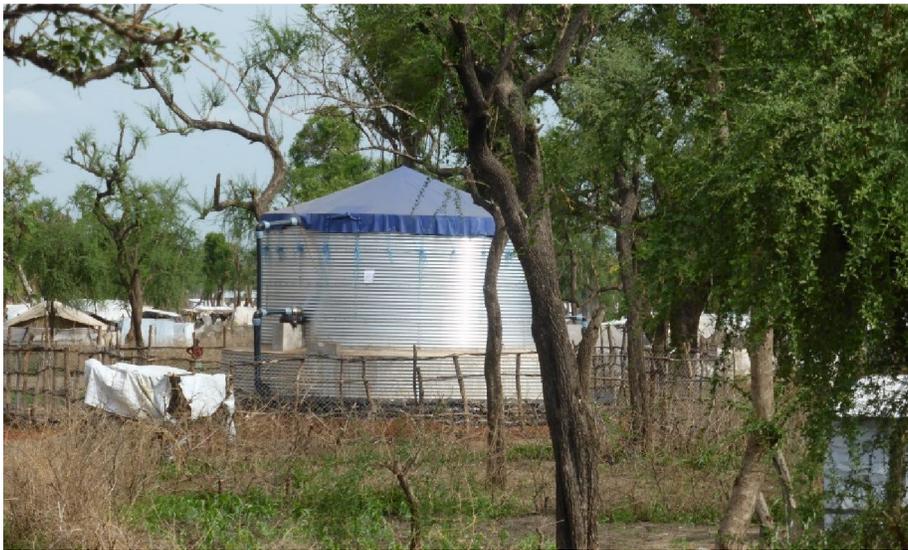




DESIGN AND INSTALLATION OF A WATER SUPPLY NETWORK



Batil refugee camp

Maban County, South Sudan

June 2014

John Knight - Medair

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ACKNOWLEDGMENTS

The design, installation and commissioning of the water supply network in Batil camp has been a large and complex project carried out in challenging circumstances. It would not have been possible without the commitment, energy, expertise and experience of a large number of people and organisations. The authors want to particularly thank the following agencies and donors:

- CARE & PAE who have drilled most of the boreholes in Batil camp. PAE also assisted us with topographical surveying when we were siting the storage tanks
- GOAL, MSF and ICRC who worked (together with Solidarites International) in setting up the initial emergency water supply
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In addition we would like to recognise the contributions of all the Medair and Solidarites staff, the refugee casual workers, and all the community involved in digging the trenches for the pipeline. It has truly been a team effort. **Thank you.**

Photo credits:

- *Wendy van Amerongen (Medair)*
- *John Knight (Medair)*
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1. INTRODUCTION

Batil refugee camp was established in June 2012 and quickly grew to almost 40,000 people. Between June and December an emergency water supply was set-up by four agencies (GOAL, Solidarites, MSF and ICRC) together with CARE and PAE¹ who drilled most of the boreholes in the camp. As the camp grew and new boreholes were drilled, a distribution network evolved based around a large number of small water storage sites interconnected with approximately 15 km of lay-flat hose (mainly 3"). The storage sites were mainly bladder tanks (typically 10,000 l) mounted on small platforms of about 1.2 m height, although there were five larger 'pyramids' constructed in the camp comprised of sandbags stacked to a height of 2.5 m or higher. The priority was on achieving minimum standards for water supply as quickly as possible, rather than designing a sustainable distribution network.

Some improvements were begun by GOAL between January and April 2013 with the installation of about 5.3 km of buried PVC/ HDPE pipes. Then two new boreholes were drilled by PAE in April which significantly improved the water supply capacity. These were connected to the existing network by installing a further 2.3 km of HDPE pipe in May.

It had always been the intention to replace the emergency water supply network with a more permanent, efficient system. By May 2013 the number of WASH agencies working in the camp had been reduced to two – Medair and Solidarites International. Together we put together a design for an improved water distribution network in Batil camp, which was discussed and agreed with UNHCR last July. There were five basic objectives for the implementation of the new water network:

- to replace all the lay-flat hose with buried HDPE pipe.
- to simplify the system, reducing the number of storage sites – making it cheaper and easier to operate.
- to design the system such that water is pumped directly from the borehole to an elevated storage, and is then distributed by gravity (rather than using additional surface pumps to pump from one storage to another)
- to spread the load so that no one borehole is required to pump more than 12 hours per day.
- to identify any areas where new tap stands are required to improve access to water (in accordance with the UNHCR standard of 200 m radius from the dwellings)

Design water demand was calculated as 1000 m³/day, based on a population of 40,000 collecting 25 l/p/day²

Work on the installation of the new network commenced at the beginning of August 2013. The project took 10 months to complete, and was officially opened on the 12th June 2014 with a celebration with the

¹ PAE is a private contractor, employed directly by the US State Department. Their work in Maban is co-ordinated by UNHCR. They drilled two high-yield boreholes in October 2012; an additional two in April 2013; and recently a fifth borehole in April 2014.

² Camp population at the time was 38,289 but has since increased to 39,366. 25 l/p/day is assumed to be peak dry season demand, with 10 – 15% lost in distribution and collection.

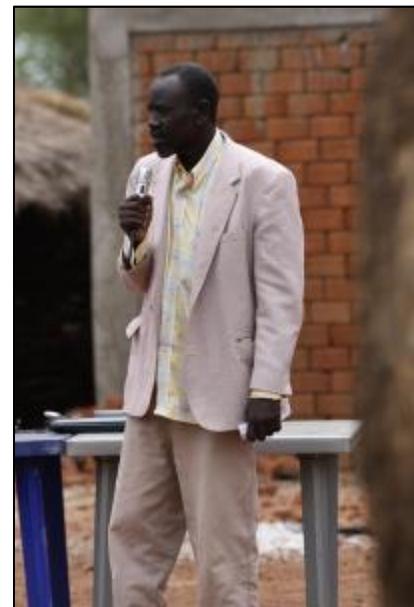
community leaders, UNHCR and other partners working in the camp. This report outlines the design and installation of the network, describing in some detail the process of installing pipework and the Oxfam storage tanks. It is intended as a reference for future staff working in Batil camp, and also tries to highlight “lessons learnt” so that these can be applied in similar situations elsewhere.



Inauguration of the water network – 12 June 2014



Women's representative opening speech



Umda Ahmed opening speech

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2. NETWORK DESIGN

2.1 DESIGN CONCEPT

In May 2013 a consultant employed by Solidarites produced a report on Batil camp entitled: “Small scale water system diagnosis in Yusuf Batil camp”, which provided analysis and recommendations on the future development of the water network. In essence it proposed a centralised water distribution system with two large water towers in the middle of the camp and a network of around 24 km of new pipeline distributing this to the existing tapstands. However, it was decided not to adopt this approach – partly because of concerns about building large elevated water towers on the black cotton soil in Maban which is unstable; and partly because of the length of the network involved. The design chosen was a semi-decentralised network.

Based on the experience with the temporary pyramids we knew that an elevation of 2.5 m provided sufficient pressure to tapstands up to 500 m away (later confirmed with hydraulic calculations of head loss in pipelines). Although we were switching to more permanent storage we could not easily increase the height beyond 2.5 m using our preferred design – Oxfam tanks with back-filled plinths. (Raising the tanks higher would probably require a steel lattice tower and we were not keen to pursue this design option).

Hence the network was based around a number of storage areas each of which would provide water by gravity to a mini (radial) network of 4 to 5 tapstands generally no more than 500 m away. Based on maps of the camp it was determined that 9 storage tanks would be required to provide geographical coverage of all areas and the camp was thus divided into 9 zones representing populations served by the respective storage tanks.

One advantage of this approach is that there is some resilience, so a fault with one storage tank would not affect the whole camp. At the time there were 9 motorised boreholes in Batil, so on average one pump supplies one storage tank. However, 5 of the pumps were relatively low yield so the pipe network was designed with interconnections between the various boreholes in order that water could be supplied to storage tanks from various sources in case one pump has inadequate yield or breaks down.

2.2 DESIGN CALCULATIONS

2.2.1 Calculating storage requirements

There is no magic formula for calculating the amount of storage capacity required in a camp; it must be sufficient to cope with peak demand and provide some contingency. The benefits of additional storage capacity need to be weighed against the cost. It was decided to install Oxfam T70 tanks at each of the

storage areas, with the exception of S9 which was added later with a T45 tank. Thus total storage capacity is 605 m³ or about 60% of the anticipated daily demand³.

