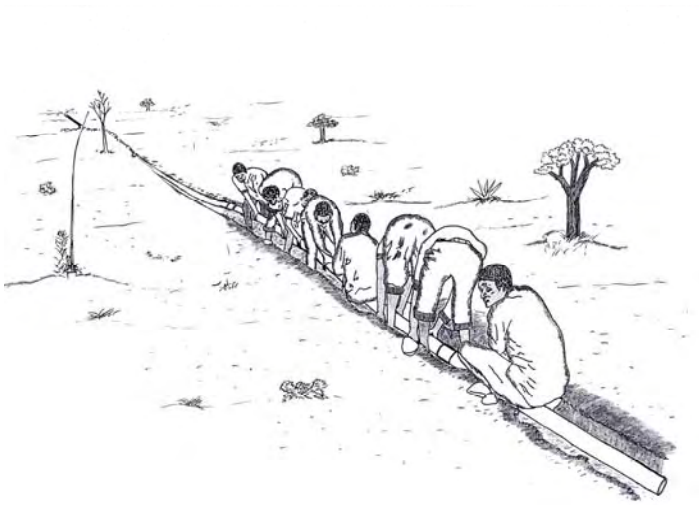
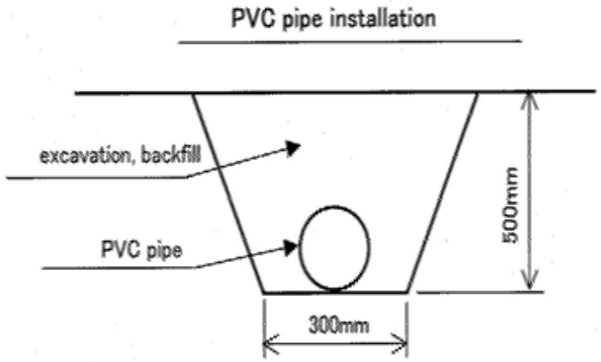
1-2-3 Dam Spillway Rehabilitation

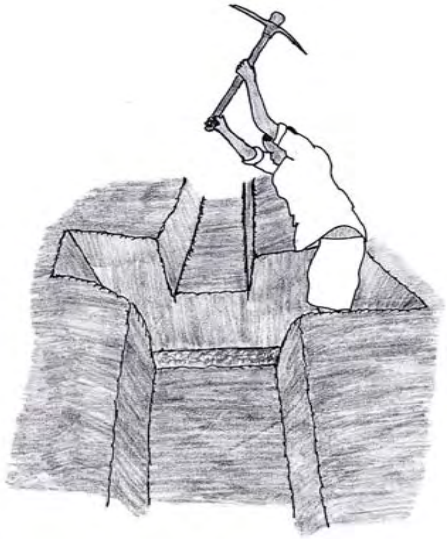
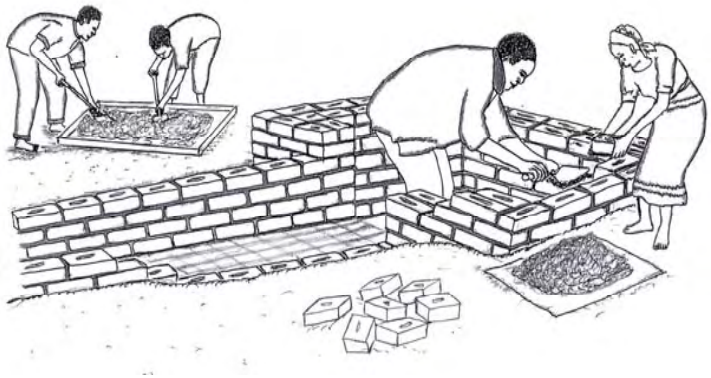
Step	***Process***	***Description***	***Remark***
1		***<u>Tools and Materials Required</u>*** ***<u>Tools</u>****; Wheelbarrows, pickaxes, shovels, hoes, drum, pails, tape measures, 20 m strings, levels, trowels.* ***<u>Materials</u>****; Portland cement, river sand, stones.*	
2		***<u>Spillway Rehabilitation</u>*** *1. Spillway shall be made of concrete or stone masonry.* *2. The thickness of stone masonry shall be more than 30cm.*	

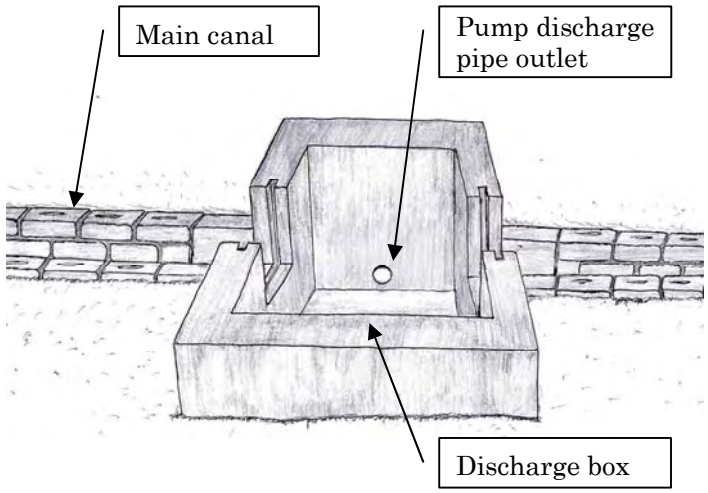
1-3 Motorized Pumping System

Steps	***Process***	***Description***	***Remarks***
1a	***a) <u>Pump Mechanics</u>***  	***<u>Tools and Pump Mechanics Required</u>*** *(a) Suction pipe* *(b) Motorised pump* *(c) Delivery Pipe*	
1b	***b) <u>Delivery Pipeline</u>***  	***<u>Tools for Delivery Pipeline Required</u>*** *(a) Shovels* *(b) Hoe* *(c) Pickaxe* *(d) PVC Pipes*	

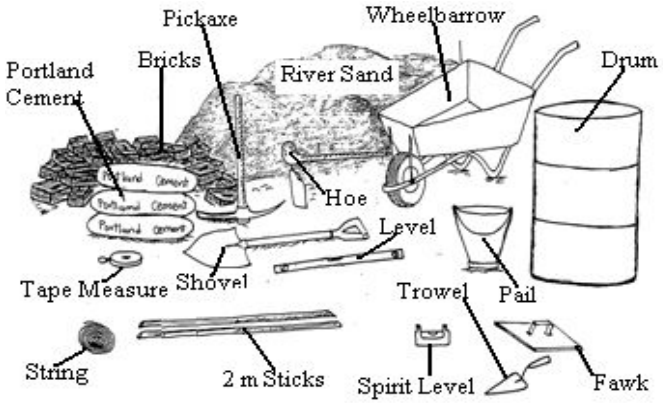
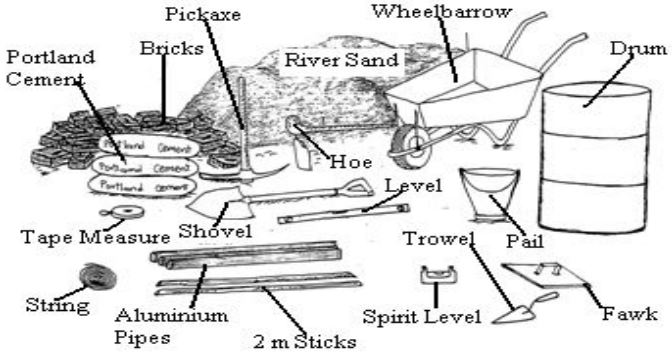
Step	Process	Description	Remarks
1c	***c) Discharge Box***  	***Tools and Materials Required for Discharge Box*** ***Tools****; Wheelbarrows, pickaxes, shovels, hoes, drum, pails, tape, measure, 20 m string, level, trowel, hawk, spirit level* ***Materials****; Portland cement, river sand, bricks,*	
2	***Motorized Irrigation System Lay-out***  		

