Subsurface dams built of soil

Content **Page**

1) What are subsurface dams? And why build them of soil?

Although much water has been drawn from subsurface dams during the last 100 years, very few persons know about these structures. Even experienced engineers have problems explaining precisely what subsurface dams are. It is not their fault. The subject of subsurface dams is not part of the curriculum for engineers nowadays.

The simplest way to explain what subsurface dams are, is to say they are earth dams built under the surface of sand and across dry riverbeds. Subsurface dams block the downstream flow of water in the sand of riverbeds which have been saturated by floods or rainwater.

The reason for building subsurface dams of soil taken from a nearby riverbank or field is that soil is much cheaper than concrete and easier to work with. In fact, it is so simple to build subsurface dams of soil that farmers can do it themselves after a few days of training.

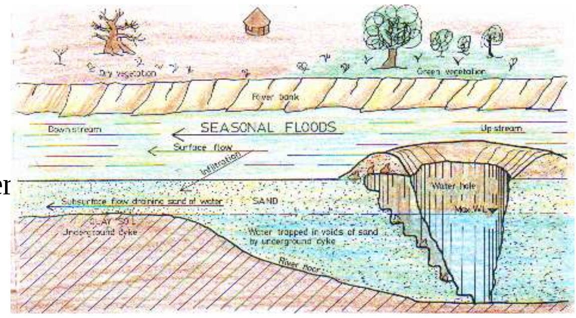
2) Benefits of subsurface dams

1) Whether subsurface dams are built of soil or any other construction materials, they cannot be damaged by floodwater or erosion because they are situated below the surface of the sand in riverbeds.
2) Siltation cannot cause any problem due to the reason mentioned above.
3) Evaporation occurs only for a few days when the surface of the sand is fully saturated.
4) Seepage occurs only if surveying was incorrect.
5) The water cannot be contaminated by animals or insects because it is stored, invisibly, under the surface of riverbeds.
6) Downstream water sources are not interrupted because the floodwater is not blocked.
7) The most clayey soil found in nearby riverbanks can be used instead of concrete.
8) Laymen can learn to identify suitable sites and construct the dams after short training
9) The cost of survey, design and construction is cheaper than for any other type of water supply structure in semi-arid, arid and semi-desert regions.

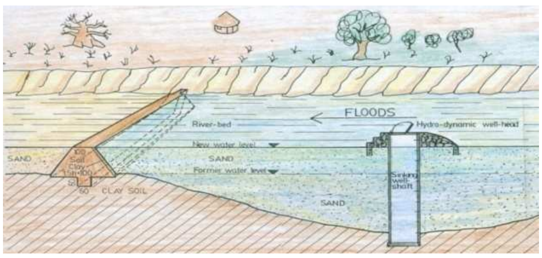
3) The first subsurface dams built of soil in Africa about 1905

The history of subsurface dams in East Africa begins at Dodoma in Tanganyika (now Tanzania) around 1905. Although people and animals have drawn water from dry riverbeds since the dawn of time, there is no known explanation of this hydro-geological phenomenon until a hundred years ago. The explanation is that water can be available in dry riverbeds where naturally-created dykes (subsurface dams) are situated under the surface of the sand and thereby block the underground downwards flow of water in the voids between sand particles in riverbeds.

Water trapped in the sand of a dry riverbed by an underground dyke situated downstream of the water hole.



The 1,252 km long railway from Dar es Salaam to Kigoma at Lake Tanganyika was built by German engineers from 1905 to 1912. The railway was built through arid and semi-arid land where there is no surface water. One of the biggest problems of laying railway tracks in rough landscapes was WATER for people and their water-consuming steam locomotives. The only water source available in the great central plateau around Dodoma was seasonal waterholes in the dry riverbeds which were only flooded for a few days in the two short annual rainy seasons.



This challenge was overcome by constructing a series of subsurface dams built of soil onto underground dykes in the dry riverbeds.

These subsurface dams supplied sufficient water for people and steam locomotives until the steam engines were replaced by diesel engines some 75 years later.

When the diesel powered locomotives took over from the steam engines in the 1970s, the railway stopped drawing water from the subsurface dams. At about the same time, well-meaning western donors advocated the benefits of the modern western world. Slogans like this were heard: 'Why should you use manual labour for building earth dams when we can give you earth moving machines for free?' and 'Why construct subsurface dams of soil when we can give you free boreholes, pumps and many kilometers of pipelines?'

The use and knowledge of subsurface dams built of soil was therefore, literally, buried under the sand for the next 15 years. Then in 1990, UNDP/ILO/Africare/Danida in Tanzania decided to hire the undersigned to dig up the history and performance of subsurface dams built in Tanzania almost a hundred years ago.