Water demand in each zone was initially measured using a water point survey, ie counting the number of buckets/ jerrycans collected at each tapstand in a day. Later, working with REACH, we used the satellite images and GIS software to count the number of shelters in each zone and hence apportion the total water demand for the camp between the zones according to the percentage of the camp population living in each zone.

The results of this analysis and a proposed pumping schedule are shown in Appendix A.

Batil camp is very flat (see pipeline calculations below). Unfortunately this meant there were no natural elevated sites that could be used for the installation of storage tanks; but on the positive side it meant that there was little risk of a negative gradient from the tank to the tap stand. Locations for storage tanks were thus selected on the basis of being:

- Relatively central in each zone
- Accessible for large trucks
- Not prone to flooding
- Not settled or otherwise developed by the community

2.2.2 Pipeline calculations

GIS mapping enabled us to estimate the lengths of pipeline required (10% was added in each case allowing for deviations from a straight line). The initial estimate was 16 km of new pipeline for the whole camp.

PAE were able to assist us with a limited topographical survey measuring the change in elevation between the proposed storage sites and tapstands. This survey showed that the topography was indeed very flat with rarely a rise or fall of more than 1.0 m across the camp (which is approximately 5 km from north to south). While this did not help us with siting the storage tanks this data did enable more precise calculations of residual head at tapstands, based on the friction loss in the pipes and the rise or fall in topography. (There was only one tapstand TS13, in the far south-east of the camp where the pressure head was too low).

³ It was later decided to add small T11 storage tanks at three of the boreholes where there are adjacent tapstands, thus increasing storage capacity to 635 m³



Figure 1: PAE topographical survey

The diameter of the pipelines was calculated according to the following assumptions:

- Flow rate per tap: 0.17 l/s (supplying 20 litres in 2 minutes)
- All taps are open at the same time (maximum flow rate = maximum frictional head loss)
- Secondary head loss in bends and valves was assumed to be negligible, though a head loss of 0.25 m was estimated for each tapstand
- A minimum of 1.5 m head at each tap stand was needed (1.0 m at tap level since the tap is approximately 0.5 m above the ground level)
- Design for flow velocities in range of 0.7 to 2.0 m/s to avoid sediment settling.

According to the results of those calculations, the final network design was composed of a mixture of mainly 3" and 4" HDPE pipes (except 2" HDPE pipes for the local storages at borehole level), depending on the distance of the tap stand to the tank, and the demand of each tapstand. The larger the distance and number of taps of each tapstand, the bigger the diameter of pipe installed.

2.2.3 Additional tapstands

The maps produced by REACH were also used to show access to water – based on UNHCR standard (200 m) and SPHERE (500 m). From the maps 6 additional tapstands were sited where there were gaps in the camp. Later, additional tapstands were added to connect some of the schools and health centres.

See maps attached:

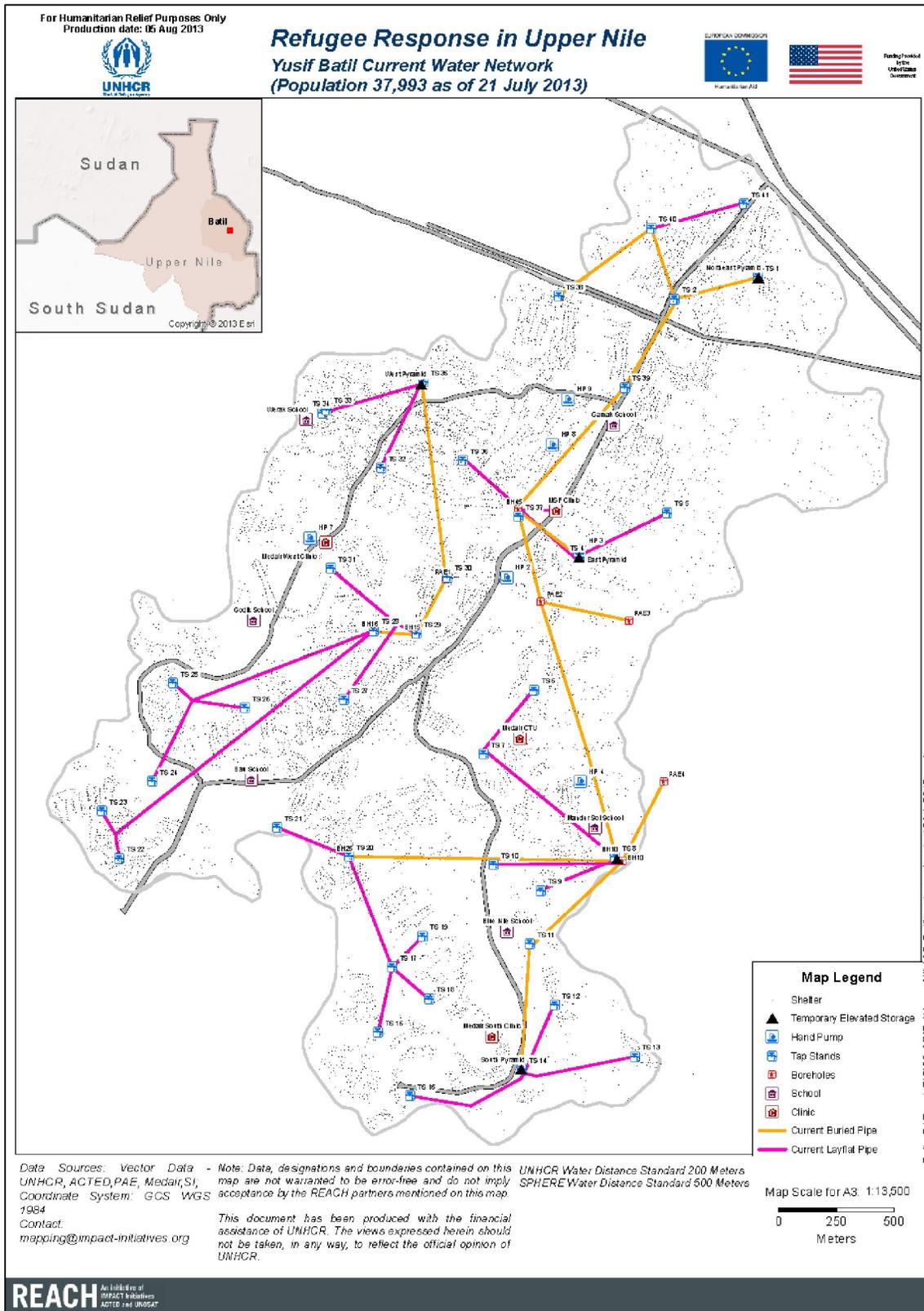
Map 1: Emergency water network – December 2012 (ICRC)