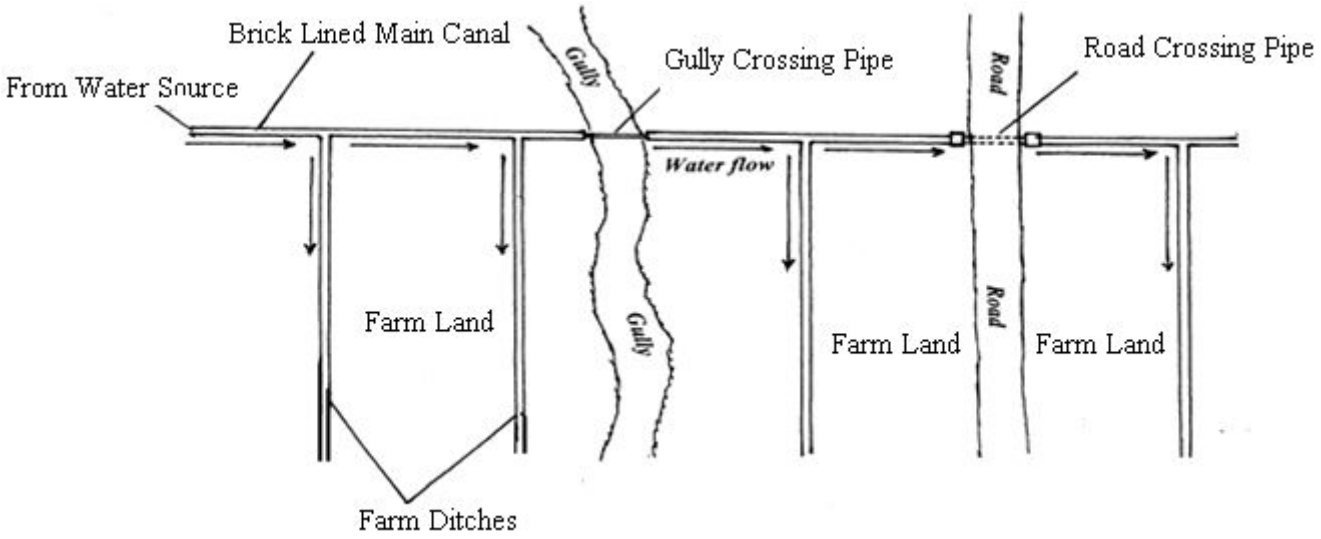
Step	***Process***	***Description***	***Remark***
3		***<u>Installation of pipes</u>*** *1. Pipes are connected tightly so that leakage may not happen.* *2. Pipes are backfilled and compacted.*	
4		***<u>Cross Section of Pipeline Excavation</u>*** *1. Pipes should be installed at 50cm depth.*	- *The pipes should be installed at the depth where without reach of normal cultivation depth.* - *The pipes should be covered with soil for protection.*

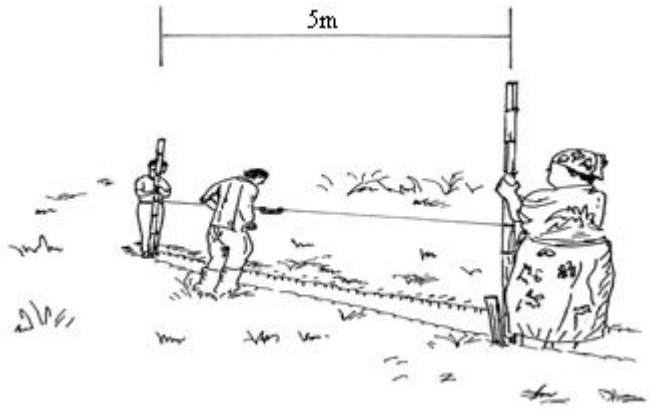
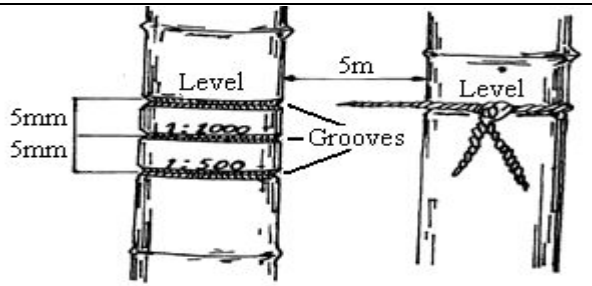
Step	***Process***	***Description***	***Remark***
5		***Excavation of Discharge Box*** *1. Excavation should be done to the required shape and depth.* *2. All surpluses, soft and unsuitable material are removed and replaced with suitable materials which are thoroughly compacted.*	***Standard Dimension of Discharge Box*** - *Standard dimension of discharge box is* · *Width: 1.0m* · *Length: 1.0m* · *Depth: 0.8m* - *Discharge pipe is installed at 10 cm from the bottom.* - *Top elevation of the wall is 10 cm higher than the canal wall.*
6		***Construction of Discharge Box*** *1. Discharge box should be made of bricks.* *2. Thickness of wall should be 2 rows of bricks.* *3. Thickness of base should be 2 layers of bricks.*	

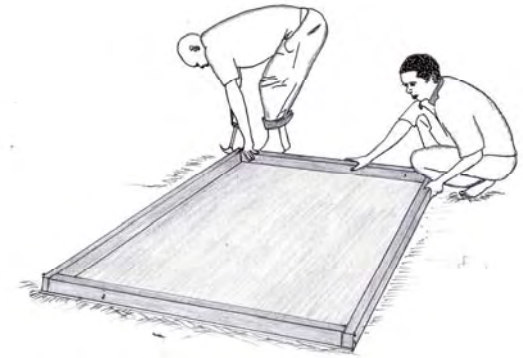
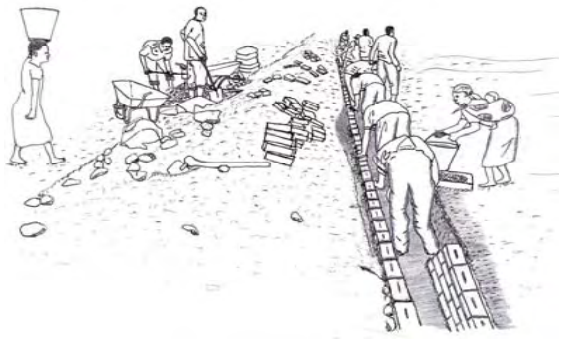
Step	***Process***	***Description***	***Remark***
7		***Completed Discharge Box***	

