

UNHCR Circular Water Reservoir 50m³

D317-2016a

**Tools and Guidance for
Refugee Settings**



UNHCR
The UN Refugee Agency

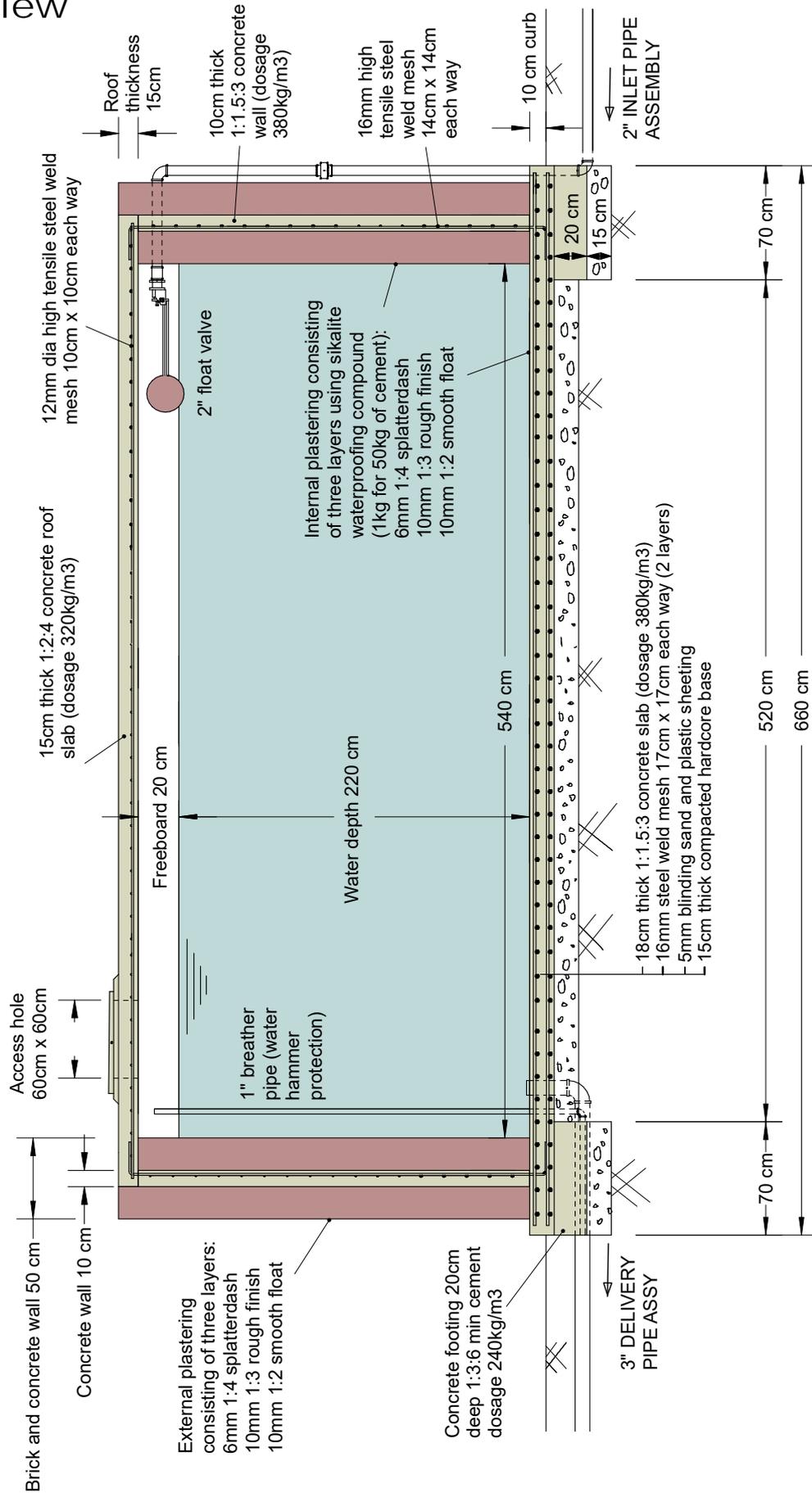
UNHCR Standardized Designs for Refugee Settings Circular Reinforced Concrete Water Reservoir 10m³

FOREWORD

These circular reinforced concrete water reservoir designs form part of UNHCR’s series of Standardized WASH Design Guidelines for Refugee Settings which are the result of an extensive review process with WASH actors active in refugee settings. It is recognized that the Standardized WASH Designs will require continuous review and amendment in response to changes in engineering best-practice and feedback from the field. Therefore further review will be managed by a Technical Review Committee which will meet regularly to discuss issues related to the use of the design and an annual review will be reported back to the WASH community. More urgent amendments will be reported as, and when, required. Note that this reservoir is based on a design prepared by International Rescue Committee Ethiopia.

FOREWORD	1
ENGINEERING DRAWINGS	2
STEP-BY-STEP ASSEMBLY DRAWINGS	5
BILL OF QUANTITIES	6
VISUAL BILL OF QUANTITIES	7
SPECIFICATIONS FOR CONSTRUCTION OF WATER SUPPLY RELATED INFRASTRUCTURE IN REFUGEE SETTINGS	8
300SCOPE	8
301SITE SELECTION	8
302PREVENTION OF SURFACE OR GROUNDWATER CONTAMINATION	8
303SPECIFICATIONS OF COMMON CONSTRUCTION MATERIALS	8
304SOAKAGE PIT SIZING BASED ON SOIL INFILTRATION RATES	10
305SLOPES FOR WATER COLLECTION POINTS AND DRAINAGE CHANNELS	11
306SURFACE FINISHES AT PUBLIC WATER COLLECTION POINTS	11
UNHCR STANDARD DESIGNS FOR WATER SUPPLY	12
USEFUL REFERENCES	13