Map 2: Emergency water network – July 2013

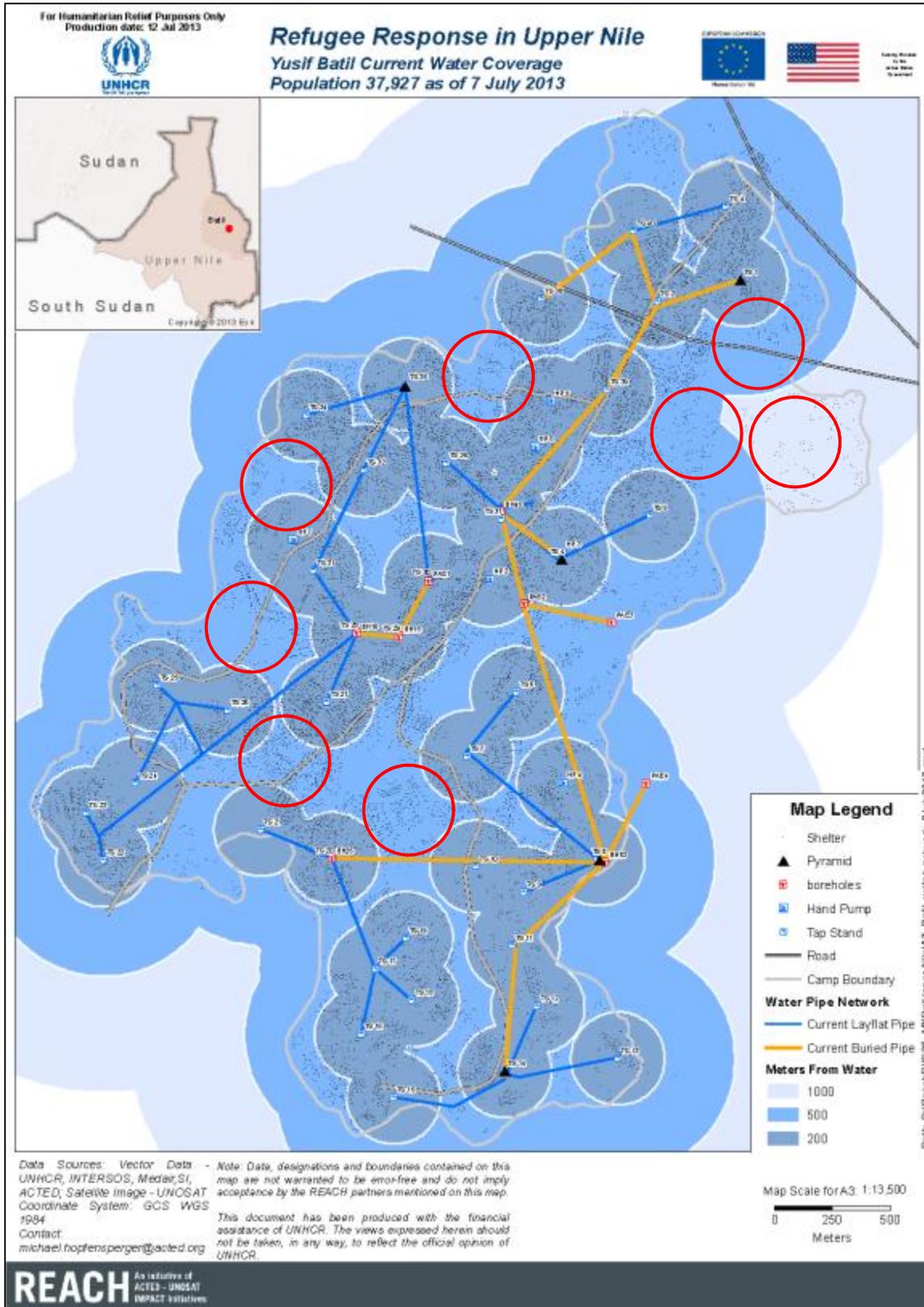
Map 3: Emergency water network gap analysis – July 2013

Map 4: Proposed sustainable water network – July 2013

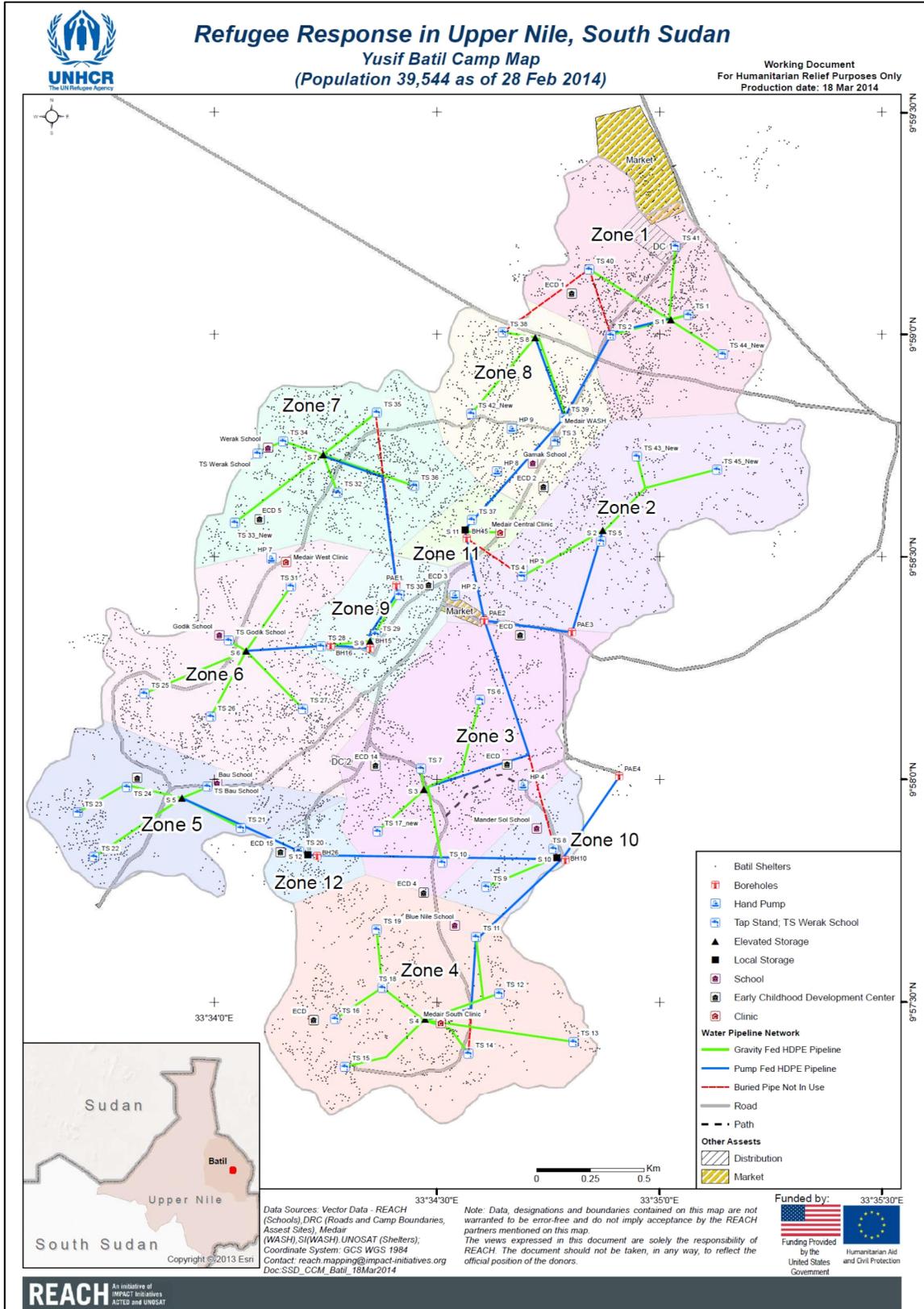
Map 2: Emergency water network - July 2013



Map 3: Emergency water network gap analysis - July 2013



Map 4: Proposed sustainable water network - July 2013



3. PIPELINE INSTALLATION

3.1 OVERVIEW

Initially it was estimated that about 16 km of HDPE pipe would need to be installed in the camp. By June 2014 over 18.5 km had been installed by the Medair and Solidarites teams.

The main steps involved in HDPE Pipeline Installation are given below and described in greater detail in the following sub-sections:

1. Identification of pipeline route
2. Community consultation
3. Welding of HDPE pipes (using a hydraulically-operated butt welding machine)
4. Mobilising community to dig trench
5. Pipeline pressure testing
6. Installation of pipeline and backfilling of trench

3.2 IDENTIFICATION OF PIPELINE ROUTE

If possible, stand on high points to get a better overview of the area where the proposed pipeline is to go. Consider:

- Length (shorter will reduce amount of pipe required and amount of head (pressure) lost along the pipeline, which may be critical depending on the system)
- Avoiding tents / households
- Alignment (acceptable curve radius will depend on the pipe flexibility)
- Avoid flood zones (installing pipe in flooded areas during the wet season will be challenging; erosion of soil cover to the pipe may happen quicker)
- Avoid trees (roots may damage pipe; a rough indication of root zone is the tree dripline)
- Minimise road crossings and if necessary try to cross perpendicular to minimise crossing length (heavy vehicle loading could damage the pipeline if it is not sufficiently protected)

3.3 CONSULTATION WITH COMMUNITY

In Batil Camp people are living within a community / village structure, each with their own leader – the sheikh. Once the pipeline route was established, the communities living along the route were identified and the appropriate sheikhs mobilised. A site meeting was held to explain the project to the affected sheikhs and to walk along the proposed route. The sheikhs were encouraged to give any feedback and their agreement with the route was sought.

3.4 HDPE PIPE WELDING

The HDPE pipes for this project were bought in 6 m lengths. The method used for joining the 6 m sections together was butt fusion welding using the ITS Ital PT160/ PT200 machine as shown in Figure 2. The procedure for welding is given below and Appendix A contains two summary sheets with specific details for 3" and 4" HDPE pipe.



Figure 2: Setup of the welding machine

Welding was done at a central site and 'pipe strings' of typically 8 pipes were welded together. Pipe string length is a compromise between weight (a string of 8 pipes can be comfortably carried by 4 people); and number of 'joining welds' (reducing the number of pipes in the string results in more 'joining welds' done on site which are more difficult to achieve good quality control over). Due to the time required for setting-up and heating and cooling, the team were able to weld about two "strings" (ie about 100 m) per day.