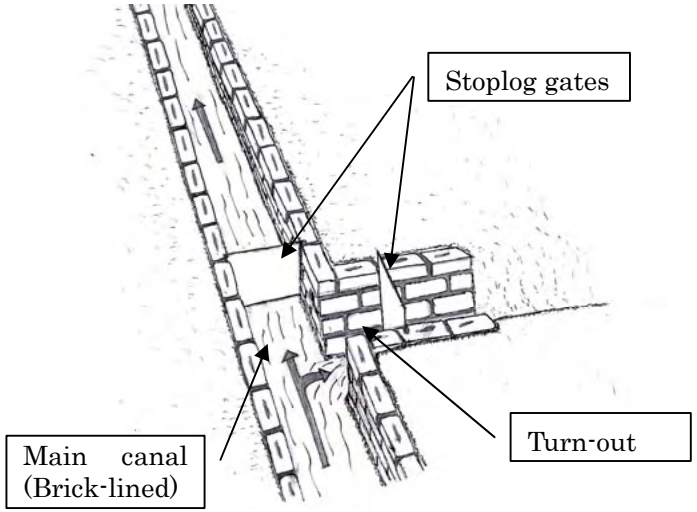
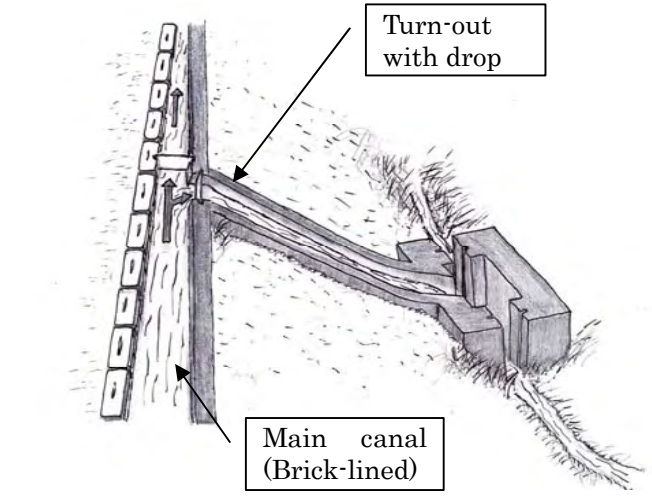
1-4 Brick-Lined Canal System

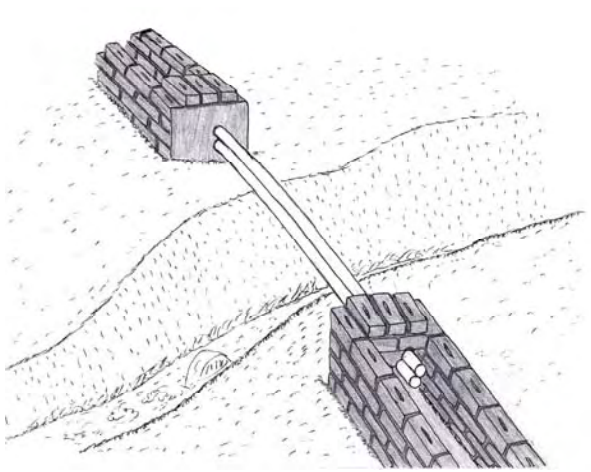
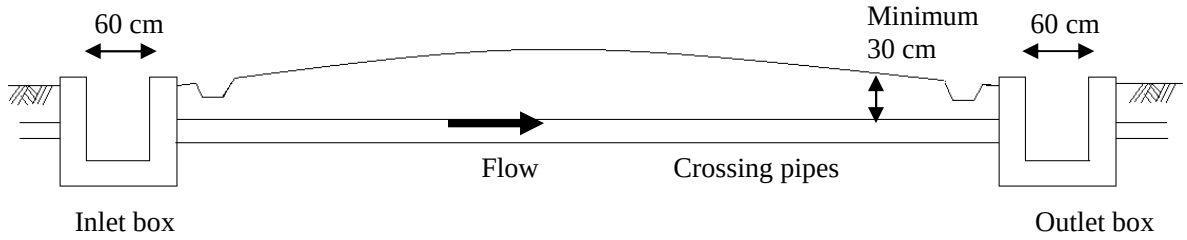
Step	***Process***	***Description***	***Remark***
1a	a) <u>Main Canal</u>  	***<u>Tools and Materials Required for Main Canal</u>*** ***<u>Tools</u>****; Wheelbarrows, pickaxes, shovels, hoes, drum, pails, tape measures, 20 m string, levels, trowels, hawks, spirit levels.* ***<u>Materials</u>****; Cement, river sand, bricks, PVC pipes, 2m sticks (2).*	
1b	b) <u>Gully Crossing and Road Crossing</u>  	***<u>Tools and Materials Required for Gully Crossing and Road Crossing</u>*** ***<u>Tools</u>****; Wheelbarrows, pickaxes, shovels, hoes, drum, pails, tape measures, 20 m string, levels, trowels, hawks, spirit levels.* ***<u>Materials</u>****; Cement, gravel, river sand, bricks, aluminum pipes, 2m sticks (2).*	

Step	***Process***	***Description***	***Remark***
2	***System Lay-out*** 		

Step	***Process***	***Description***	***Remark***
3		***Setting Alignment with Line Level*** *1. First of all, canal alignments are set using line level.* *2. Slope of the canal should be 0.1% (5mm difference in 5m, see the next Step).*	- *Starting from beginning point of the canal, canal bed elevation is determined at every 5m and the point is excavated to the determined elevation.* - *Canal bed slope are made by excavating between the two points.* - *After excavation, the elevations are checked again.*
4		***Canal Slope Determination*** *1. Make grooves on both 2m sticks following dimensions on the illustrations.* *2. Markings on the left stick indicates the slopes obtained when the a 5m string is moved along the grooves.*	- *Ensure that the grooves on the levels on the sticks are of equal distance from the ground.*
5		***Excavation of Canal Line*** *1. Excavation should be made to the required shape and depth.* *2. All surpluses, soft and unsuitable materials are removed and replaced with suitable materials which are thoroughly compacted.*	

Step	***Process***	***Description***	***Remark***
6		***Mortar Box Making*** *1. Mortar box, sand, cement and water are prepared. Bricks are brought along the canal.* *2. A movable plywood mixing place can be used where the construction is at different places .Make a box (1.2m by 1.8m) using 1x8 inches timber and Plywood Standard.*	- *Water for mortar is carried from the water source and stored in a drum.* - *Its advantage is that it can be easily shifted to another place more such as for canal construction.*
7		***Canal Bed Brick Laying***	
8		***Canal Side-Wall Construction*** *1. Bricks are laid straight. Thickness of joint mortar shall be 1 to 2 cm.* *2. The joint between bricks are filled with mortar completely.* *3. The surfaces of brick masonry are finished neat and smooth.*	- *Thickness of joint mortar is roughly indicated using a little finger.* - *Bricks are soaked in the water or wetted by sprinkling water before laying in order not to absorb water from mortar.*