4) Field work and documentation in the 1980s

My experience on low-cost water projects was documented in 'Rainwater Catchment and Water Supply in Rural Africa' in 1980. Subsurface dams built of soil are described briefly and can be ordered under 'Manuals' in www.waterforaridland.com

In 1988, Ake Nilsson describes how subsurface dams can be constructed of various materials such as; clay, concrete in stone masonry, concrete in formwork, ferro-cement, brick wall and sheets of plastic, tarred-felt, steel, corrugated iron or PVC as well as injection screens of cement mortar in his 'Groundwater Dams for Small-scale Water Supply'.

Unfortunately, at that time neither Ake Nilsson nor I knew the two most important aspects of extracting water from dry riverbeds, namely; a) probing and drawing plan and profiles of riverbeds and b) prioritize the structures of wells, subsurface dams, weirs and sand dams. These two important criteria, which were learnt during the Dodoma assignment, have been documented in a handbook 'Water from Dry Riverbeds' in www.waterforaridland.com and in a few video films in www.thewaterchannel.tv with English narration and French subtitles.

5) The Dodoma assignment in 1990

In April 1990, a team from the Ministry of Water and I went to the Bihawana Roman Catholic Mission some 15 km south-west of Dodoma which Ake Nilsson has described in his book.

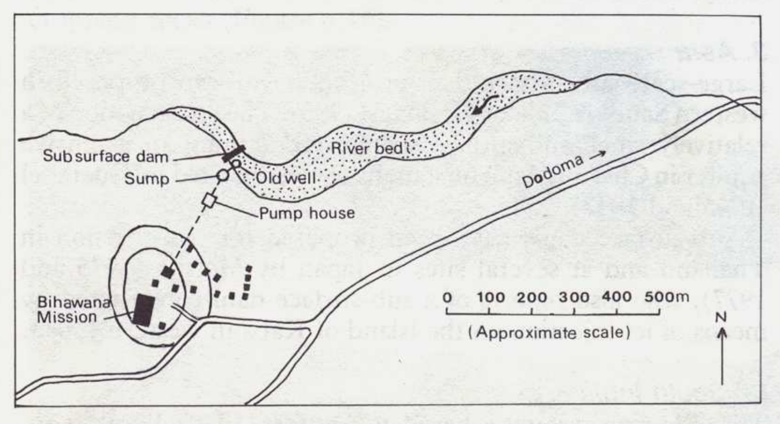


Figure 6.9. Plan of Bihawana scheme, Dodoma.

We found that a subsurface dam built of soil in a nearby riverbed in 1967 has made the mission an oasis with fruit trees, wine grapes, vegetables, fodder and good livestock, all in stark contrast to the dry and dusty landscape of Dodoma.

After the Catholic Father had shown us the subsurface dam and the farm, he invited us for a glass of the red wine he has produced himself from the vineyard, while he told us of all the benefits achieved from their subsurface dam.

The Catholic Father kindly showed us the survey and design drawings for the subsurface dam. The survey report had a plan and a longitudinal profile showing the depths of sand and water at intervals of 20 metres over a distance of 500 metres.

In the early 1950s, very appropriately the mission first sunk a well in the riverbank where the sand and water were deepest. Then in 1967, when more water was required for expansion of the farm, the subsurface dam was built of soil on an underground dyke downstream of the well. The subsurface dam raised the water level in the sand thereby increasing the storage capacity of water in the sand.

After having understood this simple and logical methodology, we had only to figure out how to measure the depth of sand and water in riverbeds? The answer was: Probe the riverbed by hammering a pointed iron rod down into the sand until it hits the floor under the sand. Pull the rod up and measure the depth of sand and water seen on the iron rod. Repeat the procedure for every 20 meters until a deep depression and a downstream dyke are found. Thereafter draw plan and profiles of the probed riverbed on millimeter graph paper and identify the deepest place for a well and the shallowest place for a subsurface dam downstream of the well.

Then estimate the volume of sand and extractable volume of water from the sand. Adapt the standard design and bill of quantities and cost to the actual site conditions. Compare the found construction cost and recurrent cost with alternative water structures. More details on the procedure can be found in “Water from Dry Riverbeds” in www.waterforaridland.com