Some key points:

- Safety when using the machine (eg heating mirror reaches temperatures greater than 200° Celsius)
- Weld in dry conditions (erect temporary shelter if necessary)
- In hot weather ensure the machine is well shaded (to avoid overheating)
- Cover the ends of the welded pipe strings (eg with tape) to prevent animals, stones etc. from entering the pipelines

Step 1: Pipe preparation

1. Place 2 pipes in the machine
2. Bring pipe ends together, do an initial alignment check, adjust clamps as required
3. Note: ensure the clamps are fastened tightly and equally (ie one side of the clamps shouldn't be significantly tighter than the other side); also ensure that the pipe isn't being squashed.

4. Wipe pipe ends clean of dirt/dust. If using a wet cloth make sure to dry pipe after.

Step 2: Shaving

1. Insert the Facing Tool
2. Press and hold button to start Facing Tool
3. Close trolley to bring pipe ends against Facing Tool
4. Cut until several continuous shavings come off both pipes
5. Open trolley
6. Release button and remove Facing Tool

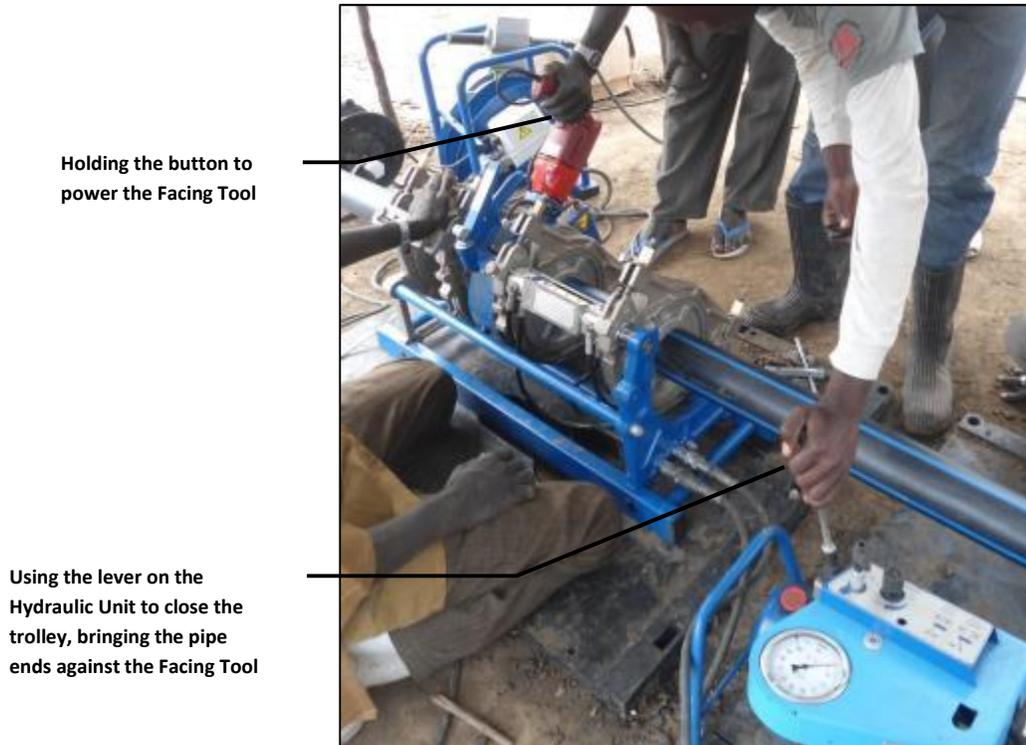


Figure 3: Shaving the pipe using the Facing Tool

Step 3: Alignment

1. Bring pipe ends together to re-check the alignment
2. Adjust clamps as necessary to achieve 'perfect' alignment (tolerance of up to 10% of wall thickness is acceptable)
3. Note 1: the purpose of shaving is to ensure a flush join of the pipe ends; if by adjusting the clamps there is now a gap between the pipe ends, repeat Steps 2 and 3.
4. Note 2: there may be small variations in size between different pipes such that it is not possible to achieve good alignment; consider changing for a new pipe.

Step 4: Bead formation

1. Wait for Heating Mirror to reach required temperature
2. Insert Heating Mirror into machine

3. Close trolley to bring pipe ends against Heating Mirror at the required pressure
4. Wait the specified period
5. Reduce pressure to the required value
6. Wait the additional waiting period
7. Open trolley and remove Heating Mirror
8. Close trolley to bring pipe ends together and slowly increase to the required pressure
9. Wait the specified 'cooling time' period
10. Release pressure, unfasten the clamps and remove pipe



Figure 4: Bead Formation using the Heating Mirror



Figure 5: Waiting during the Cooling Time



Figure 6: A 'good' weld

A good weld is one where the bead formation is symmetrical and (for 3 and 4" pipe) 1mm in size. (Note: if the bead is too large the constriction inside the pipe will result in additional frictional losses).

3.5 COMMUNITY MOBILISATION FOR TRENCH DIGGING

Carry welded pipe strings onto site and weld the sections together to make one continuous pipeline.



Figure 7: Carrying welded pipe string onto site

Concurrently the affected sheikhs were asked to help mobilise people to start digging the trench.

This involved:

- Measuring 50m sections, marking off each section with a piece of wood dug into the ground (wrapped with tape for easy identification)
- A 'Team Leader' was nominated (by the Sheikh) and recorded for each section. Many people could dig, but all payment was made directly to the Team Leader
- Trench dimensions of 50cm wide by **80cm deep** were adopted; this gave sufficient space adjacent to the pipe for compaction, and sufficient depth beneath ground level to protect pipe from surface loading, erosion etc.
- Measuring sticks were given initially (a piece of wood measured to 80cm and wrapped with some tape to mark 50cm). Later people provided their own sticks
- Payment was agreed as 7 SSP (South Sudanese Pounds) per metre for the digging, and 3 SSP per metre for the backfilling

- At completion measurements were checked and the Team Leader paid
- Depending on how motivated the community was, digging generally took between 2 – 4 days



Figure 8: Measuring 50m sections



Figure 9: Measuring sticks to show trench width & depth

3.6 PIPELINE PRESSURE TESTING

The purpose of pressure testing the pipelines was to check they will act satisfactorily under normal operating conditions (ie. no leaks, sufficient strength). A **test pressure of 2.5 – 3.0 Bar** was adopted which is significantly higher than the maximum design pressure (less than 1 Bar). It is important to do the testing directly prior installation / backfilling in order to minimise the risk of any damage to the pipe going undetected.

The test involves filling the pipeline with water, then pressurising the water (by pumping water into the line and partially closing a valve at the end of the line). This will force water out of any cracks / damaged / poorly welded joints which will then be observed by those inspecting the pipeline.

Testing equipment

- Sufficient water readily available to ensure continual flow for the duration of the test (5000L or 10,000L bladder)
- Pressure gauge plus connectors
- 2 x 90 degree bends, ball valve, plus connectors
- Surface pump
- VHF radios

Testing procedure

1. Set up all testing equipment as shown in Figures 10 and 11
2. Position a couple of people at either end of the pipeline with VHF radios to enable communication throughout the entire test, and position people along the pipeline
3. Begin with the valve half open
4. Start pumping
5. When water begins to exit the end of the pipeline, start gradually closing the valve
6. Note: DO NOT fully close the valve as this could damage the pump (known as 'dead heading' the pump)
7. Continually monitor the pressure gauge and communicate the readings to the team at the valve
8. The valve needs to be (partially) closed to the position which gives the required test pressure
9. Once test pressure is achieved, everyone walks along their section of pipeline carefully inspecting for leaks. The pressure should be continuously monitored
10. Once the entire pipeline has been inspected, switch pump off and disassemble testing equipment;
11. If leaks are detected, cut out damaged section and weld back together



Figure 10: Bladder connected to surface pump



Figure 11: Pump outlet connected to pressure gauge, connected to the HDPE pipeline to be tested



Figure 12: Configuration of the pipeline for pressure testing, with the valve for controlling flow rate (and pressure)

3.7 PIPELINE INSTALLATION AND BACKFILLING



Figure 13: trench for installation

Make sure trench is clear of any sharp objects (sticks, stones) and install pipeline in trench so that it lays flat. Mobilise community to backfill the trench, encourage compaction around the pipeline (it was a struggle to achieve this!). Make sure all soil removed during the digging is returned to the trench – preferably leaving a ‘mound’ on the surface, as this will settle with time and rainfall. Inspect the work and make the final payment to the Team Leader.