Sectional View



D-317

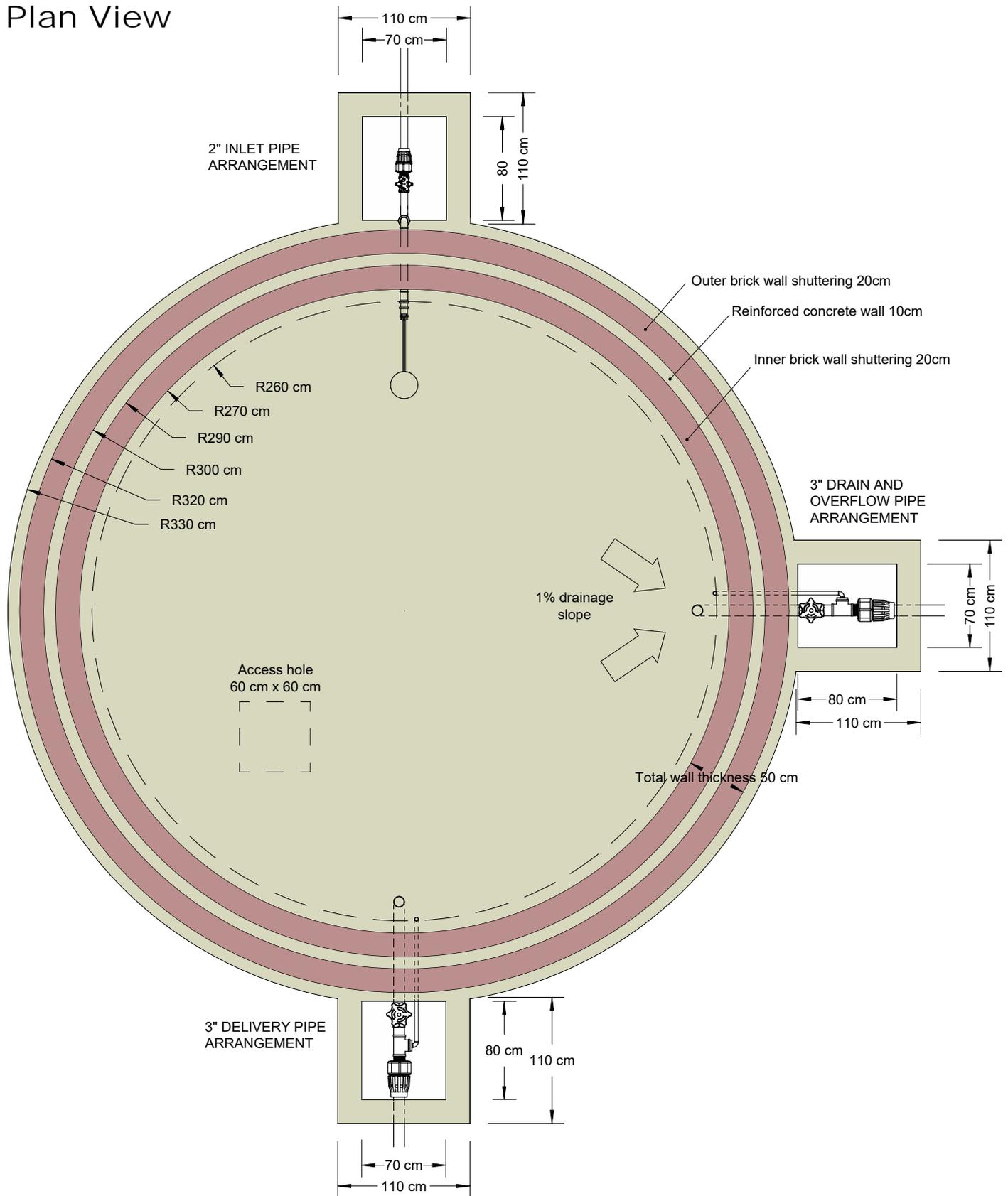
TITLE
50m³ Round Water Reservoir
Sectional View
PROJECT
Project Name, Country

DRAWN BY
B. Harvey - 11/10/16
APPROVED BY
M. Burt - 15/11/16
SCALE
1:30

UNITS
metres
SHEET
1 of 3
DATE PUBLISHED
15/11/16



Plan View



NOTES

1. Ensure concrete is not over-watered = risk of cracking (no more than 1/4 height reduction during slump test).
2. Slabs to be cast in one continuous operation. All concrete works to be well rodded (preferably vibrated).
3. Ensure all concrete works are kept damp and out of direct sunlight for at least 7 days while curing.

D-317

TITLE
50m³ Round Water Reservoir
 Plan View and General Layout
 PROJECT
 Project Name, Country

DRAWN BY
 B. Harvey - 11/10/16
 APPROVED BY
 M. Burt - 15/11/16
 SCALE
 1:40

UNITS
 metres
 SHEET
 2 of 3
 DATE PUBLISHED
 15/11/16



Pipe Assembly Detail

3" DELIVERY PIPE ASSEMBLY

220cm x 1" Ø GI Pipe

30cm x 3" Ø GI Pipe

3" GI Elbow

125cm x 3" Ø GI Pipe

3" Gate Valve

3" GI Nipple

3" GI Tee

90mm Ø PE Pipe Adaptor (Male)

90mm Ø PE Pipe

3" x 1" Ø GI Reducer (M-F)

1" GI Nipple

1" GI Elbow

25cm x 1" Ø GI Pipe

1" GI Elbow

150cm x 1" Ø GI Pipe

3" DRAINAGE PIPE ASSEMBLY

DRAINAGE PIPE ASSEMBLY EXACTLY THE SAME AS DELIVERY PIPE EXCEPT VERTICAL 3" DRAIN PIPE IS 5CM SHORTER.

2" INLET PIPE ASSEMBLY

56cm x 2" Ø GI Pipe

2" GI Elbow

2" GI Socket

2" Float Valve Assembly

145cm x 2" Ø GI Pipe

2" Ø GI Union (F-F)

105cm x 2" Ø GI Pipe

2" GI Elbow

35cm x 2" Ø GI Pipe

3" Gate Valve

90mm Ø PE Pipe Adaptor (Male)

63mm Ø PE Pipe

Notes

1. Alternative valve and pipe arrangements may be used if the inlet or outlet pipe diameters are different.
2. Valves to be positioned centrally. Valve box dimensions may be increased or reduced to match valve assembly arrangements.
3. The bottom of the valve box should be kept open (i.e. filled with compacted hardcore) to allow any excess water to drain.

DRAWN BY
B. Harvey - 11/10/16

APPROVED BY
M. Burt - 15/11/16

SCALE
1:25

UNITS
metres

SHEET
3 of 3

PUBLISHED
15/11/16

STEP-BY-STEP ASSEMBLY DRAWINGS

Please follow the step-by-step procedure for the 30m³ water reservoir D316/2016a. Note that the process is similar but the dimensions will be different.