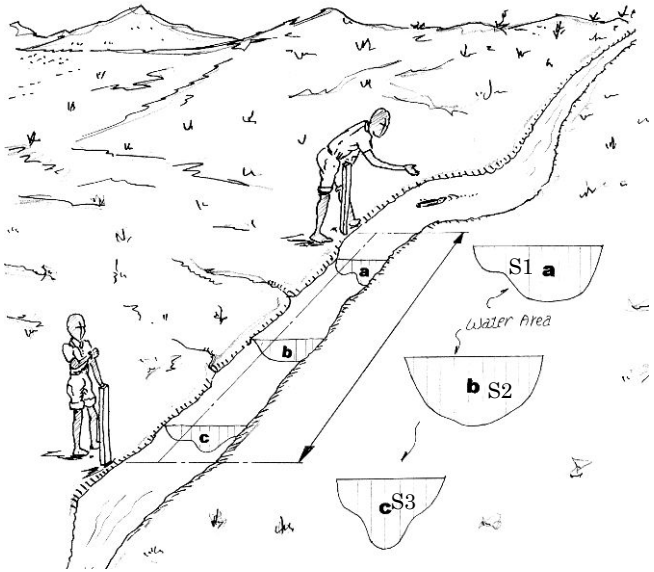
Step	***Process***	***Description***	***Remark***
9		***<u>Turn-out Without Drop Structure</u>*** *1. Turnouts are constructed for every 40 to 50m depending on the design.*	- *Each turnout is closed by stop log or plastic bag with soil.*
10		***<u>Turn-out With Drop Structure</u>*** *1. Drop structure is constructed at the point where elevation difference between main canal and secondary canal is big.* *2. Drop structure is constructed also at the steep slope to avoid erosion.*	

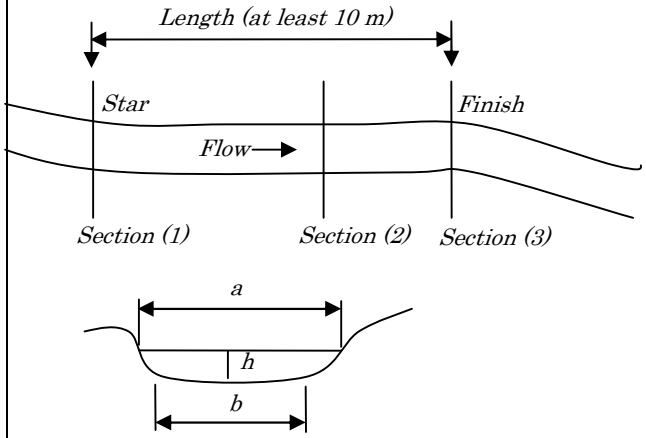
<table>
<tr><th>Step</th><th>Process</th><th>Description</th><th>Remark</th></tr>
<tr><td>11</td><td>  </td><td><u>Gully Crossing</u>
1. A gully crossing is constructed to convey water across a gully.
2. The length of pipe is normally less than 6m.
3. The pipe is required to be installed at the height of 10cm from canal bed.</td><td>- Considering the strength of pipe and necessity of support, the length is less than 6m.
- Since the length of pipe is limited, the location of gully crossing is decided considering the length.</td></tr>
<tr><td>12</td><td><u>Road Crossing</u>
 

1. Pipes are installed under ground and soil covering depth shall be more than 30cm.
2. The pipes are installed at the height of 10cm from canal bed.</td><td>- Road crossing is constructed to convey water across the road.
- Siphon type is not suitable due to difficulty of maintenance.</td></tr>
</table>

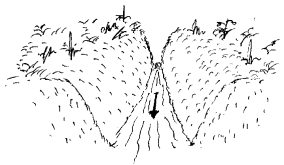
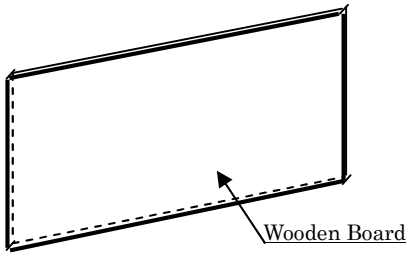
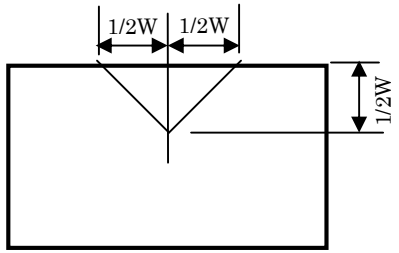
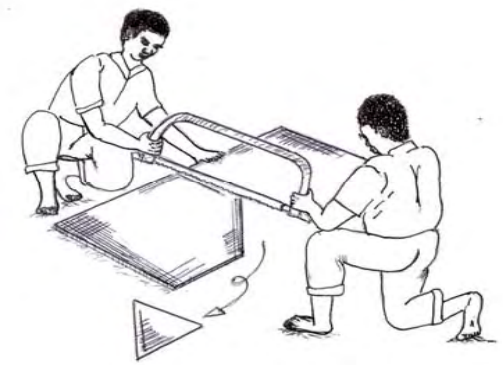
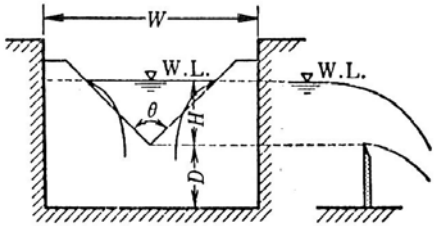
2 Water Management of Irrigation Systems

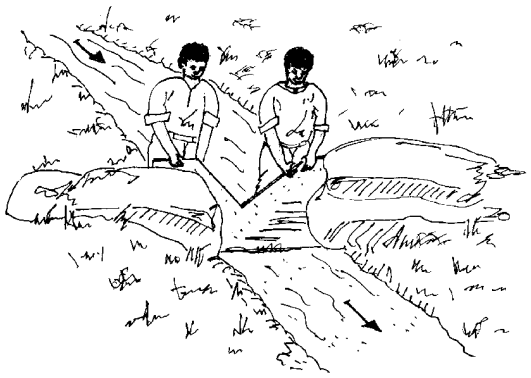
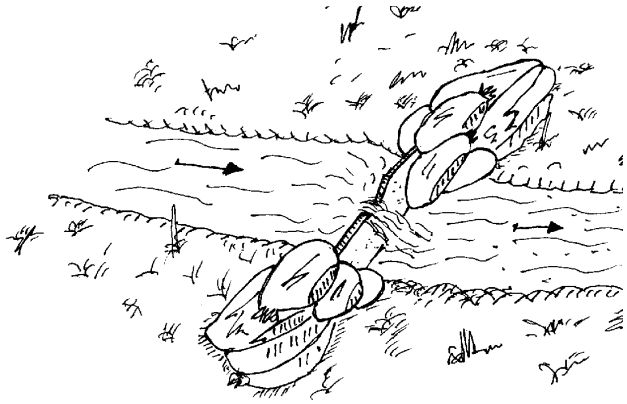
2-1 Discharge Measurements at Rivers and Creeks (Float Method)