For ease of locating the pipeline in future (especially if those who installed it have gone) it is recommended to install a physical marker at regular intervals (eg. 100m) along the pipeline route. Also record the GPS of the pipeline for example at the start, end, and at tee junctions. [As yet this has not been done in Batil camp].

3.8 ROAD CROSSINGS



Where the pipeline crosses a major road in the camp it has been protected from vehicle loading by being installed inside a larger diameter pipe.

While digging across the road ensure there is sufficient space for a diversion and make sure this is clear to traffic. Aim to do the road crossing as fast as possible to minimise disruption.

Figure 14: HDPE pipelines inside larger diameter PVC pipes for protection at road crossing

3.9 CHALLENGES & LESSONS LEARNED

- Initially it was unknown how long it would take to dig trenches and several pipeline routes were dug concurrently before the pipe had been welded. This was during the wet season and resulted in the trenches being open to the rain for a few weeks, leading to significant portions of the trenches collapsing. Lessons learned:
 - Plan activities so as to minimise the length of time the trench is open, especially if working in wet season
 - Weld pipe in advance of trench digging, as this is the longest duration activity
- During the pipeline route walkover with the sheikhs, encourage them to inform affected households immediately about the planned work.
- People complained that payment was not sufficient. Our response was the rate is agreed across the entire camp and we need to be consistent; also the water project is ultimately for their benefit.
- People complained they wanted additional payment for digging through swampy ground. Our response was to keep the rate the same, avoiding a situation where everybody starts to claim that their section is of greater difficulty. Take care about setting precedents.
- The advantage of placing the pipeline along the route is that it shows people where to dig so that the trench alignment is smooth. The disadvantage is that occasionally the pipeline was damaged during digging. Be sure to emphasise to people to take care not to hit the pipeline.
- We started installing pipeline markers (0.5" one-metre sections of GI pipe) as markers every 100 m along the route. However, even when these were concreted in they were removed by the community. As yet we have not replaced them.

4. INSTALLATION OF OXFAM WATER TANKS

4.1 DESIGN

The Oxfam Tank design hereby described does not correspond fully with the standard Oxfam Tank kit.

The design was adjusted in two aspects:

- i) An Oxfam T95 tank was installed, but with a T70 liner. Practically, this meant that the first of the 4 rings was back-filled with murrum, and then the liner installed to fit the remaining 3 rings. The aim of this modification of the standard design was to increase the height of the outlet. The target was to provide a total head of 2.50 m. In practice the head achieved was about 2.30 m: - 0.30 m (murrum base) + 1.3 m (plinth) + 0.65 m (1st ring of T95 tank) + 0.05 m (height of outlet).
- ii) Instead of the standard two 3" outlets, each tank was specified with a different number of outlets, with a mixture of 3" and 4" fittings. The purpose was to have separate outlets for almost each tap stand, in order to avoid any alteration of the flow at tap stand level, since the tap stands have high demand and one tank supplies several tap stands. Ball valves were specified in preference to gate valves because they last longer and can quickly be identified as open or closed.

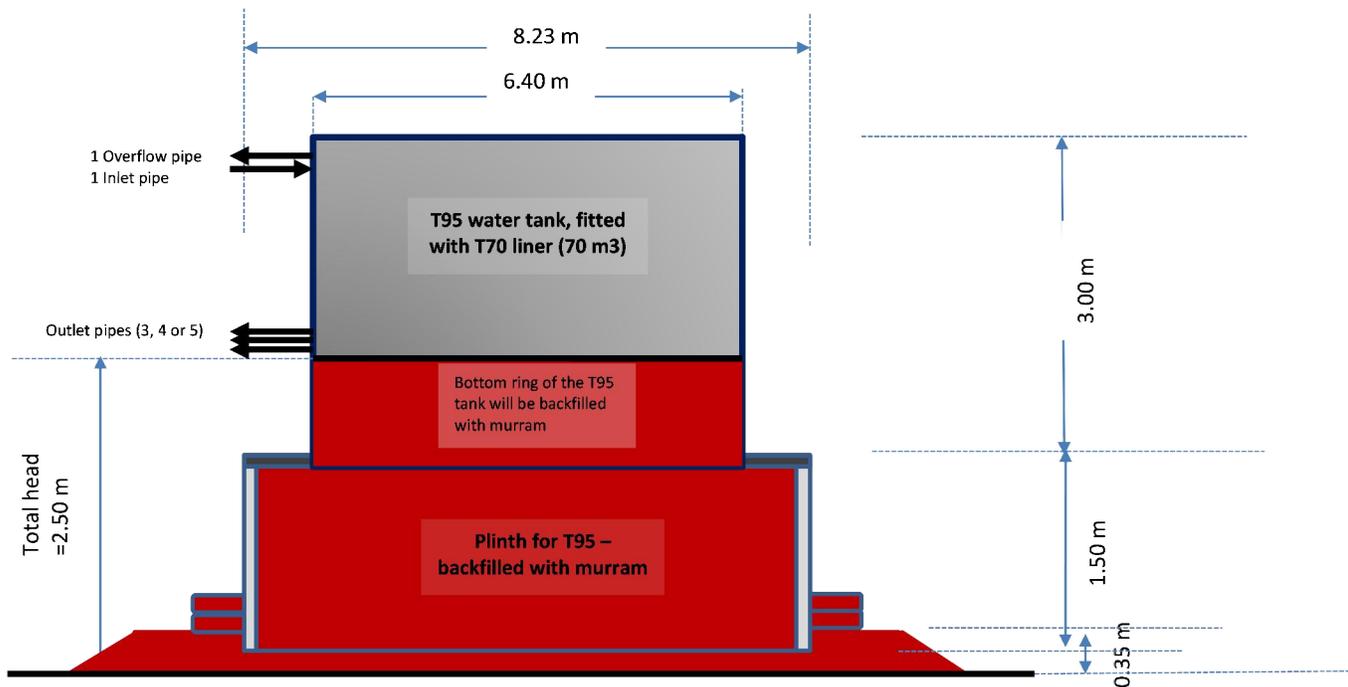


Figure15: Design of the Oxfam tanks

4.2 INSTALLING THE PLINTH

Note: The plinth could have been set directly into the ground, but we decided to install a maram (laterite stone) platform before, with two main purposes:

1. To raise the total elevation to 2.50 m (due to the topographical constraints of Batil, the elevation was not sufficient for the installation of water tanks allowing gravity flow)
2. To protect the plinth from the variations of volume of the black cotton soil. In the guidelines for installation of Oxfam Tanks it is advised that “In black cotton soils, or other locations where ground conditions can be soft, it is inadvisable to erect tanks taller than 2.3m, unless stringent precautions are taken to prevent subsidence caused by erosion of foundations and wind pressure. This might require a gravel (or concrete) foundation”.

Regarding the selection of the storage sites, see Section 2.2.1 earlier.

4.2.1 Marking out & clearance

- Once selected (and agreed with the local sheikhs), a compound measuring approximately **16 x 16 m** was fenced-off at each site so the land was clearly demarcated and would not be otherwise developed
- An area of diameter **10.5 m** was marked out, with iron ‘pegs’ around the circumference (very useful later on when the maram is being poured and the initial marks in the ground are lost)
- The ground was cleared to 0.1 m below ground level to improve bonding between the maram & clay soil



Figure 16: Delivering the maram after clearing the ground

4.2.2 Maram & levelling

- In total 4 trips (20 tonne trucks) of maram were used for the 'base'; an initial 2 trips which were spread and compacted. Then 2 further trips were added allowing the elevation of the platform of approximately 0.30 m above ground level.
- **It is really important to get the base levelled before beginning to install the plinth.** In order to achieve this we used a 6 m length of steel box-section (2x3") as a levelling tool; this was dragged across the maram (with a spirit level on top) to sweep excess gravel and ensure a uniform, level surface.
- **When compacting the maram a small amount of water was sprinkled on the surface to help compaction.** The main lesson learnt was not to add an excess of water otherwise the plate compactor simply sinks into the maram, so the best approach was to pour water with pierced buckets imitating watering cans.

4.2.3 Installing the plinth

A) INSTALLATION OF STEEL PANELS

- Before starting note that the iron-sheets used for the plinth are not the same as those for the tank. Firstly they are thicker (1.2 mm as opposed to 0.8 mm); secondly, they were rolled to a radius of 4.12 m (as opposed to 3.2 m)



Figure 17: the difference between the plinth & tank sheets was noticeable – but there was room for confusion!