1. Area of 6m x 6m to be cleared and perfectly leveled. Check all posts are the same level as the centre post. Mark out the inner and outer foundation radii using 5cm x 5cm wooden posts. All posts 10cm above ground and exactly the same level. This level will become the upper edge of the reservoir curb.

2. Excavate the 70cm wide footing and valve boxes to a level 15cm below the top of the posts. The valve boxes may need to be resized to fit the size of the valves being installed. These sites are for 3" valves.

3. Excavate the floor slab area to a level 30cm below the top of the posts.

4. Install wooden shutter to the top of the posts. ENSURE WOODEN SHUTTERING IS PERFECTLY SQUARE AND LEVEL. Ensure hardcore base is well compacted. Allow 20cm wall thickness for the valve boxes. Add 15cm of crushed and compacted hardcore covered with 1cm blinding sand into footing, valve boxes and below slab.

5. Position delivery pipe assembly and drain pipe assembly centrally. Breather pipe on delivery man to prevent water hammer. Breather pipe on drain assembly provides overflow function. Set delivery pipe outlet 5cm above reference post. Set drain pipe outlet to same height as reference post.

6. Tightly block the pipe exits with paper or plastic bags to prevent them becoming blocked with concrete during casting. Valve assemblies to be positioned centrally in valve box shuttering.

7. 2.69m³ footing concrete 20cm thick (1:1.5:3 cement dosage 240 kg/m³). Ensure hardcore base is well compacted. Remove reference post. Ensure footing is kept damp and out of direct sunlight during curing.

8. Blind the foundation layer with 5mm sand then cover with plastic sheeting. This is essential to eliminate the risk of shrinkage cracks and ensure the floor structure is able to 'float' during curing. Position lower panel 2cm above foundation base. Install two 4.05m² x 60cm panels of 12mm diameter high tensile steel weld mesh 14cm spacing each way 10cm apart.

9. Bend 16-8m x 2.65m section of 12mm diameter high tensile steel weld mesh 14cm spacing each way into a cylinder with radius 2.65m. Bend 25cm of the upper and lower rebar projects by 90 degrees. Position wall rebar 2cm above foundation base.

10. 4.6m³ concrete 15cm thick slab (1:1.5:3 cement dosage 380 kg/m³). ENSURE CONCRETE IS NOT OVER-WATERED = RISK OF CRACKING. SLUMP TEST (NO MORE THAN 1/3 SLUMP HEIGHT REDUCTION).

11. Ensure slab is kept damp and out of direct sunlight for at least 7 days during curing.

12. Prepare 20cm thick brick masonry wall shuttering. The wall thickness will be 10cm. There should be 2.5cm space on the inner side of the weld-mesh and 7.5cm on the outer.

13. Interior shuttering wall height 2.0m.

14. Exterior shuttering wall height 2.14m.

15. 3.4m³ concrete 10cm thick walls (1:1.5:3 cement dosage 360 kg/m³). Concrete should be well rodded to prevent voids or bubbles. Ideally with spikes vibrator. Prepare roof shuttering support trusses 198cm high.

16. Note that these support timbers will need to be removed piece by piece through the roof slab access manhole once the roof slab is cured. They should be screwed or lightly nailed together.

17. Install 1.19m diameter high tensile steel weld mesh 14cm spacing each way. Weld mesh to be positioned 2cm above wooden formwork base. Prepare shuttering for 96cm x 60cm access hole near one corner. The shutter should be 17cm (3cm higher than the roof slab).

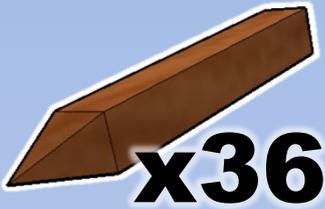
18. 2.8m³ concrete 14cm thick slab (1:2:4 cement dosage 320 kg/m³). Take care to ensure correct granulometry of aggregate 12-25mm. 3cm high concrete lip 7cm wide.

BILL OF QUANTITIES

Description	QTY
Wooden Stakes (65cm x 5cm x 5cm)	36 pcs
Wooden Planks (4m x 20cm x 2.5cm)	46 pcs
Wooden Posts (4m x 5cm x 5cm)	9 pcs
Wooden Beams (4m x 5cm x 2.5cm)	9 pcs
Nails (6cm Galvanized)	4 kg
High Tensile Steel Weld-Mesh Ø12mm 10cm x 10cm	36 m ²
High Tensile Steel Weld-Mesh Ø16mm 17cm x 17cm	85 m ²
High Tensile Steel Weld-Mesh Ø16mm 14cm x 14cm	57 m ²
Tying Wire Ø 1mm	1 kg
Plastic Sheeting	36 m ²
Inlet Pipe Assembly (2" Gate Valve, 2" GI Pipe x 35cm, 2" GI Elbow, 2" GI Pipe x 105cm, 2" GI Union, 2" GI Pipe x 105cm, 2" GI Elbow, 2" GI Pipe x 16cm, 2" GI Socket, 2" Float Valve)	1 pc
Outlet Pipe Assembly (3" GI Tee, 3" GI Nipple, 3" Gate Valve, 3" GI Pipe x 85cm, 3" GI Elbow, 3" GI Pipe x 105cm, 3" GI Pipe x 30cm, 3" – 1" GI Reducer (M-F), 1" GI Nipple, 2" GI Elbow, 1" GI Pipe x 110cm, 1" GI Pipe x 220cm)	1 pc
Drain Pipe Assembly (3" GI Tee, 3" GI Nipple, 3" Gate Valve, 3" GI Pipe x 85cm, 3" GI Elbow, 3" GI Pipe x 105cm, 3" GI Pipe x 25cm, 3" – 1" GI Reducer (M-F), 1" GI Nipple, 2" GI Elbow, 1" GI Pipe x 110cm, 1" GI Pipe x 220cm)	1 pc
Metallic Valve Box Covers (70cm x 70cm x 2mm)	4 pcs
Coarse Sand	18.5 m ³
Bricks 20cm x 9cm x 6cm	12,000 pcs
Coarse Gravel (12mm – 25mm)	15.6 m ³
Cement (50kg sacks)	155 sacks
Compacted Hardcore Sub-Base	5.4 m ³

Bill of Quantities

1. **Wooden Stakes (pc)**
5cm x 5cm x 65cm



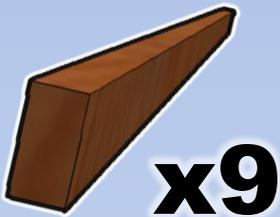
2. **Wooden Planks (pc)**
2.5cm x 20 cm x 4m