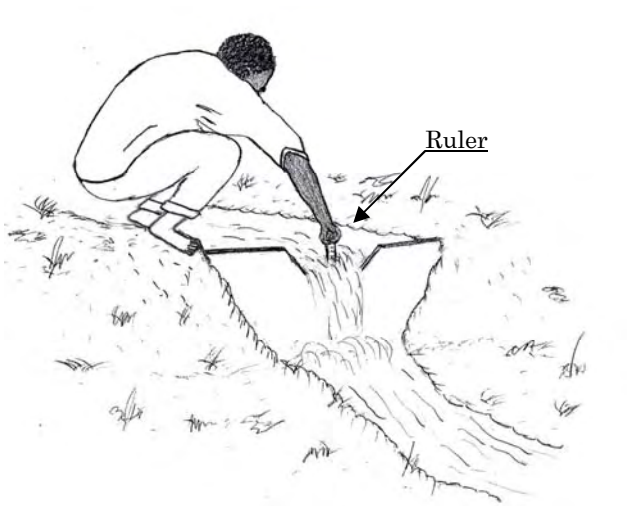
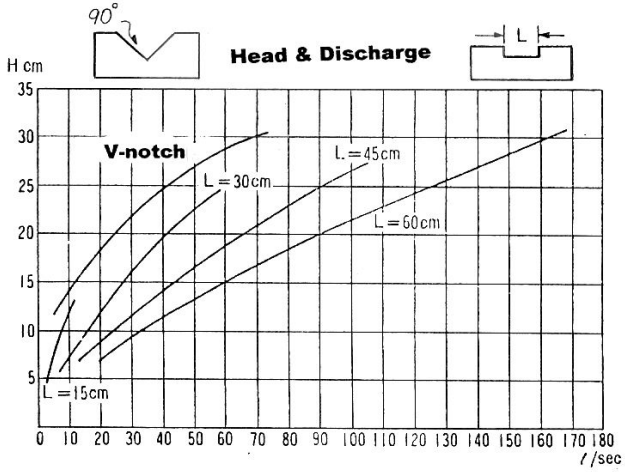
Step	Process	Description	Remark
1		***Site Selection and Measurement of Water Area*** *1. To measure discharges for the rivers / stream, straight sections are preferred.* *2. The shape of the rivers/streams along this section should be as uniform as possible.*	- *River or stream discharges can be estimated when the stream is in a well-defined channel with a flow that would carry a small float object such as a plastic water bottle or a wooden stick.* - *By using these materials, the discharges can be estimated by multiplying the flow velocity to be measured at which a float is carried along by the average cross-sectional area of the stream.*

Step	Process	Description	Remark
2		***Measurement of Flow Velocity and Discharge Calculations*** *1. Place a stake/peg along the bank at the selected section (1) and measure 10 m downstream.* *2. Place a stake at the selected section of the stream (3).* *3. Place the floating object in the center of the stream at the section (1), and start the time in second.* *4. Stop timing when the floating object reaches section (3) and record the time in second.* *5. Repeat steps 3 and 4 at least three times in order to determine the average time necessary for the stick to travel from section (1) to (3). The stick should not touch the stream bank during the trial. If it does, repeat the run and do not include the time for the bad trial when calculating the average time.* *6. Measure the following in the selected stream section: the stream width (b), the surface water width (a), and the water depth (h). The cross section width in the selected portion of the stream will not be regular, and so (a), (b) and (h) need to be measured in several places to obtain an average value.* *7. Calculate the average area of the stream cross-section (A), using the following equation:* $A = 1/2 \times (a + b) \times h$ *8. Calculate the average flow velocity (V)* $V = 0.8 \times L/t$ *(m/sec)* *Where;* t = *Average travel time (sec)* L = *Distance between section (1) to (3) (m)* *0.8 = Reduction factor because not all the water flow as fast as that in the center* *9. Calculate the flow (Q) in the stream, using the following equation:* $Q = V \times A$ (m^3/sec)	

2-2 Discharge Measurement at Irrigation Canals (V-Notch Method)

Step	***Process***	***Description***	***Remark***
1		***Selection of Discharge Measuring Site*** *1. Discharge measuring sites having uniform cross section is selected in the canals.*	- *If there was no existing of uniform cross section around the measuring sites, canal is shaped with uniform section.*
2		***Preparation of Wooden Board and Setting Angle of 90 Degrees*** 	- *Generally, the V-notch is made of wooden board at an angle of 90 degree, of which procedures are shown in the left figure.*
3		***Making V-notch*** 	- *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

Step	***Process***	***Description***	***Remark***
4		***Setting V-notch*** *1. The V-notch is set up at suitable site near the place where is planed to construct the diversion weir.*	- *To protect canal bed from erosion at the set V-notch, V-notch is embedded at least 15 cm.*
5		***Stabilization of V-Notch*** *1. The V-notch must stand perpendicularly to the stream flow. To stabilize the V-notch, sand bags can be used.*	

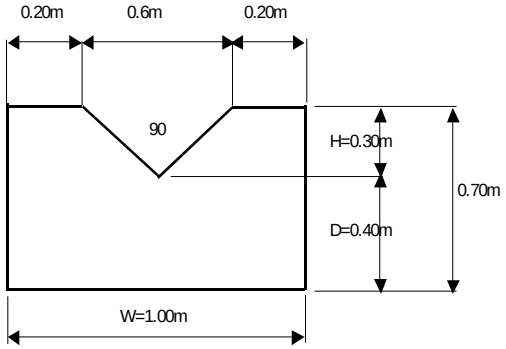
Step	***Process***	***Description***	***Remark***
6		***<u>Measure The Depth of Nappe</u>*** *1. The stream flow starts overflow.*	- *After setting the V-notch, the stream flow starts overflow through the V-notch. The V-notch is left as it is. When the nappe becomes stable, the depth of nappe is measured.*
7-1		***<u>Read Graph or use Tables</u>*** *1. 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 measuring 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.* *<u>An exercise in case of V-notch;</u>* *The depth of nappe: 25cm* *The amount of flow: 40 lit/sec*

Step	Process	Description	Remark

7-2

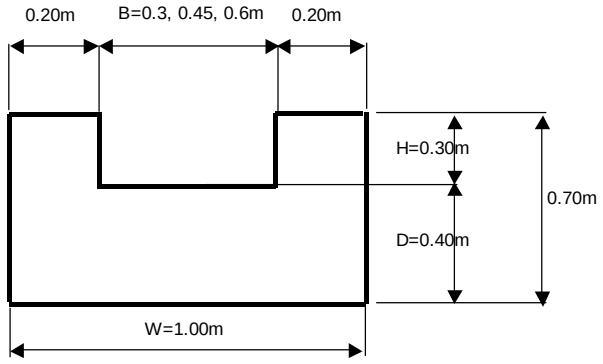
In case of V-notch:

Overflow depth on V-Notch	Discharge	
h(m)	Q (m^3/min)	Q (lit/sec)
0.08	0.15	2.52
0.10	0.26	4.41
0.12	0.42	6.95
0.14	0.61	10.21
0.16	0.86	14.26
0.18	1.15	19.15
0.20	1.5	24.92
0.22	1.9	31.62
0.24	2.36	39.31
0.26	2.88	48.02

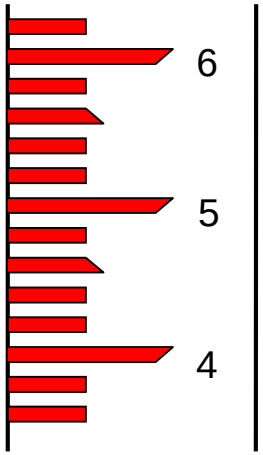
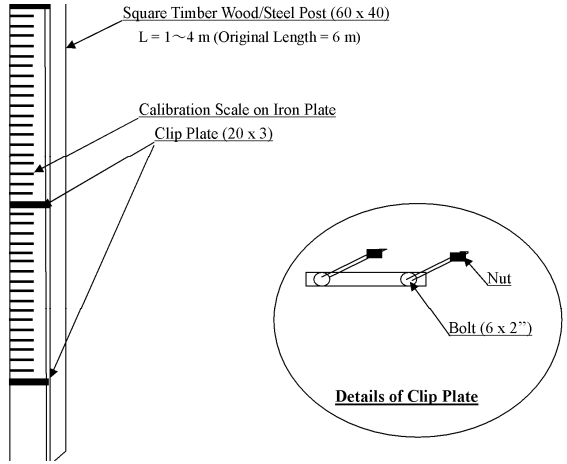


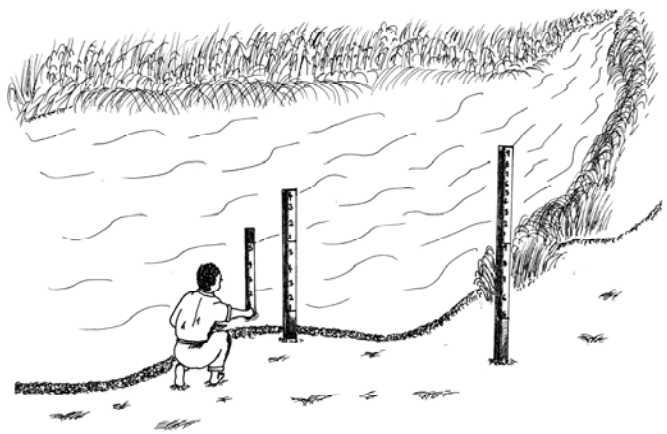
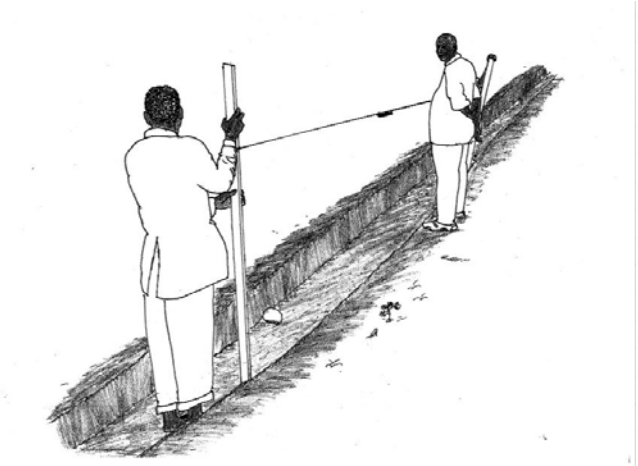
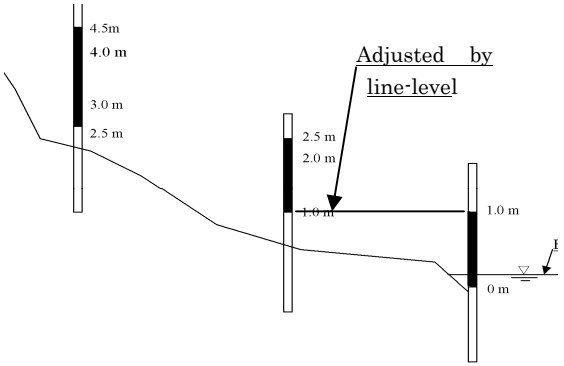
In case of rectangular notch:

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

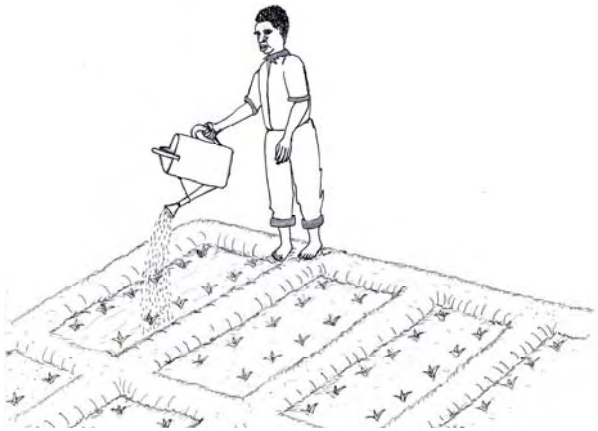
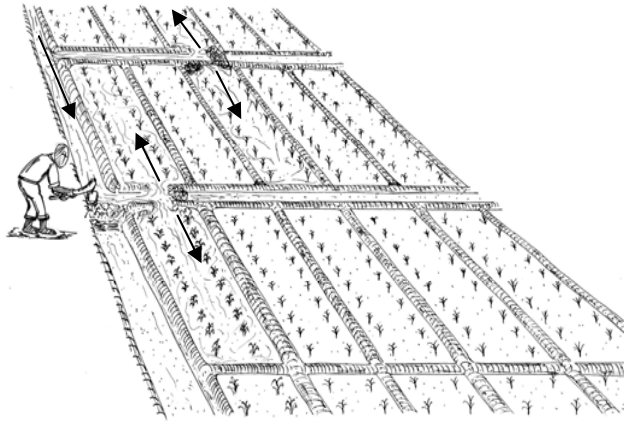