- The plinth (Oxfam Code TP/1) has a diameter of **8.23 m**. This was marked out and a shallow trench 0.10 m in depth was constructed around the ring of the plinth so that it could be set into the compacted base.



Figure 18: installing the plinth panels in the demarcated trench

- Note: when installing the iron-sheets, they should be bolted together in such a way that one end overlaps on the outside; the other end on the inside.
- Upper rings can continue to be bolted outside lower rings or, if preferred, adjacent sheets can be woven in and out of lower ring. This enables the upper sheet to be supported at its midpoint while its own bolts are inserted.



Figure 19: "Woven" installation of steel panels in order to reinforce the resistance of the rings

- The two rings of the plinth create a platform of 1.4 m high (1.3 m above the base allowing for digging-in)
- Do not fully tighten any bolts at this stage. Once the first ring of sheets is assembled, use a spirit level on each joint to get it vertical, and then the rest of the tank can be built up correctly from this.
- Setting the iron-sheets so that the plinth was exactly horizontal required some patience and fine adjustment **but is important and should not be rushed!**
- Once the levelling has been done, it is important to check that all the bolts are well-tightened!

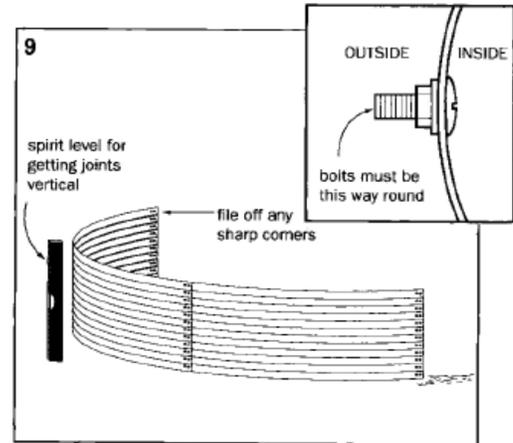


Figure 20: tightening the bolts of the plinth

B) BACKFILLING WITH MARAM

- Approximately 10 trips of maram were used for back-filling the plinth
- A large team of 10 to 15 casual workers was required for backfilling
- Before compacting, levelling was done with the 6m steel bar
- The maram was compacted every 0.15 m
- Sand-bags were filled with maram and laid in layers around the plinth. Ideally these should be placed at the same time as the maram is being built up inside the plinth in order to equalize pressure between the inside & outside. (They also form a useful step for lifting buckets of maram into the plinth)

Figures 21 - 26: Installation of the plinth



4.3 INSTALLING THE T95/ T70 TANK

4.3.1 Back-filling the first ring

- As for the plinth when installing the iron-sheets, they were dug in 0.1 m to provide a firm footing.
- An additional 4 trips of maram (making 18 in total) were used for the 1st ring of the tank.
- The compaction and levelling techniques were the same as for the installation of the tank.
- For the final layer, the maram was sieved in order to remove large stones which could potentially protrude and puncture the liner. A thin layer of sand was also added to protect the liner against abrasion.



Figures 27 - 29: Installing the 1st ring of the tank

4.3.2 Installing the rest of the rings

- According to the design, the outlets will vary from one tank to another.
- As a general fact, all the outlets and washout will be placed in the second ring, whereas the inlet and overflow will be placed on the top ring.

- The installation is similar to the process described for the installation of the plinth panels.
- Do not forget to preposition the bag containing the liner inside the tank before installing all the panels, since it is very heavy to carry and it is difficult to introduce it once all the rings are installed.



Figure 30: Installing the rest of the rings of the tank

4.3.3 Installing the liner

- Once all the rings installed, check with the spirit level that the walls are straight.
- Cover joints between sheets with self-adhesive tape to protect the liner.



Figure 31: Putting tape in the joints for protecting the liner

- Fit smaller capping around the top of the tank. Tape the capping to the tank every 50 cm.



Figure 32: Installing the PVC capping

- Installation of the flange assembly: step 1
 - Screw studs into the threaded holes so that they protrude 5 cm to the side of the welded pipe.
 - From inside the tank, pass the flange assembly through the holes in the tank wall
 - Screw on the ball valve and fully tighten. If the ball valve remains in a non-vertical position, remove the flange assembly from the holes, turn it until reaching the vertical position, and introduce the pipe and studs through the holes again.
 - Tighten nuts and washers on the outside
 - Pass the first rubber gasket over the studs.

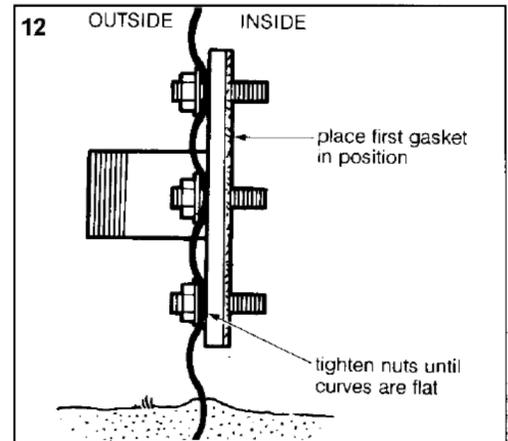


Figure 33: Installation of the flange kit

- A layer of sand was added on top of the murrum to provide added protection for the liner in case of sharp stones or loose pieces of murrum. Before installing the liner this was carefully raked to remove any remaining stones, and it was “landscaped” with a small fillet near the walls to prevent the edge of the liner being trapped against the ironsheets. (In addition Solidarites added a plastic sheet on the top of the sand layer to protect the liner).
- When working inside the liner it is important to avoid contamination as much as possible. We either used a tarpaulin on top of the liner (Medair) or required the workers to first wash their feet (Solidarites). Note; that during the day the liner was sometimes too hot to work bare-footed.
- The junction between the base of the liner and the walls of it must lie against the fillet of sand. The operators can kick softly the liner to make it fit with the fillet of sand.

- The seam of the liner in the wall must NOT coincide with any hole in the tank sheets. If this happens, rotate the liner base slightly.
- When the liner is unfolded, extend a plastic sheet on it to avoid any damage of the material.



Figure 34: Unfolding the liner

- Tie ropes to the eyelets in the edge of the liner.



Figure 35: Tying the ropes to the eyelets

- Lift the liner over the border of the tanks and ask daily workers to hold the liner (just to prevent it from slipping inside the tank, but not to pull on it). Lift the liner working from a ladder/platform. The base has to be protected to avoid damage to the liner (*ex. folded plastic sheet*)



Figure 36: positioning the liner

- Adjust the position of the liner to minimize wrinkles and to have an equal margin of liner hanging on the border towards the outside.
- Secure the liner with the larger size of PVC capping and then install the clips on the capping at intervals of 50 cm. If the end of the capping needs to be cut, be careful to cut it far from the liner.
- Put one clip in each side of the joint of the capping.



Figure 37: installing the second PVC capping

- Release the control ropes progressively.
- **IMPORTANT:** When the tank is complete, the liner joints should hang vertically and not stretch when the floor/wall seam is pushed in to the corner.
- Installation of the flange assembly: step 2

IMPORTANT: It is crucial to be very careful in this part of the installation, since it might determine the presence or not of leakages at flange level.

- With the liner correctly positioned and not under any tension, **cut small circular holes in the liner** by pressing it against the end of the studs and cutting around them carefully (tip: this can also be done hitting with a wrench gently on the protrusion of the studs on the liner - it allows to make the holes at the exact diameter of the stud, and therefore reducing the risk of leakages)
- Slide the liner over the studs and against the first gasket. Now pass the second gasket and plain flange over the studs.
- Put PTFE tape around the studs before tightening the nuts to avoid leakage.
- Tighten the nuts of the flange assembly.
- Cut the liner inside of the flange, leaving a 3 or 4" diameter outlet hole (depending on the diameter of each flange).

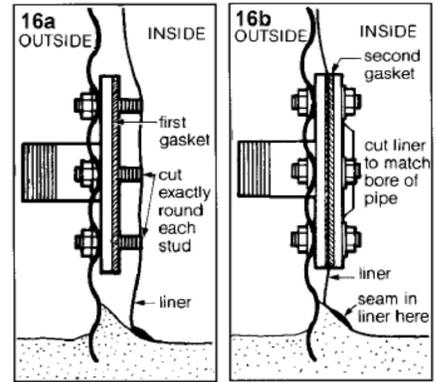


Figure 38: Installation of the flange kit

4.3.4 Installing the roof

- Screw the eye nut on to the end of bolts joining upper and lower rings of tank sheets. Space them equally around the tank (4 eye nuts per steel panel- one eye nut every 3 holes in the panel)



Figure 39: eye nut

- Assemble the support column and stand it in the center of the tank. Do not cut the length; the roof must have some slope for shedding rainwater.