3. **Wooden Posts (pc)**
5cm x 5cm x 4m



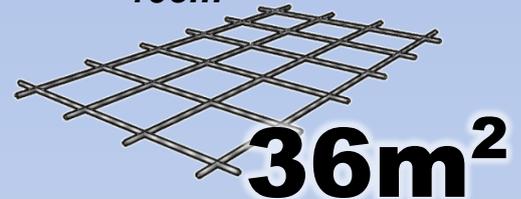
4. **Wooden Beams (pc)**
10cm x 5 cm x 4m



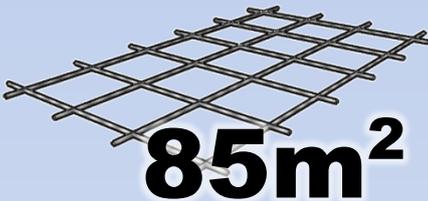
5. **Nails 6cm (kg)**



6. **Steel Weld-Mesh**
12mm Ø x 10cm x 10cm



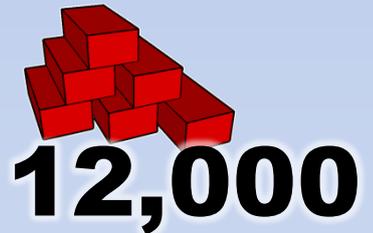
7. **Steel Weld-Mesh**
16mm Ø x 17cm x 17cm



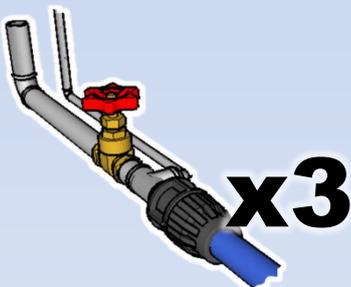
8. **Steel Weld-Mesh**
16mm Ø x 14cm x 14cm



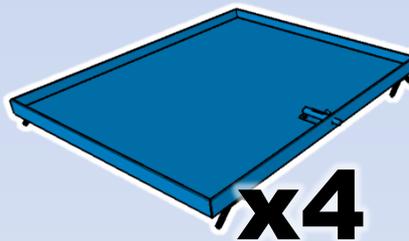
9. **Bricks 20cm x 9cm x 6cm**



10. **Valve and Pipe Assemblies (pc)**



11. **Metallic Covers 70cm x 70cm x 2mm**



12. **Cement 50kg (sacks)**



13. **Sand (m3)**



14. **Gravel (m3)**



15. **Compacted Crushed Hardcore Base (m3)**



SPECIFICATIONS FOR CONSTRUCTION OF WATER SUPPLY RELATED INFRASTRUCTURE IN REFUGEE SETTINGS

300 SCOPE

300.1 These design guidelines specifically define the quality of materials and workmanship to be used when constructing water supply related infrastructure in refugee settings. A description of principles of water supply programmes in refugee settings, in addition to technical options and their advantages and disadvantages, can be found in the UNHCR WASH Manual.

301 SITE SELECTION

301.1 A basic requirement is that the site selected for water supply related infrastructure is free from the risk of high winds, flooding, subsidence, or erosion.

302 PREVENTION OF SURFACE OR GROUNDWATER CONTAMINATION

302.1 UNHCR and WASH actors must ensure that all water supply related infrastructure including treatment systems and soakaway systems do not contaminate surface water or shallow groundwater sources. Risks are generally low and related to contamination from water treatment chemicals, water treatment by-products and sludges and contamination from wastewater.

302.2 All tapstands, or other water collection and usage points, should be equipped with adequately designed soakage systems located at least 30 metres away from groundwater sources. The bottom of any pit or soakaway must be at least 1.5m above the highest average groundwater table level. These distances should be increased for fissured rocks and limestone.

302.3 In some situations temporary groundwater contamination from on-site soakage systems may not be of immediate concern if the groundwater is non-potable. An example of this can be found in areas where groundwater is heavily saline beyond drinking water health limits of $1,500\mu\text{S}/\text{cm}^2$. In all cases, local legislation should be respected.

303 SPECIFICATIONS OF COMMON CONSTRUCTION MATERIALS

303.1 Gravel used for constructing concrete footings and slabs must be clean and free from mud, dust and plant material. Rounded aggregates are preferred. If crushed stone aggregates are used then additional cement should be added (see table below). UNHCR and WASH actors must ensure that only aggregates between 12mm and 25mm are used to prevent inter granular crack propagation across load bearing concrete structures (e.g. tapstand floor slabs, water reservoir roof slabs, and columns used in reinforced concrete water towers) and to ensure an adequate covering of steel reinforcement bars.

- 303.2 Sand used for water supply related concrete works should be coarse (no fines), clean and free from mud, dust and plant material.
- 303.3 Water should be non-saline and free from organic matter.
- 303.4 Cement must be fresh (manufactured in the last three months) dry, and should be stored in a safe, dry, place at least 15cm off the ground.
- 303.5 Reinforcement bars should be free from rust and of the correct type and size for concrete construction work (typically a characteristic yield stress of at least 210 N/mm²). Steel reinforcement should be placed as per the designs (typically 7/8 of the slab or wall thickness) to ensure the bars function correctly in tension. All bars should have at least 12mm concrete covering under every bar. All laps should be a minimum of 25cm.
- 303.6 Concrete mix strengths Mass concrete footings should be cast with a 1:3:6 concrete mixture with a minimum cement dosage of 240 kg/m³. Concrete slabs and drainage channels should be cast as single continuous structures using a 1:2:4 concrete mixture with a minimum cement dosage of 320kg/m³. Water retaining structures (reservoir walls and bases) should be cast using a waterproof 1:1.5:3 concrete mixture (note that 1:2:4 is not waterproof) with a minimum cement dosage of 380kg/m³. Additional cement should be added if hand mixing (see table below). Care should be taken to ensure that concrete mixtures are not over watered (bucket slump test should show no greater than ¼ reduction in the slump height). Cast concrete works should be immediately covered with plastic sheeting, straw, cement bags, sacking or leaves to keep the concrete moist and cool during the full curing period. All concrete should be well rodded (ideally vibrated) to remove air voids. The concrete should be cured with frequent watering at least twice daily for at least 10 days before use. The quantities of cement, sand and aggregate for 1m³ of concrete can be found in the table below.