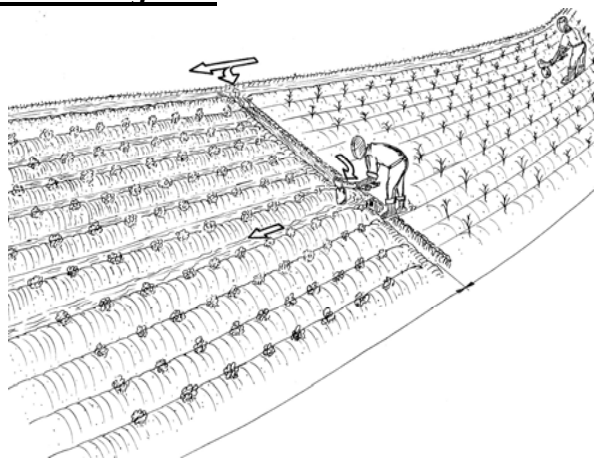
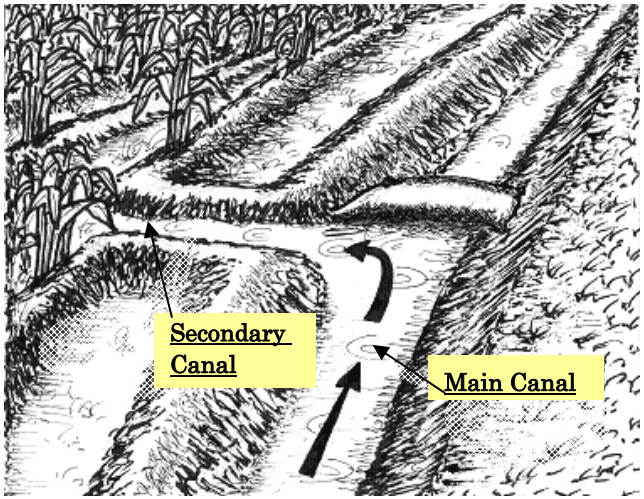
2-3 Installation of Staff Gauge for Water Level Observation

Step	Process	Description	Remark
1		***Painting of Scale*** *1. In order to observe the water level of rivers/streams, reservoirs and canals, water level gauge (staff gauges) are needed. Water level gauges are graduated on the iron plate using paints, and its length is adjusted depending on the required water height to be measured.*	- *One of the easy ways to procure staff gauge is of usage of ready - made vinyl ribbon-lot with a length of 3m or 5 m.*
2		***Fabrication of Staff Gauge*** *1. After graduation of calibration scale on the iron plate, the iron plate is attached to the square timber wood using clip plate.*	- *The clip plates are fixed by bolts or nails.*

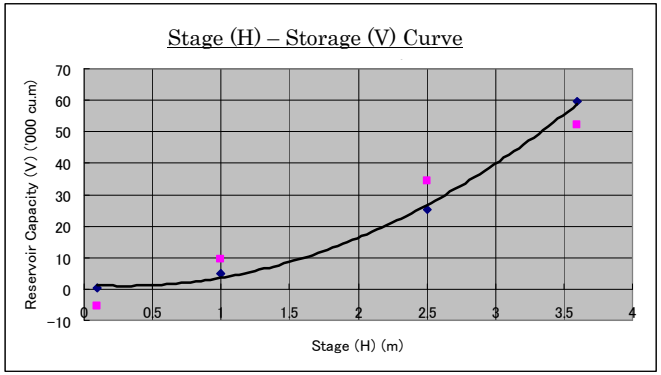
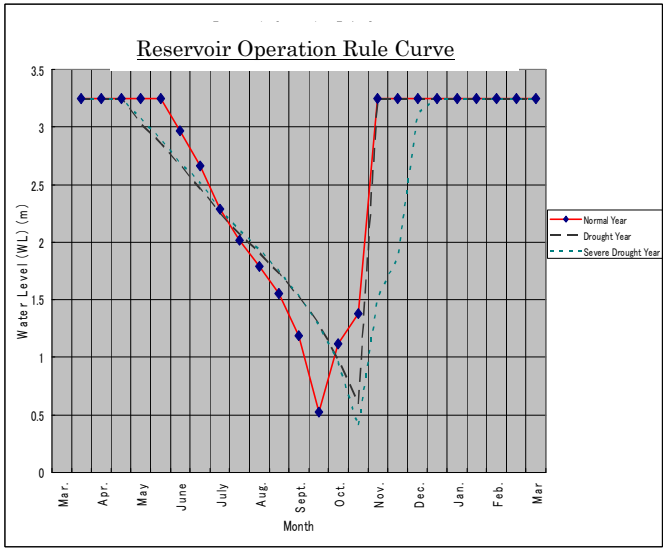
Step	***Process***	***Description***	***Remark***
3		***Installation of Staff Gauge*** *1. Staff gauges attached on the square timber wood is installed in and around the rivers/streams, reservoirs and canals by hitting with a hammer. In this case, the staff gauges are preferable to be the linearly-arranged positions in line from view point of easy observation.*	- *Location of the staff gauges should not be affected by the turbulence of flow. And furthermore, in selecting the location, easy access to the gauging site during the wet season should be taken into account.*
4		***Setting Horizontal Elevation by Line-level*** *1. Horizontal connection in height among the staff gauges to be installed is adjusted using line-level after installation of staff gauges.* 	

2-4 Irrigation Water Supply and Distribution Method

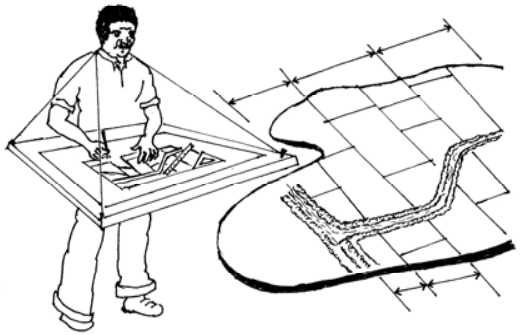
Step	*Process*	*Description*	*Remark*
1	***Watering Can Irrigation***  ***Basin Irrigation*** 	***Irrigation Water Supply Methods*** *For upland crops;* 1) *Watering can/bucket irrigation* 2) *Basin irrigation* 3) *Furrow (ridge) irrigation* *For paddy rice;* 4) *Plot-to-plot irrigation*	- *Watering can/bucket irrigation is applied in areas without irrigation systems, or for the purposes of supplemental water supply.* - *Basin irrigation is mostly applied in dry season to save irrigation water (size 1.2 m x 3-4m).* - *Furrow (Ridge) irrigation is mostly applied in wet season to prevent crop from water logging conditions.* - *Plot-to-plot irrigation is normally applied in paddy fields without systematic water systems.*

Step	Process	Description	Remark
	Furrow Irrigation 		
2	***Rotational Irrigation*** 	***Water Distribution Methods*** *1. Water distribution methods and schedules are decided through the related farmer's discussion.* *1) For dry season;* - *Rotational irrigation water supply methods* *2) For wet season;* - *Simultaneous irrigation water supply or no water supply*	- *Rotational irrigation water supply methods with an adequate irrigation interval are practiced to cope with scarce water sources for irrigation during the dry season at main and secondary canal level.* - *Irrigation intervals of 3-day to 5-day are used, based on the characteristics of soil, required crop water requirements, canal and pump capacity, etc.*