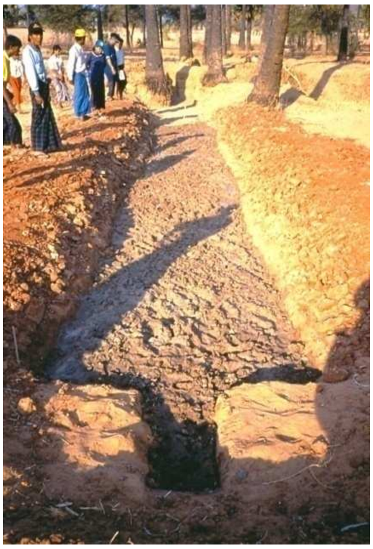
Having understood how to extract water from dry riverbeds successfully, we surveyed, designed and constructed several types of subsurface dams at Dodoma. Interestingly, our newly gained expertise was confirmed when an old man at one of the construction sites told us an interesting story: When he was a small boy around 1920, another white man built a subsurface dam of soil just where we were building ours, and the dam and its well supplied water for his community until the village got piped water recently. The old subsurface dam was found to be only 4 metres upstream from ours. The old well was exactly where our probing showed that our well should be.

A subsurface dam being built of rubble stone masonry and an old well. Dodoma 1990

6) Small subsurface dams built of soil in the 1980s, 1990s and 2000s

A subsurface dam built of soil and covered with stones at Dodoma in 1990.

One of the subsurface dams built of soil at Kibwezi, Wote and Matiliku in 1992-96.



Subsurface dams built of soil in the Dry Zone of Myanmar (Burma) in 1995-6

Training on subsurface dams in Kenya, Eritrea, Ethiopia, Uganda and South Sudan in 2000-10

7) A subsurface dam that supplied water for 40,000 people

In Hargeysa, the capital of Somaliland, an old dusty survey report from 1954 describes how Engineer S.R. Chetwynd Archer, a Chartered Civil Engineer from Tanganyika, had been invited to Hargeysa to design a water supply system from a subsurface dam for 40,000 people.

Mr Archer's report describes in detail how to survey for subsurface dams and design a subsurface dam of soil with intake chambers and distribution lines. (The report will be available shortly in the 'Briefs' of www.waterforaridland.com

The subsurface dam, its intake, pump house and distribution lines were supplying water for the capital for some 40 years.

A person stands on the remains of the subsurface dam.

The pump house situated at the deepest point in the riverbed upstream of the subsurface dam.

Then in 2004, exceptionally high rainfalls with huge flash-floods removed nearly all the sand and the upper part of the subsurface dam in the riverbed.

In 2006 only the lower part of the subsurface dam built of clayey soil could be seen.

8) A subsurface dam of soil that provides 17,000 litres of water per hour

In 2005/06, ASAL Consultants Ltd. was contracted by the new Athi and Coast Water Services Boards/Danida to design and construct 6 pilot projects to supply 68,000 people with piped water within 2 km of their homesteads in the dry parts of Kitui and Taita-Taveta. One of these 6 projects was the 'Kisasi Water Project' situated 25 km south of Kitui township. This project was designed to provide sufficient water for 20,000 people and their livestock, i.e. to cater for expansion of the present population of about10,000 people.

8.1) An entrepreneurial methodology

These 6 pilot water projects were implemented using an entrepreneurial practice whereby a Main Contractor (ASAL Consultants Ltd.) sub-contracted local expertise and labour. Two District Water Engineers were contracted as consultants on survey, design and supervision. Some 30 experienced artisans were contracted as sub-contractors, who subsequently sub-contracted about 300 local builders and trainees, half being females, for 50% of the usual salaries. The savings by paying half salaries were recorded as part of the communities' contribution towards cost-sharing and reduced construction costs.

Excavation of trenches for pipes and back-filling were also sub-contracted to several hundreds of community members, mostly women, for 50% of the usual labour cost. The savings were also recorded as the communities' contribution towards cost-sharing and reduced construction costs.

Local materials, such as hardcore (stones) and ballast (crushed stones) were made and transported to the places reachable with ox-carts and sold to the project for 50% of the market price by mostly elderly members of the communities. The savings were recorded as the communities' contribution towards cost-sharing and reduced construction costs.

The value of the communities' unpaid services, such as drawing and carrying water and sand from nearby riverbeds to construction sites, stores and accommodation for the 30 contractors and labour for clearing bush for roads, pipelines and construction sites were delivered free by the communities as part of their contribution.

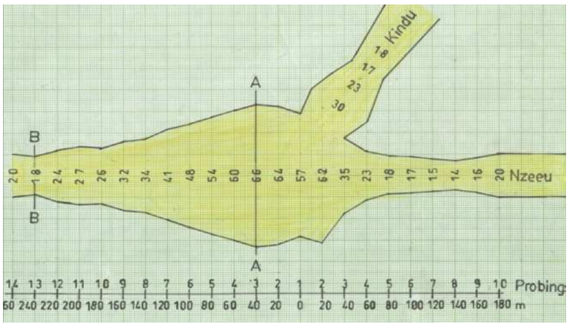
The construction cost of the 6 water projects was estimated as Ksh 156 million (US$ 2.2 million). The application of the entrepreneurial methodology reduced the construction cost by Ksh 11.5 million (US$ 0.164 million), while it also promoted local employment and business for thousands of people living in the famine stricken dry land of Kitui and Taita-Taveta.