Concrete Mix	Quantity of Cement in Kg				Coarse Dry Sand (m ³)	Aggregate 12mm – 25mm (m ³)
	Machine Mixing		Hand Mixing			
	Gravel	Broken Stone	Gravel	Broken Stone		
1:1.5:3	370	390	380	400	0.42	0.84
1:2:4	290	310	300	320	0.45	0.90
1:3:6	190	210	200	220	0.46	0.92

Source: Indian Civil Engineer's Handbook (Khanna, 2001)

- 303.7 Cement plasters Interior and exterior plasters should be applied as three layers as follows:

- 6mm 1:4 splatterdash
- 10mm 1:3 rough finish
- 10mm 1:2 smooth float

Each layer should preferably be applied when the previously layer is still 'green' (not fully cured). Each layer should be thoroughly wetted and the previously layer keyed (scratched) to ensure proper bonding. Interior

plasters of water retaining structures should be mixed with sikalite waterproofing compound (1kg per 50kg cement). The quantities of cement and sand for a 100m² of plaster can be found in the table below.

	100m ² 6mm thick		100m ² 12mm thick	
	Cement (kg)	Sand (m3)	Cement (kg)	Sand (m3)
1:4 splatterdash	274	0.766	---	---
1:3 rough finish	---	---	734	1.541
1:2 smooth float	---	---	979	1.371

Source: Indian Civil Engineer's Handbook (Khanna, 2001)

303.8 **Brick mortar strengths** Above ground general purpose load bearing brick walls used in normal building construction, exposed to weather and heat, should be laid with a 1:6 mortar mixture with a minimum cement dosage of 250 kg/m³. Below ground brick walls subject to soil pressure or seismic conditions should be laid with a 1:4 mortar mixture with a minimum cement dosage of 380 kg/m³. Joint thickness should be 8mm - 12mm. The quantity of mortar required can be calculated as 0.23 to 0.25 of the brick wall volume. The quantities of cement and sand for 1m³ of wet mortar can be found in the table below.

	1:4	1:5	1:6	1:7
Cement (kg)	380	312	250	220
Sand (m3)	1.1	1.1	1.1	1.1

Source: Indian Civil Engineer's Handbook (Khanna, 2001)

304 SOAKAGE PIT SIZING BASED ON SOIL INFILTRATION RATES

304.1 The sizing of soakage pits, trenches and drain fields is dependent upon local site soil infiltration rates, the number of users and the quantity of waste water that is expected to be generated per person. Soakage pit dimensions should be determined by on-site soil infiltration tests (see Appendix 20 of Engineering in Emergencies. Alternatively refer to the table of typical soil infiltration rates on page 213 of the UNHCR WASH Manual). Soakage pits for wastewater from showers or septic tanks are likely to be much bigger than those for wastage from tapstands (see table below). In some cases communal shower blocks and septic tank installations may require drain fields rather than soakage pits.

	Clean Water (litres/m2/day)	Wastewater (Sewage and Sullage) (litres/m2/day)
Sand	720 – 2,400	33 - 50
Sandy Loam	480 – 720	24
Silt Loam	240 - 480	18
Clay Loam	120 - 240	8
Clay	24 - 120	Unsuitable

Source: Engineering in Emergencies (RedR, 2010)

305 SLOPES FOR WATER COLLECTION POINTS AND DRAINAGE CHANNELS

305.1 All water collection surfaces and drainage channels should be inclined to ensure that there is no standing water at water points. In general a slope of 1% should be sufficient to ensure that the water is gradually evacuated towards soakage pits.

306 SURFACE FINISHES AT PUBLIC WATER COLLECTION POINTS

306.1 All concrete surfaces at water collection points should be given a non-slip finish (the surfaces should be lightly brushed with a yard brush before the surface has cured) to ensure safe access by all users including the elderly, pregnant women, disabled users and small children. The surface should be sufficient to facilitate cleaning while also preventing slipping.

UNHCR STANDARD DESIGNS FOR WATER SUPPLY

The following technical designs for water supply are available from UNHCR.

D-300/2015a	Emergency Tapstand (Wooden Pallets) with Drainage
D-301/2015a	Post Emergency Tapstand Design (Rectangular Concrete)
D-302/2015a	Post Emergency Handpump Apron Design (Rectangular Concrete)
D-303/2015a	Post Emergency Hand Dug Well Apron Design (Circular Concrete)
D-304/2015a	Borehole Design (Fractured Rock)
D-305/2015a	Borehole Design (Alluvial Aquifer)
D-306/2015a	Emergency Raised Water Platform (Sandbags)
D-307/2015a	Emergency Raised Water Platform (Concrete Rings)
D-308/2015a	Emergency Raised Water Platform (Corrugated Steel Rings)
D-309/2015a	Elevated 6m Water Tower with 20m ³ , 25m ³ , 50m ³ 60m ³ and 75m ³ Water Reservoir (Reinforced Concrete)
D-310/2015a	Elevated Water Tower 15m high with 109m ³ Reservoir (Steel)
D-311/2015a	Post Emergency Elevated Water Tower 4m (Steel)
D-312/2015a	Square Water Reservoir 10m ³ (Reinforced Concrete)
D-313/2015a	Square Water Reservoir 30m ³ (Reinforced Concrete)
D-314/2015a	Square Water Reservoir 50m ³ (Reinforced Concrete)
D-315/2015a	Circular Water Reservoir 10m ³ (Reinforced Concrete)
D-316/2015a	Circular Water Reservoir 30m ³ (Reinforced Concrete)
D-317/2015a	Circular Water Reservoir 50m ³ (Reinforced Concrete)
D-318/2015a	Circular Water Reservoir 45m ³ (Ferrocement)
D-319/2015a	Circular Water Reservoir 75m ³ (Ferrocement)
D-320/2015a	Circular Water Reservoir 90m ³ (Ferrocement)

These designs may be found at <http://wash.unhcr.org/wash-technical-designs/>.