Figure 40: installing the central pillar

- Pass ropes through the eye nuts, tension and tie off. Do not over tension to avoid damage to tank steel panels.

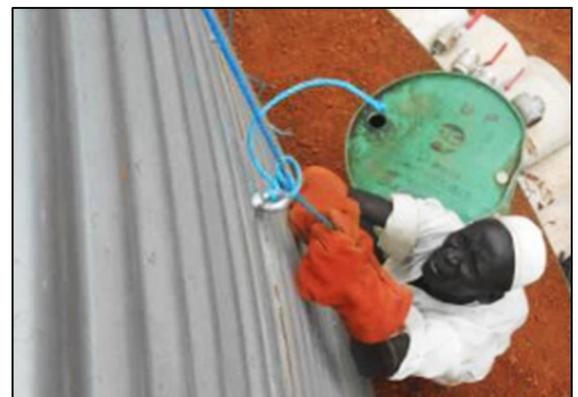
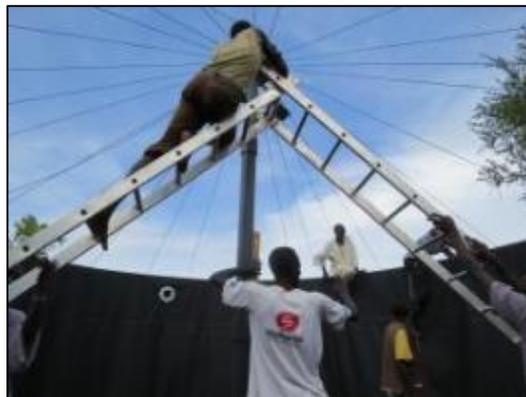


Figure 41: installing the ropes

- Check that the column is vertical with the spirit level
- Lift PVC cover over the central column and the support ropes. In the middle of the PVC there is a hole for facilitating the installation of the roof on the column.
- Tension the cover over the tank wall and secure to eye nuts with the rope. It is better to cut the rope into 28 equal pieces, to make each tie off independently.



Figure 42: checking the inclination



Figure 43: installing the PVC cover



Figure 44: One of the tanks completely installed

5 CONNECTIONS AND COMMISSIONING

5.1 CONNECTIONS TO THE PIPELINE

The connection to the pipeline was done using a combination of mainly HDPE compression fittings and galvanized iron fittings when needed.

The basic structure of each connection was:

For outlets:

- Ball valve: 3" or 4" depending on each line. Each outlet is controlled with a ball valve in order to regulate the flow and to allow the tank to be closed for operations such as manual chlorination or cleaning when needed.
- HDPE compression adaptor to threaded M (or HDPE compression adaptor to threaded F + GI nipple as alternative): 90 mm or 110 mm depending on each line.
- HDPE compression elbows: 90 mm or 110 mm depending on each line.



Figure 45: installing the outlets

For inlets:

- HDPE compression adaptor to threaded F (or HDPE compression adaptor to threaded M + GI socket as alternative): 90 mm or 110 mm depending on each line.
- HDPE compression elbows: 90 mm or 110 mm depending on each line.



Figure 46: installing the inlet

For overflow and wash outs:

The overflow was connected to the wash out pipe in order to be able to direct excess water or waste water coming from the cleaning of the tank through the same line.



Figure 47: overflow linked to wash out

5.2 COMMISSIONING OF THE TANK

- Disconnect inlet (if it was connected) and pump water through the inlet pipe for 30 minutes to clean; inject chlorine solution and pump for another 30 minutes. Then re-connect inlet.
- Clean inside of tank with soft broom to remove sand/ dust and flush out the waste water.
- Close all outlet valves and fill tank about $\frac{1}{4}$ full.
- Add concentrated chlorine solution directly to the tank and leave overnight. This will make sure the tank is well dis-infected and will also allow you to see if the water level has dropped noticeably (measure with a stick after filling the tank and next day).
- Next day drain the tank (using the outlet pipes rather than the wash-out in order to provide an initial flush of the lines).
- Fill the tank again , and add concentrated chlorine solution to finish flushing the outlet pipes. Open one outlet valve and allow water to flow under gravity for 30 minutes to clean-out the pipe. As soon as this is done then make the connection to the tap stand. (Note: tap stand cannot be used as tank has still concentrated chlorine solution in it).
- Once all the outlet pipes have been cleaned/ disinfected then you can drain any excess chlorine solution from the tank using the wash-out.
- Refill the tank
- Open the valves
- Check that the time of filling a 20 litre jerry can is less than 3 minutes (Sphere standard)
- Begin using the water!

Last details after the commissioning of the tank:

- Put a layer of cement over the maram in the plinth to provide water-proofing.



Figure 48 Plinth – finishing touches

A thin layer of concrete was poured over the plinth to prevent water ingress, with a small slope to allow runoff. Brick pillars were constructed underneath the outlets to support the heavy valves.

- Provide a proper “exit” for the overflow/ wash-out pipe.



Figure 49 Overflow pipe

The overflow pipe was extended about 18 m (3 pipe lengths) from the tank so any overflow does not damage the tank foundations. The outlet should not be completely buried so it is immediately obvious when the tank is overflowing! The outlet was protected with some fine wire mesh to prevent damage, eg children filling the pipe with stones. It is probably not worth making a soak-pit in the clay soil

- The temporary fence installed initially was replaced with chain-link – and a lockable door to restrict access



Figure 50 The finished tank (S3)



Figure 51: cleaning the tank



Figure 52 : connecting the tap stands



Figure 53: testing the flow at tap stand level



Figure 54: collecting the old layflat pipes



Figure 55: Dismantling and cleaning the emergency bladders

And finally... enjoying the water!



6 CONCLUSIONS

The water network started to be functional between the last week of May and the first week of June 2014.

The final maps for the network are attached at the end of the chapter.

6.1 STANDARDS ACHIEVED

6.1.1 Flow at water points

Methodology: The time to fill a 20 litre container was tested in all the water points. The measurement was done with all the taps open at the same time in order to check the time of filling with the minimum flow.

Results (from 25 tapstands)

- Only 1 had a flow rate less than the SPHERE standard of 0.11 l/s (3 minutes to fill a 20 litre jerrycan)
- A further 6 had a flow rate between 0.11 l/s and 0.167 l/s which was the design minimum flow rate (2 minutes to fill a 20 litre jerrycan)
- The average flow rate was 0.21 l/s

SPHERE standard: 7.5 liters/minute (for a standard of 250 persons per tap)

6.1.2 Number of people per tap

Number of tap stands in the camp: 408 (including Medair and SI area of intervention)

Last population data according to UNHCR: 39,366 persons (UNHCR update of May 2014)

Number of persons per tap: 96 persons in average in Batil.

UNHCR standard: 80-100 refugees per tap

SPHERE standard: 250 persons per tap (based on a flow of 7.5 liters/minute)

6.1.3 Distance to water points

Methodology: This standard was calculated by REACH according to UNOSAT data of December 2013.

The data shows 14,913 shelters of 4 categories in Batil camp while UNHCR says there are 9,232 households. The breakdown of the structures is 6,902 Tents, 269 Admin buildings, 7,737 Improvised shelters, and 5 semi-permanent structures.

Using the data from Medair and Solidarites International, REACH used a buffer system from all water points in order to show both UNHCR and SPHERE distance standards. Then, the shelter points that fall within each standard were identified.

Results: Using the UNOSAT shelter locations for December 2013, out of 14,913 shelters:

- 10,747 shelters within 200 meters of a water point: 72% of shelters according to UNHCR standards.
- 3,990 shelters within 500 meters of a water point: 27% of shelters according to SPHERE standards
- 176 shelters outside 500 meters of a water point: 1% of the shelters not fulfilling any of the two standards.