8.2) Mobilization and training of communities for the construction works

The first training sessions took place at public meetings called for by the District Commissioners. The Main Contractor informed the communities of the objectives and methodologies which would be discussed with 20 committee members from each of the 6 projects during a week of training at a centre at Kibwezi. The one-week training on community management of construction activities involved 120 committee members and 113 builders, 1/3 being female.

8.3) Probing, plan and profiles of Nzeeu riverbed

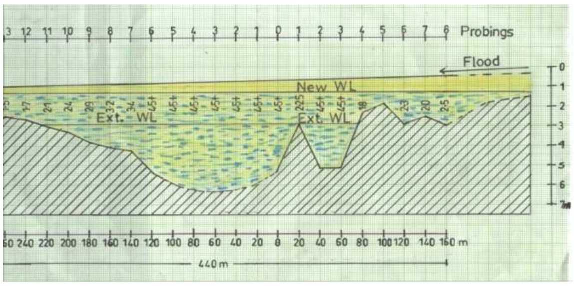
DOWNSTREAM UPSTREAM



The surveyors started probing from the junction of Nzeeu and Kindu riverbed at point 0 and downstream.

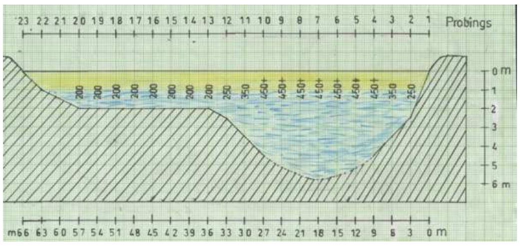
Thereafter they returned to point 0 and surveyed upstream as shown on these sketches.

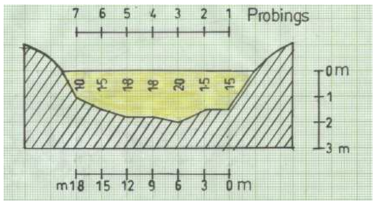
Plan



The plan and profile show a large underground water reservoir at No. 3 and an underground dyke with a narrow point at probing point No. 13 which is a perfect foundation for either a subsurface dam a weir or a sand dam

Longitudinal profile





Cross profile of extraction point for intake. Cross profile for subsurface dam.

The Survey Report will be available shortly under 'Briefs' in www.waterforaridland.com

Three options for increasing the volume of sand and water in Nzeeu riverbed

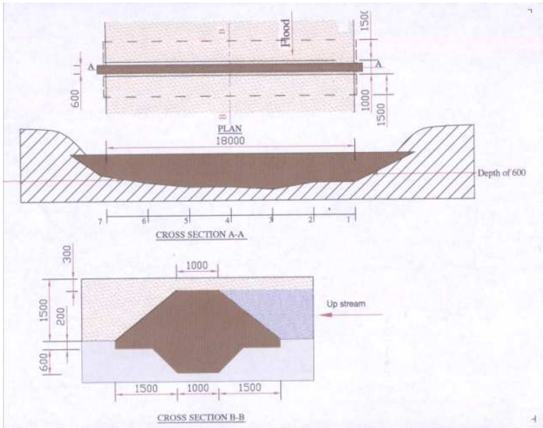
	Max. depth m	Max. width m	Throw-back m	1/6	Sand Volume m^3	% Water extraction	Water volume m^3
Existing	5.00	66.00	380.00	1/6	20,900	30	6,270
Subsurface dam	0.8 + 5.00	68.00	420.00	1/6	27,608	30	8,282
Weir	1.4 + 5.00	70.00	440.00	1/6	32,853	30	9,856
Sand dam	2.3 + 5.00	72.00	480.00	1/6	42,048	30	12,614

Reference: 'Water from Dry Riverbeds' in www.waterforaridland.com

8.4) A subsurface dam built of soil

The downstream underground flow of water between the sand particles of Nzeeu riverbed was stopped by constructing a 20 meter long and 2.1 meter deep subsurface dam built of clayey soil taken from nearby riverbanks onto a natural dyke across the riverbed.

The crest of Nzeeu subsurface dam.