USEFUL REFERENCES

Emergency water supply

- ◆ ACF (2005), 'Water, sanitation and hygiene for populations at risk – second edition'. ACF, Paris, France.
http://www.actioncontrelafaim.org/publications/fichiers/wsh_acf_0.pdf
- ◆ Chalinder, A. (1994), 'Water & sanitation in emergencies: a good practice review', Overseas Development Institute (ODI), London,
<http://www.odihpn.org/download/gpr1pdf>
- ◆ House S., and Reed, B. (2004) 'Emergency water sources 3rd Ed.', WEDC, Loughborough University, UK.
http://wedc.lboro.ac.uk/resources/books/Emergency_Water_Sources_-_Complete.pdf
- ◆ Lambert, R., and Davis, J. (2002), 'Engineering in emergencies 2nd Ed.', Register of Engineers for Disaster Relief (RedR), London.
- ◆ SPHERE (2011) 'Humanitarian charter and minimum standards in disaster response'. <http://www.sphereproject.org/resources/download-publications>
- ◆ UNHCR (2007), 'Handbook for emergencies – third edition'. UNHCR, Geneva. <http://www.unhcr.org/472af2972.html>
- ◆ UNHCR (1992), 'Water manual for refugee situations', UNHCR, Geneva.
<http://www.unhcr.org/3ae6bd100.pdf>

Surface water

- ◆ House, S., Reed, B. and Shaw, R., (1989) 'Selecting sources of water: WEDC technical brief #55'. WEDC, Loughborough University, UK.
<http://www.lboro.ac.uk/well/resources/technical-briefs/55-water-source-selection.pdf>
- ◆ Smout, I. and Shaw, R. (1989), 'Surface water intakes: WEDC technical brief #22'. WEDC, Loughborough University, UK.
<http://www.bvsde.paho.org/eswww/tecapropiada/otratec/waterlin/tb22.pdf>
- ◆ Wijk-Sijbesma, C.A., and Smet, J.E.M. (2002), 'Small community water supplies: Surface water intakes and small dams', IRC International Water and Sanitation Centre, Delft
http://www.samsamwater.com/library/TP40_11_Surface_water.pdf
- ◆ WEDC (2012), 'Intakes from rivers: WEDC trial course unit'. WEDC, Loughborough University, UK.
http://wedc.lboro.ac.uk/resources/units/EWS_Unit_5_Surface_Water_Intakes.pdf
- ◆ USAID (1984) 'Maintaining intakes', USAID, Washington USA.
[http://www.watersanitationhygiene.org/Maintaining_Intakes_\(USAID\).pdf](http://www.watersanitationhygiene.org/Maintaining_Intakes_(USAID).pdf)
- ◆ USAID (1984), 'Constructing intakes for ponds, lakes and reservoirs', USAID, Washington USA. [http://www.watersanitationhygiene.org/Intakes\(USAID\).pdf](http://www.watersanitationhygiene.org/Intakes(USAID).pdf)
- ◆ USAID (1984), 'Constructing intakes for streams and rivers', USAID, Washington USA.

[http://www.watersanitationhygiene.org/Intakes for Streams and Rivers \(US AID\).pdf](http://www.watersanitationhygiene.org/Intakes for Streams and Rivers (US AID).pdf)

- ◆ USAID (1984), 'Designing intakes for ponds, lakes and reservoirs', USAID, Washington USA. <http://www.lifewater.org/resources/rws1/rws1d2.pdf>
- ◆ USAID (1984,) 'Designing intakes for streams and rivers', USAID, Washington USA. <https://www.lifewater.org/resources/rws1/rws1d3.pdf>
- ◆ USAID (1984), 'Designing intakes for ponds, lakes and reservoirs', USAID, Washington USA. <http://www.lifewater.org/resources/rws1/rws1d2.pdf>
- ◆ USAID (1984,) 'Designing intakes for streams and rivers', USAID, Washington USA. <https://www.lifewater.org/resources/rws1/rws1d3.pdf>

Spring captures

- ◆ Skinner, B. and Shaw, R. (1989), 'Protecting springs an alternative to spring boxes: WEDC technical brief #34'. WEDC, Loughborough University, UK. <http://www.lboro.ac.uk/well/resources/technical-briefs/34-protecting-springs.pdf>
- ◆ Oxfam GB (2008), 'Spring protection: technical brief #5', Oxfam GB, Oxford, UK. <http://oxfamilibrary.openrepository.com/6/tbn5-spring-protection-030608-en.pdf>
- ◆ USAID (1984), 'Constructing structures for springs', USAID, Washington USA. <http://my.ewb-usa.org/theme/library/myewb-usa/project-resources/technical/rws1c1.pdf>
- ◆ USAID (1984), 'Designing structures for springs', USAID, Washington USA. <https://www.lifewater.org/resources/rws1/rws1d1.pdf>
- ◆ USAID (1984), 'Maintaining spring structures', USAID, Washington USA. <http://my.ewb-usa.org/theme/library/myewb-usa/project-resources/technical/rws1o1.pdf>

Hand dug wells

- ◆ Abbott, S. (2001), 'Hand dug well manual'. <http://www.sswm.info/ABBOT%204000%20Hand%20Dug%20Well%20Manual.pdf>
- ◆ Colins, S. (2000), 'Hand dug shallow wells', Swiss Resource Centre for Development (SKAT), St. Gallen, Switzerland. <http://www.skat.ch/publications/2005-10-31.1053710342/file>
- ◆ Pickford, J. and Shaw, R. (1989), 'Upgrading traditional wells: WEDC technical brief #39'. WEDC, Loughborough University, UK. <http://www.lboro.ac.uk/well/39-upgrading-traditional-wells.pdf>
- ◆ Reed, A. and Luff, R. (2000), 'Instruction Manual for Hand Dug Well Equipment', Oxfam GB, Oxford, <http://oxfamilibrary.openrepository.com/oxfam/1/hand-dug-well-manual-250406-en.pdf>

- ◆ USAID (1984), 'Designing hand dug wells', USAID, Washington USA. <http://my.ewb-usa.org/theme/library/myewb-usa/project-resources/technical/rws2d1.pdf>
- ◆ USAID (1984), 'Selecting a well site', USAID, Washington USA. <http://my.ewb-usa.org/theme/library/myewb-usa/project-resources/technical/rws2p3.pdf>
- ◆ USAID (1984), 'Constructing hand dug wells', USAID, Washington USA. <http://my.ewb-usa.org/theme/library/myewb-usa/project-resources/technical/rws2c1.pdf>
- ◆ USAID (1984), 'Finishing wells', USAID, Washington USA. <http://my.ewb-usa.org/theme/technical/rws2c8.pdf>