2-5 Reservoir Operation by Operation Rule Curve

Step	Process	Description	Remark
1		***Reservoir Stage (H)-Storage (V) Curve*** 1. *Irrigation scheme with a reservoir (small impounding dam) as water sources is managed considering an available amounts of water stored in the reservoir.* 2. *The stored water in reservoir is presented by stage (H)-storage (V) curve. This curve is to be prepared by the Irrigation Officers based on the reservoir operation analysis.*	- *In addition to the H-V curve, stage (H)-reservoir area (A) curve is also presented by the Irrigation Officers.*
2		***Reservoir Operation by Rule Curve*** 1. *Decision of the adequate extents of cropping areas for the dry season is made depending on the reservoir water level at the beginning of the winter season.* 2. *If the reservoir water level is reduced at an early stage such as the end of April, the year corresponds to the drought year. In this case reservoir should be operated considering appropriate ways. One of the ways is a reduction of dry season cropping areas.* 3. *Reduction rates of the dry season cropping areas are decided by the simulated reservoir operation rule curve.*	- *The reservoir operation rule curves are formulated through a few cases of simulation considering available inflow to reservoir, release of water from reservoir to meet the demand, water losses in the reservoir.* - *The simulation cases are normal and drought years.*

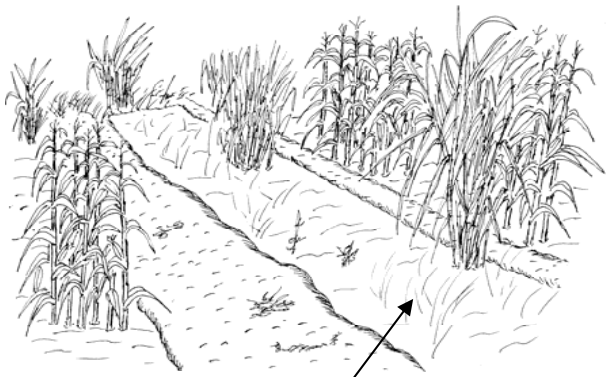
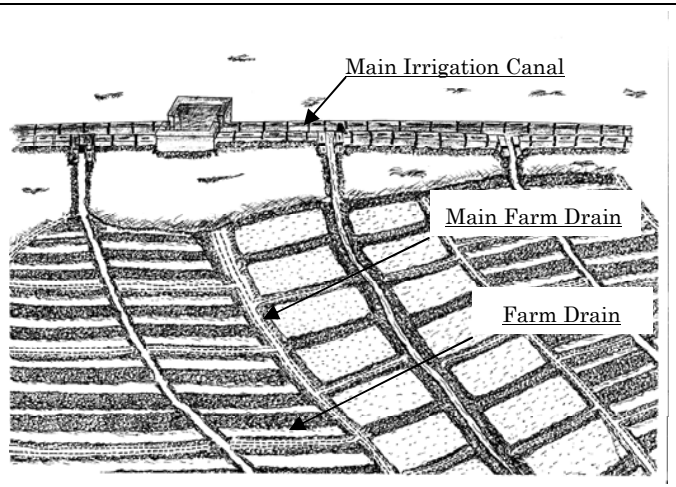
2-6 Record Keeping on Water Management

Step	***Process***	***Description***	***Remark***
1		***<u>Contents of Record Keeping on Water Management</u>*** *1. Record keeping on water management is important to carry out effective and economical operation of the scheme. Items required in record keeping in relation to water management are summarized below;* *<u>1) During wet season cropping (November to March)</u>* *- Rivers/streams and reservoir water levels.* *- Water surplus and shortage conditions.* *- Major farming activities and encountered problems.* *<u>2) During dry season cropping (April to October)</u>* *- Rivers/streams and reservoir water levels.* *- Water supply conditions; location of irrigation area, irrigated areas, water requirement, etc.* *- Pump operation conditions; actual head (m), pump discharge (lit/sec), pump operation hours (hr), fuel consumption (lit), etc.* *- Water surplus and shortage conditions.* *- Major farming activities and encountered problems.*	
2		***<u>Implementation of Record Keeping</u>*** *1. Record keeping on the water management is made on daily or weekly basis by "Water Sub-Committee" or "Water-Board Committee" or "Operation and Maintenance Committee (O&M)" members of the farmer's group.*	*- Recording forms are prepared in accordance with the following types of irrigation technology;* *1) Gravity diversion weir type* *2) Water impounding dam type* *3) Motorized pump type*

2-7 On-Farm Facility Maintenance

Step	Process	Description	Remark
1		**Types of On-farm Facilities** 1. Due attention on the maintenance of the following farm level facilities is necessary, that is, turn-outs (TO), secondary canals (SC), farm ditches (FD), off-takes (OT). 2. In addition to the main irrigation facilities such as diversion weir, pumps, conveyance pipes, and main canal, maintenance works of these farm level facilities are also within the jurisdiction of the farmers or farmer's groups.	
2		**On-farm Facilities Maintenance** **Turn-outs;** 1. The turnout is a structure constructed at the point where secondary irrigation canal branches out from the main canal to regulate water flowing into the secondary canal. 2. The farmers /farmers' group within the target area undertake maintenance works of the turnout, including de-silting the box structure and cutting grasses around it to ease up irrigation application. **Secondary Canals and Farm Ditches;** 1. The secondary canals and farm ditches are farm level irrigation canals provided after the turnout to deliver irrigation water to the field. This is categorized as main farm ditch (MFD) and supplemental farm ditch (SFD). 2. Farmers undertake the maintenance work by cleaning secondary canals, farm ditches, repair and reinforcement of embankment and paddy ridges adjacent to their fields. **Off-takes;** 1. The off take is a pre-fabricated facility or just bunds of soils installed or provided at the beginning of the internal ditches which controls and regulates the water flowing to the individual or group of farms. 2. The maintenance of this facility is automatically the concern of individual or group of farmers to be served. As these are only temporary at the farm level, maintenance is so minimal which is just checking the leakage during operation.	

2-8 Improvement of Drainage Conditions (Water-logging) at Farm Level

Step	Process	Description	Remark
1		***Causes of Water Logging*** *1. Water logging at farm level takes place because of the following reasons, especially in the motorized pump schemes;* *1) Motorized pump irrigation areas are originally located in the areas closing to the relatively big rivers with abundant perennial flow such as the Bua and Lilongwe Rivers. Therefore, ground-water level around the gentle slopping areas is high during the wet season.* *2) In addition to these hydro-geological conditions in the areas, excess water caused by rainfall is inflowing into the areas from their catchments.* *3) No provision of adequate drainage systems in the areas, because of low priority for drainage sector, in comparison to that for irrigation sector.*	
2		***Countermeasures for Water Logging*** *1. Following earthen farm and main drains are provided by farmer's groups;* *1) Farm Drains:* *Earthen farm drains are excavated along the contour line with adequate interval less than 30-40 m, considering the topography around the area. Some grasses are planted in the drains to protect soil erosion.* *2) Main Farm Drains:* *Earthen main farm drains are excavated at a right angle to the contour line between secondary irrigation canals. Vetiver grasses are also planted in the main drains to protect soil erosion.*	