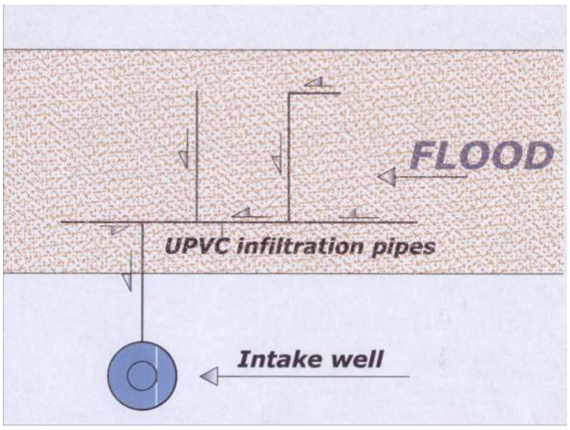
Design of Nzeuu subsurface dam.

Bill of Quantity and cost of Nzeuu Subsurface Dam

Description	Unit	Quantity	Unit cost 2005 Ksh	Total cost 2005 Ksh	Value of community contribution
Labour cost					
Surveyor/designer	Surveyor	1 x 2 days	1,200/day	2,400	
Supervisor	Supervisor	1 x 6 days	1,200/day	7,200	
Contractor	Contractor	1 x 22 days	800/day	17,600	
Artisans	Artisans	2 x 20 days	200/day	8,000	8,000
Trainees	Trainees	4 x 20 days	100/day	8,000	8,000
Labourers	Labourers	10 x 20 days	100/day		8,000
Cost of labour				**43,200**	**24,000**
Materials					
Clayey soil	Tonnes	69	100	6,900	6,900
Cost of materials				**6,900**	**6,900**
Transport of materials					
Hiring suction pump					
Tractor trailer loads	3 tonnes Days	23 loads	900	20,700	10,350
Hiring dewatering pump		4 days	800	3,200	
Cost of trans. and pump				**23,900**	**10,350**
Cost and value				**74,000**	**41,250**
Cost of subsurface dam				**115,250**	

8.5) Infiltration pipes

72 m of 160 mm perforated PVC pipes were laid as deep as possible in trenches dug in the sand. The pipes drain water from the sand into the well.

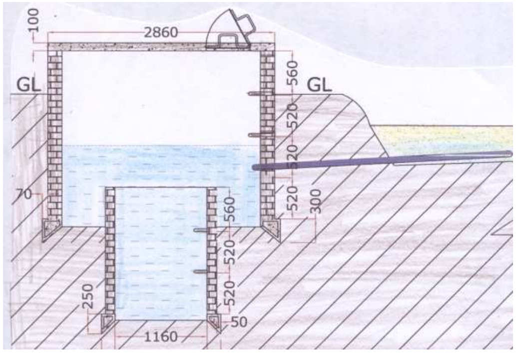


Bill of Quantity and cost of 72 metres of infiltration pipe

Description Perforating and laying 72 metres of 160 mm PVC pipe deep in a riverbed and sloping towards a well in the riverbank	**Unit**	**Quantity**	**Unit cost** **2005** **Ksh**	**Total cost 2005** **Ksh**	**Value of community contribution** **Ksh**
Labour cost					
1 Surveyor	Surveyor	4 days	1,200/day	4,800	
1 Supervisor	Supervisor	6 days	1,200/day	7,200	
1 Contractor with	Contractor	1 x 15 days	800/day	12,000	
2 artisans and	Artisans	2 x 15 days	200/day	6,000	6,000
4 trainees	Trainees	4 x 15 days	100/day	6,000	6,000
10 labourers	Labourers	10 x 15 days	100/day	15,000	15,000
Total cost of labour				**51,000**	**27,000**
Materials					
Dewatering suction pump	8 days		800	6,400	
Perforated PVC pipes,160 mm	6 m length	14 pipes	3,100	43,400	
Cost of materials				**49,800**	
Transport of materials					
Tractor trailer loads	3 tonnes	1 load	900	900	450
Cost of transport				**900**	**450**
Cost and value				**101,700**	**27,450**
Total cost and value				**129,150**	

8.6) The intake well

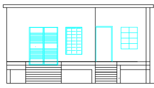
The trapped water in the sand of the riverbed is extracted from a 3 metre wide and 4 metre deep hand-dug well sunk in the deepest part of the riverbank which supplies 17,000 litres of water per hour for about 8 hours every day.