Hand drilled wells

- ◆ Elson, B. and Shaw, R. (1989), 'Simple drilling methods: WEDC technical brief #43'. WEDC, Loughborough University, UK. <http://www.lboro.ac.uk/well/resources/technical-briefs/43-simple-drilling-methods.pdf>
- ◆ Herwijnen, A. (2005), 'Rota Sludge and Stone Hammer Drilling Part One - Drilling Manual', ETC Foundation, Leusden. http://www.itacanet.org/doc-archive-eng/water/Rota_sludge_drilling_Pt1.pdf
- ◆ Herwijnen, A. (2005), 'Rota Sludge and Stone Hammer Drilling Part One - Production Manual', ETC Foundation, Leusden. http://www.itacanet.org/doc-archive-eng/water/Rota_sludge_drilling_Pt2.pdf
- ◆ Wurzel, P. (2001), 'Drilling boreholes for handpumps', Swiss Resource Centre for Development (SKAT), St. Gallen, Switzerland. <http://www.rural-water-supply.net/resources/documents/default/148.pdf>
- ◆ USAID (1984), 'Designing bored and augured wells', USAID, Washington USA. <http://my.ewb-usa.org/theme/library/myewb-usa/project-resources/technical/rws2d4.pdf>
- ◆ USAID (1984), 'Designing driven wells', USAID, Washington USA. <http://my.ewb-usa.org/theme/library/myewb-usa/project-resources/technical/rws2d2.pdf>
- ◆ USAID (1984), 'Designing jetted wells', USAID, Washington USA. <http://my.ewb-usa.org/theme/library/myewb-usa/project-resources/technical/rws2d3.pdf>
- ◆ USAID (1984), 'Constructing bored and augured wells', USAID, Washington USA. <http://my.ewb-usa.org/theme/library/myewb-usa/project-resources/technical/rws2c4.pdf>
- ◆ USAID (1984), 'Constructing driven wells', USAID, Washington USA. <http://my.ewb-usa.org/theme/library/myewb-usa/project-resources/technical/rws2c2.pdf>
- ◆ USAID (1984), 'Constructing jetted wells', USAID, Washington USA. <http://my.ewb-usa.org/theme/library/myewb-usa/project-resources/technical/rws2c3.pdf>

Machine drilled wells

- ◆ Ball, P. (2001), 'Drilling wells', Swiss Resource Centre for Development (SKAT), St. Gallen, Switzerland. <http://www.rural-water-supply.net/ressources/documents/default/1-147-2-1355235564.pdf>
- ◆ Carter, R., Chilton, J., Danert, K. and Olschewski, A., 'Siting of Drilled Water Wells - A Guide for Project Managers', Rural Water Supply Network (RWSN), St. Gallen, Switzerland. <http://www.rural-water-supply.net/ressources/documents/default/187.pdf>
- ◆ Danert, K. et al (2010), 'Code of Practice for Cost Effective Boreholes', Rural Water Supply Network (RWSN), St. Gallen, Switzerland. <http://www.rural-water-supply.net/ressources/documents/default/1-128-2-1344514867.pdf>
- ◆ ICRC (2010), 'Borehole Drilling and Rehabilitation under Field Conditions: Technical Review', International Committee of the Red Cross (ICRC), Geneva. <https://www.icrc.org/eng/assets/files/other/icrc-002-0998.pdf>
- ◆ USAID (1984), 'Designing cable tool wells', USAID, Washington USA. <http://my.ewb-usa.org/theme/library/myewb-usa/project-resources/technical/rws2d5.pdf>
- ◆ USAID (1984), 'Constructing a cable tool wells', USAID, Washington USA. <http://my.ewb-usa.org/theme/library/myewb-usa/project-resources/technical/rws2c5.pdf>
- ◆ USAID (1984), 'Finishing wells', USAID, Washington USA. <http://my.ewb-usa.org/theme/library/myewb-usa/project-resources/technical/rws2c8.pdf>
- ◆ Wurzel, P. (2001), 'Drilling boreholes for handpumps', Swiss Resource Centre for Development (SKAT), St. Gallen, Switzerland. <http://www.rural-water-supply.net/ressources/documents/default/148.pdf>

Rainwater harvesting

- ◆ ITDG (2002), 'Rainwater harvesting technical brief', Intermediate Technology Development Group (ITDG), [http://www.watersanitationhygiene.org/Rainwater%20Harvesting%20\(ITDG\).pdf](http://www.watersanitationhygiene.org/Rainwater%20Harvesting%20(ITDG).pdf)
- ◆ USAID (1984), 'Evaluating rainfall catchments', USAID, Washington USA. <http://my.ewb-usa.org/theme/library/myewb-usa/project-resources/technical/rws1p5.pdf>
- ◆ USAID (1984), 'Designing roof catchments', USAID, Washington USA. <https://www.lifewater.org/resources/rws1/rws1d4.pdf>
- ◆ USAID (1984), 'Constructing, operating and maintaining roof catchments', USAID, Washington USA. <http://my.ewb-usa.org/theme/library/myewb-usa/project-resources/technical/rws1c4.pdf>

Water network design

- ◆ Jordan, D. (1984), 'A Handbook of Gravity-Flow Water Systems', Practical Action, IT Publishing, UK.

- ◆ Knight, J. and Gonzalez Otalora, C. (2014), 'Design and installation of a water supply network, Batil refugee camp Maban County, South Sudan', Medair and Solidarites International.
<https://data.unhcr.org/SouthSudan/download.php?id=1168>
- ◆ Oxfam GB (1999), 'Water supply scheme for emergencies', Oxfam GB, Oxford, UK. <http://www.bvsde.paho.org/texcom/desastres/oxfamwfm.pdf>
- ◆ Reed, B. and Shaw, R. (1989), 'Emergency water supply: WEDC technical brief #44', WEDC, Loughborough University, UK.
<http://www.lboro.ac.uk/well/resources/technical-briefs/44-emergency-water-supply.pdf>
- ◆ USAID (1984), 'Designing gravity flow systems', USAID, Washington USA.
<https://www.lifewater.org/resources/rws4/rws4d1.pdf>
- ◆ USAID (1984), 'Designing a transmission main', USAID, Washington USA.
<https://www.lifewater.org/resources/rws4/rws4d3.pdf>
- ◆ USAID (1984), 'Designing community distribution systems', USAID, Washington USA. <https://www.lifewater.org/resources/rws4/rws4d4.pdf>
- ◆ USAID (1984), 'Constructing a distribution system with household connections', USAID, Washington USA.
<https://www.lifewater.org/resources/rws4/rws4c5.pdf>
- ◆ USAID (1984), 'Constructing community distribution systems', USAID, Washington USA. <https://www.lifewater.org/resources/rws4/rws4c4.pdf>
- ◆ USAID (1984), 'Detecting and correcting leaking pipes', USAID, Washington USA. <https://www.lifewater.org/resources/rws4/rws4o1.pdf>
- ◆ USAID (1984), 'Installing pipes', USAID, Washington USA.
<https://www.lifewater.org/resources/rws4/rws4c1.pdf>
- ◆ USAID (1984), 'Operating and maintaining household water connections', USAID, Washington USA.
<https://www.lifewater.org/resources/rws4/rws4o5.pdf>
- ◆ USAID (1984), 'Selecting pipe materials', USAID, Washington USA.
<https://www.lifewater.org/resources/rws4/rws4p3.pdf>