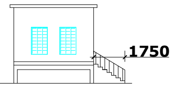
Bill of Quantity and cost of the Nzeeu intake well

Description 8 m deep intake well	**Unit**	**Quantity**	**Unit cost 2005 Ksh**	**Total cost 2005 Ksh**	**Value of community contribution**
Labour cost					
1 Surveyor	Surveyor	2 days	1,200/day	2,400	
1 Supervisor	Supervisor	10 days	1,200/day	12,000	
1 Contractor	Contractor	1 x 20 days	800/day	16,000	
2 artisans	Artisan	2 x 20 days	200/day	8,000	8,000
2 trainees	Trainees	2 x 20 days	100/day	4,000	4,000
10 labourers	Labourers	10 x 20 days	100/day	20,000	20,000
Cost of labour				**62,400**	**32,000**
Materials					
Cement	50 kg bags	10	600	6,000	
River sand	Tonnes	3	200	600	600
Crushed stones	Tonnes	3	600	1,800	1,800
Curved well blocks	Blocks	700	50	35,000	14,000
Galvanised wire, 4mm	Kg	50	150	7,500	
Iron bar, Y8	20 m length	10	500	5,000	
Dewatering pump	Days	10 days	800	8,000	
Cost of materials				**63,900**	**16,400**
Transport of materials					
Tractor trailer loads	3 tonnes	1 load	900	900	900
Cost of transport				**900**	**900**
Cost and value				**127,200**	**49,000**
Total cost				**176,200**	

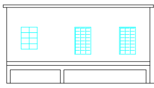
8.7) The elevated pump house



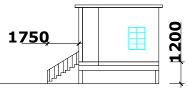
Front elevation (mm)



Eastern end elevation (mm)



Rear elevation (mm)



Western end elevation (mm)

Bill of quantities and cost of the elevated pump house

Description	Unit	Quantity / Days	Unit cost (Ksh)	Total cost (Ksh)	Community contribution
Labour					
Supervisor	Supervisor	1 x 14 days	1,200/day	16,800	
Contractor	Contractor	1 x 42 days	900/day	37,800	
artisans, trainees and	Artisans	6 x 40 days	200/day	48,000	48,000
community labourers	Trainees	10 x 40 days	100/day	40,000	40,000
	Labourers	10 x 7 days	100/day	Free	4,000
Cost of labour				**142,600**	**102,000**
Materials					
Bags of cement	50 kg bags	160	600	96,000	
River sand	Tonnes	34	200	Free	3,400
Crushed stones, 1/2" to 1"	Tonnes	27	600	16,200	16,200
Concrete blocks,6"x 9"x18"	Units	1,000	50	50,000	24,000
Water	Oil-drums	150	100	Free	15,000
Y 8 twisted iron bars	Lengths	44	350	15,400	
Y 10 twisted iron bars	Lengths	100	600	60,000	
Y 12 twisted iron bars	Lengths	38	700	26,600	
Barbed wire	25kg	4	3,000	12,000	
Binding wire, 1mm soft	Kg	40	100	4,000	
Water proof cement	Kg	6	60	360	
6" x 1" timber	Metres	434	75	32,550	
4" x 2" timber	Metres	124	75	9,300	
Poles, 2.5 meters long	Kg	400	40	16,000	
Nails, 4"	Kg	15	80	1,200	
Nails, 2 1/2"	Kg	15	80	1,200	
Nails, 3"	Kg	20	80	1,600	
Nails, 2"	Kg	15	80	1,200	
Lime	25 kg	4	400	1,600	
Bitumen paint(Rc2)	5 litres	3	500	1,500	
Terpentine	5 litres	1	200	200	
Door 210cm x 150cm	Units	1	22,000	22,000	
Steel door 210cm x 90cm	Units	1	8,000	8,000	
Window 150cm x 90cm	Units	5	4,400	22,000	
Windows 120cm x 90cm	Units	3	3,200	9,600	
Paint (Bermuda blue)	Litres	1	1,400	1,400	
Cost of materials				**409,910**	**58,600**
Transport of materials					
Hardware lorries	7 tonnes	2 loads	5,000	10,000	
Tractor loads	3 tonnes	37 loads	900	33,300	
Cost of materials				**43,300**	**16,650**
Cost and value for elevated pump house				**595,810** **773,060**	**177,250**

8.9) Pump and generator

The pump in the Nzeeu pump house is a Grundfoss CR15-17, 15.0 KW, 3 Phase booster pump, with a capacity of 19m^3/hr at 154 m head. Together with a control panel and 60A isolator, float switch, chlorine doser and installation the unit cost was Ksh 560,305 in December 2004.

The pump in the photo is a Grundfoss CR32-6, 11.0 KW, 3 Phase electric booster pump with a capacity of 32 m^3/hr at 71 m head that is installed in the Mwiwe pump house. Together with accessories and installation the cost was Ksh 558,200 in Dec. 2004

The electric pump

The diesel generator seen in the photo is an Atlas Copco 41, KVA, QUB41 that powers the Mwiwe pump. The cost was Ksh 876,550 in December 2004.

The Nzeeu pump is powered by an Atlas Copco diesel generator with a bigger capacity of 41 KVA, QUB41 that powers the pump. The cost was Ksh 876,550 in December. 2004.