Motorized water pumping

- ◆ Baumann, E. (2000), 'Water Lifting', Swiss Resource Centre for Development (SKAT), St. Gallen, Switzerland. <http://www.skat.ch/publications/2005-10-31.4419482767/file>
- ◆ Oxfam (2000), 'Instruction manual for surface water pumping' (Oxfam, 2000), Oxfam GB, Oxford,
<http://www.oxfam.org.uk/equipment/Pumping%20Equipment%20Manual.pdf>
- ◆ Oxfam GB (1999), 'Water supply scheme for emergencies', Oxfam GB, Oxford, UK. <http://www.bvsde.paho.org/texcom/desastres/oxfamwfm.pdf>
- ◆ USAID (1984), 'Determining pump requirements', USAID, Washington USA.
<https://www.lifewater.org/resources/rws4/rws4d2.pdf>
- ◆ USAID (1984), 'Selecting pumps', USAID, Washington USA.
<https://www.lifewater.org/resources/rws4/rws4p5.pdf>

- ◆ USAID (1984), 'Selecting a power source for pumps', USAID, Washington USA. <https://www.lifewater.org/resources/rws4/rws4p4.pdf>
- ◆ USAID (1984), 'Installing mechanical pumps', USAID, Washington USA. <https://www.lifewater.org/resources/rws4/rws4c2.pdf>
- ◆ USAID (1984), 'Operating and maintaining mechanical pumps', USAID, Washington USA. <https://www.lifewater.org/resources/rws4/rws4o2.pdf>

Handpumps

- ◆ Arlosoroff S. et al. (1987), 'Community water supply: the handpump option', The World Bank, Washington, DC. <http://www-wds.worldbank.org/external/PDF/multi0page.pdf>
- ◆ Baumann, E. (2000), 'Water Lifting', Swiss Resource Centre for Development (SKAT), St. Gallen, Switzerland. <http://www.skat.ch/publications/2005-10-31.4419482767/file>
- ◆ Erpf, K. (2007), 'Afridev handpump installation and maintenance manual (Revision 2-2007)', Swiss Resource Centre for Development (SKAT), St. Gallen, Switzerland. <http://rural-water-supply.net/ressources/documents/default/286.pdf>
- ◆ <http://wedc.lboro.ac.uk/docs/research/WEJW2/Report - Uganda.pdf>
- ◆ Skinner, B. and Shaw, R. (1989), 'VLOM Pumps: WEDC technical brief #41', WEDC, Loughborough University, UK. <http://www.lboro.ac.uk/well/resources/technical-briefs/41-vlom-pumps.pdf>
- ◆ USAID (1984), 'Installing Handpumps', USAID, Washington USA. <https://www.lifewater.org/resources/rws4/rws4c3.pdf>
- ◆ USAID (1984), 'Operating and Maintaining Handpumps', USAID, Washington USA. http://water.engr.psu.edu/hill/teaching/rural_water/rws4o3.pdf

Water storage

- ◆ Oxfam (2006), 'Water storage manual', Oxfam GB, Oxford, UK. <http://oxfamilibrary.openrepository.com/oxfam/bitstream/10546/126731/1/water-storage-manual-260406-en.pdf>
- ◆ Skinner, B., and Shaw, R. (1989), 'Buried and semi submerged water tanks : WEDC technical brief #56', WEDC, Loughborough University, UK. <http://www.lboro.ac.uk/well/resources/technical-briefs/56-buried-and-semi-submerged-tanks.pdf>
- ◆ Skinner, B., Reed, B., and Shaw, R. (1989), 'Ferrocement water tanks : WEDC technical brief #36', WEDC, Loughborough University, UK. <http://www.lboro.ac.uk/well/resources/technical-briefs/36-ferrocement-water-tanks.pdf>
- ◆ UNHCR (2006), 'Large ferro-cement water tank design parameters and construction details ', United Nations High Commissioner for Refugees UNHCR, Geneva. <http://www.unhcr.org/49d089a62.pdf>
- ◆ USAID (1984), 'Methods of storing water', USAID, Washington USA. <https://www.lifewater.org/resources/rws5/rws5m.pdf>

- ◆ USAID (1984), 'Designing a ground level water storage tank', USAID, Washington USA. <https://www.lifewater.org/resources/rws5/rws5d2.pdf>
- ◆ USAID (1984), 'Constructing a ground level water storage tank', USAID, Washington USA. <https://www.lifewater.org/resources/rws5/rws5c2.pdf>
- ◆ USAID (1984), 'Constructing a household cistern', USAID, Washington USA. <http://wiki.watermissions.org/GetFile.aspx?Page=Water%20Storage%20RWS5&File=rws5c1.pdf>
- ◆ USAID (1984), 'Designing an elevated water storage tank', USAID, Washington USA. <http://wiki.watermissions.org/GetFile.aspx?Page=Water%20Storage%20RWS5&File=rws5d3.pdf>
- ◆ USAID (1984), 'Constructing an elevated water storage tank', USAID, Washington USA. <http://wiki.watermissions.org/GetFile.aspx?Page=Water%20Storage%20RWS5&File=rws5c3.pdf>
- ◆ USAID (1984), 'Determining the need for water storage', USAID, Washington USA. <http://wiki.watermissions.org/GetFile.aspx?Page=Water%20Storage%20RWS5&File=rws5p1.pdf>
- ◆ USAID (1984), 'Maintaining water storage tanks', USAID, Washington USA. <http://wiki.watermissions.org/GetFile.aspx?Page=Water%20Storage%20RWS5&File=rws5o1.pdf>