The diesel generator

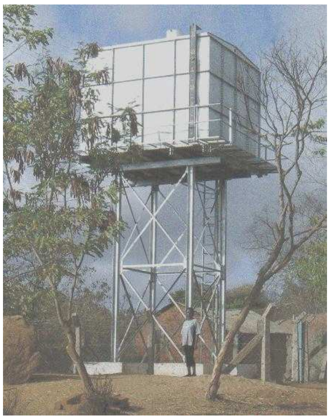
8.10) The rising main pipe line

The rising main from the pump house to the elevated steel tank consists of 85 lengths equal to 5.31 km of 100 mm diameter MG galvanized iron (G.I.) pipes. The pipes were laid in a 5.1 km long trench being 40 cm wide and 60 cm deep. The community was paid Ksh 10 for excavating 1 metre of trench and Ksh 10 for back-filling 6 metres of trenches after the pipes had been laid. A similar amount was recorded, but not paid, as that was the communities' contribution towards cost-sharing.

The cost of the rising main pipe from the pump house to the head storage tank was Ksh 7,461,435 .

An excavated trench for pipes.

8.11) The head storage tank



The head tank for the Kisasi Water Project is a 50 m^3 elevated tank made of steel plates costing Ksh 1,277,621. The tank is situated at a distance of 5.3 km from the Nzeeu intake and at a height of 74.2 m above the intake. The pumping head, with 100 mm and 80 mm G.I. pipes, delivering 19 m^3/hr is:

Delivery head	=	74.200 m
Frictional losses	=	57.023 m
Tank height	=	8.000 m
10% residual (extra) head	=	13.922 m
Required pump capacity		**153.15 m**
Capacity of installed pump		**154.00 m**

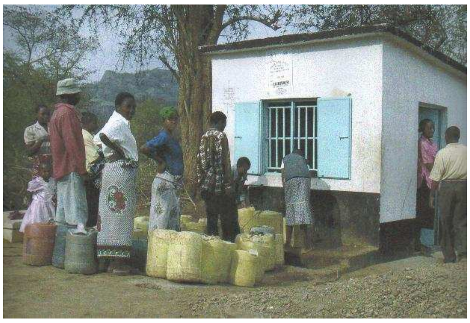
8.12) Distribution pipelines

Water is gravitated from the head tank to 10 water kiosks through 12.6 km of distribution pipelines. The pipes were laid in a 12,625m long trench being 40 cm wide and 60 cm deep. The community was paid Ksh 10 for excavating 1 metre of trench and Ksh 10 for back–filling 6 metres of trenches after the pipes had been laid. A similar amount was recorded, but not paid, as that was the community contribution towards cost- sharing.

Labour cost of pipe laying	**Ksh**
16 lengths equal to 96m of 150mm diameter GI pipe @ Ksh 18 per m	1,728
660 lengths equal to 3,960m of 160mm diameter uPVC pipe @ Ksh 14 per m	55,440
40 lengths equal to 240m of 100mm diameter GI pipe @ Ksh 16 per m	3,840
768 lengths equal to 4,608m of 110mm diameter uPVC pipe @ Ksh 12 per m	55,296
30 lengths equal to 180m of 80mm diameter GI pipe@ Ksh 14 per m	2,520
370 lengths equal to 2,220m of 90mm diameter uPVC pipe @ Ksh 10 per m	22,200
20 lengths equal to 120m of 50mm diameter GI pipe@ Ksh 12 per m	1,440
200 lengths equal to 1,200m of 63mm diameter uPVC pipe @ Ksh 8 per m	9,600
Total cost of laying pipes	**Ksh 152,064**

Material cost of the 12.625 km piping	**Ksh**
Cost of the pipes	7,000,996
Cost of the sluice valves, gate valves, air valves	231,332
Fittings (15% cost of pipes)	1,050,150
Pipe contractor for laying pipes	152,064
Excavation of 12.625 km of trench	126,250
Cost of backfilling the pipe @ Ksh 10 per 6 m	21,042
Supervision @ 15% of Ksh 147,292	22,094
Cost of community contribution	147,292
Total cost of the gravity main, excl. survey, design and management	8,751,220
15% of total cost for survey, design and management	1,312,683
Grand total for the 12.625 km long gravity main	**Ksh 10,063,903**
Total cost of laying 12.625 meters of gravity pipeline	**Ksh 10,215,967**

8.13) 10 water kiosks



The distance between water kiosks should be minimum 2 km and there should be a water kiosk where the pipeline passes through a market.

10 water kiosks were built along the 12 km long gravity distribution line.

Bill of quantities and cost of 3 water kiosks

Description	Unit	Quantity/ Days	Unit cost Ksh	Total cost Ksh	Community contribution
Labour					
A Supervisor	Supervisor	1 x 6 days	1,200/day	7,200	
A Contractor	Contractor	1 x 20 days	800/day	16,000	
6 Artisans	Artisans	6 x 12 days	200/day	14,400	14,400
12 Trainees	Trainees	12 x 12 days	100/day	14,400	14,400
3 Community labourers	Labourers	3 x 6days	100/day	Free	1,800
Cost of labour				**52,000**	**30,600**
Materials					
Bags of cement	50 kg bags	18 x 3 = 54	600	32,400	
River sand	Tonnes	9 x 3 = 27	200	Free	5,400
Ballast, 1/2" to 1"	Tonnes	4 x 3 = 12	600	7,200	7,200
Hardcore 2" to 6"	Tonnes	6 x 3 = 18	200	3,600	3,600
Concrete blocks, 6"x 9"x18"	Units	250 x 3 = 750	50	37,500	18,000
Water	Oil-drums	15 x 3 = 45	100	Free	4,500
Y 8 twisted iron	Lengths	7 x 3 = 21	350	7,350	
Weld mesh 8' x 4'	Sheets	7 x 3 = 21	370	7,770	
Binding wire, 1mm soft	Kg	2 x 3 = 6	100	600	
6" x 1" timber	Metres	63 x 3 = 189	75	14,175	
4" x 2" timber	Metres	12 x 3 = 36	75	2,700	
Poles, 2.5 meters long	Lengths	24 x 3 = 72	40	2,880	
Nails, 4"	Kg	2 x 3 = 6	80	480	
Nails, 2 1/2"	Kg	2 x 3 = 6	80	480	
Galvanised pipe, 1"	Length	1 x 3 = 3	1,800	5,400	
Galvanised pipe, 3/4"	Length	1 x 3 = 3	1,130	3,390	
Galvanised elbows, 3/4"	Unit	7 x 3 = 21	85	1,785	
Galvanised sockets, 3/4"/1"	Unit	1 x 3 = 3	80	240	
Galvanised elbows, 1"	Unit	1 x 3 = 3	45	135	
Galvanised Tees, 3/4"	Unit	3 x 3 = 9	90	810	
Gate valve, 1"	Unit	1 x 3 = 3	575	1,725	
Gate valves, 3/4"	Unit	3 x 3 = 9	510	4,590	
Water metre, Kent	Unit	1 x 3 = 3	4,920	14,760	
Steel door, 1,830 x 910 mm	Unit	1 x 3 = 3	4,400	13,200	
Steel window, 98 x 910 mm	Unit	1 x 3 = 3	3,600	10,800	
Lime	25 kg bag	1 x 3 = 3	400	1,200	
Bitumen and oil paint	Litres	7 x 3 = 21	1,225	25,725	
Cost of materials				**200,895**	**34,200**
Transport of materials					
Hardware lorries	7 tonnes	1 load	5,000	5,000	
Tractor trailer loads	3 tonnes	24 loads	900	21,600	10,800
Total for transport				**26,600**	**10,800**
				279,495	**75,600**
Cost and value of 3 kiosks				**355,095**	
Cost and value of 1 kiosk				**118,365**	

8.14) Training on financial management

During one week training shortly before the completion of the construction works, the 120 committee members were trained in the various aspects of financial management of their water projects, such as:

1) The running (operational) costs of their water project

2) Determine the cost of a jerry-can of water to cover the running costs, i.e. which must cover the running costs as well as savings for repair and maintenance

3) Control and monitoring income and expenditure

4) Record keeping of sale of water from the kiosks

5) Budgeting and planning ahead

6) Bank procedures

7) Quotations for maintenance and repairs

8) By-laws and elections

8.15) Summary of costs

Actual cost + value of community work

	Ksh
A subsurface dam built of soil, 20 m long, 2.1 m deep, 4 m wide ..	115,250
Infiltration pipes, 72 m of D 160 mm PVC	129,150
An intake well, 3 m wide and 4 m deep	176,200
An elevated pump house with one room accommodation	773,060
An electric booster pump with a capacity of 19cu.m/h. At 154 m head	558,200
A diesel generator with a capacity of 41 KVA	876,550
5.3 km G.I. 100 mm rising main pipe	7,461,435
An 50 cu.m. elevated steel tank	1,277,621
12.6 km distribution pipe	10,215,967
10 water kiosks @ Ksh 118,365	1,183,650
Total construction cost	22,767,083
+ 15% survey, design and supervision	3,415,062
GRAND TOTAL	**Ksh 26,182,145**