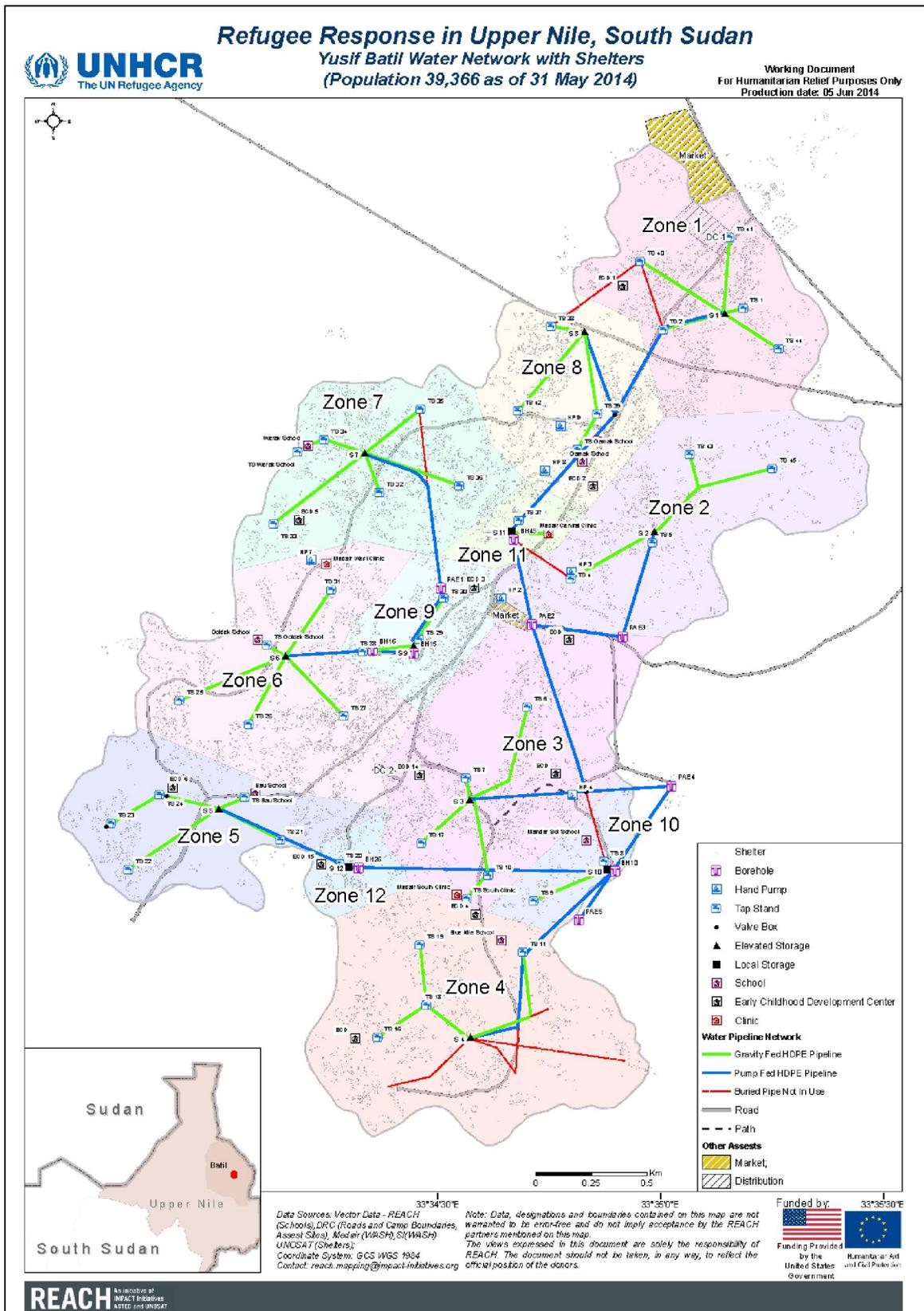
However, it is worth taking into account two factors:

- A majority of the shelters outside the 500 meters are coming from the south end of the camp. This area was affected by a security incident with the host community in March 2014. Since that incident, a large number of people (approximately 2000) have abandoned the area, some have relocated to Kaya camp and others to an area in the east of Batil. Consequently Tapstands 12, 13, 14 and 15 are now abandoned and no longer required. However, this is not yet reflected in the UNOSAT images which date back to December 2013.
- The number of shelters considered is the one of UNOSAT. Nevertheless, there are not families living in all the registered shelters, since they include administrative buildings, etc.

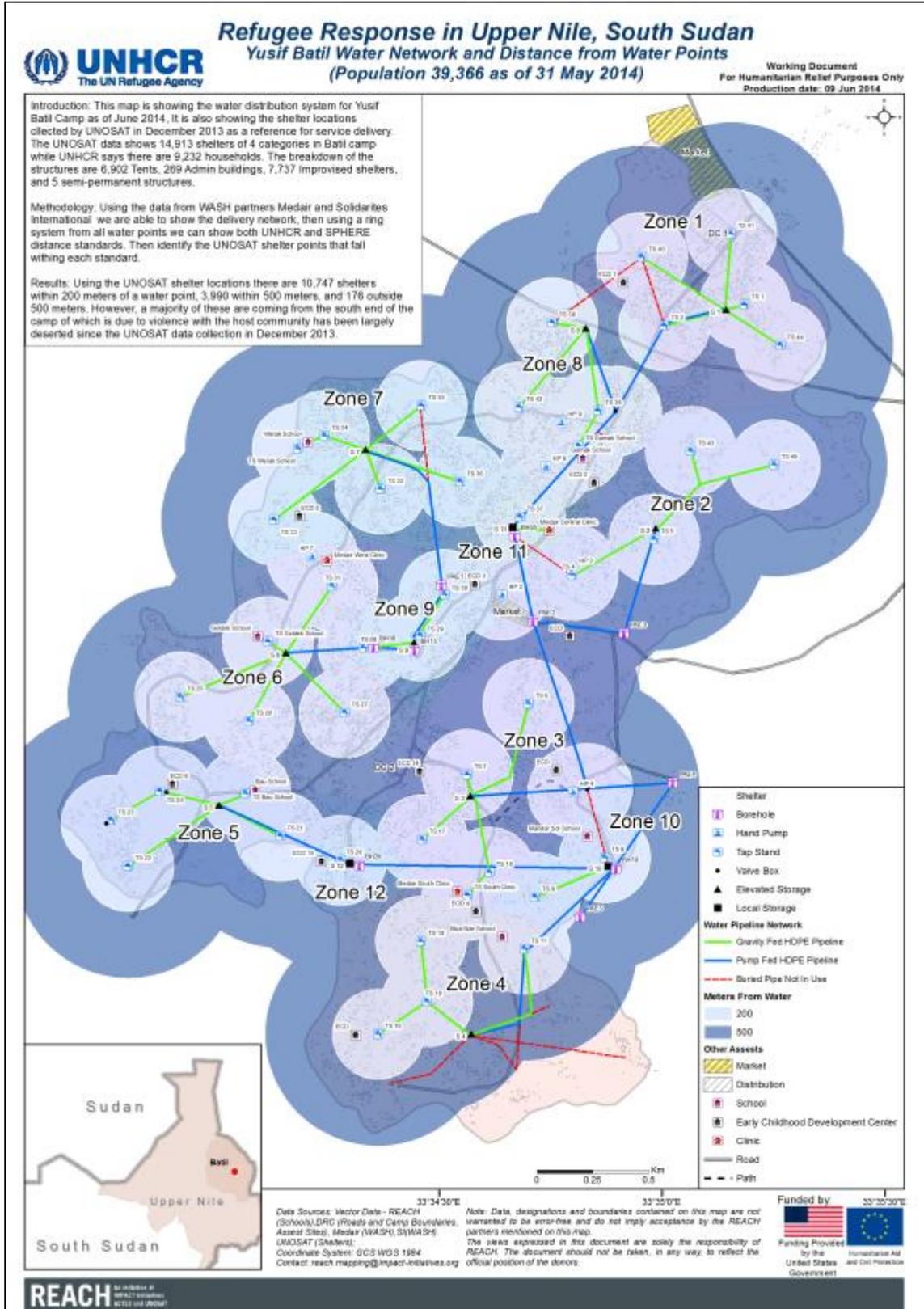
UNHCR standard: 200 m

SPHERE standard: 500 m

Map 5: Sustainable water network - June 2014



Map 6: Sustainable water network coverage analysis - June 2014



6.2 NEXT STEPS

Although the main infrastructure is now in place, there is still a need for improvements and upgrades. It is envisaged that work in the coming 12 months will focus on four areas:-

1. Water quality

Monitoring of FRC levels has been ongoing for two years in the camp but we have not yet reached our target which is to achieve 95% of samples (at tapstands) within the range of 0.5 to 1.0 mg/l. Currently, some of the boreholes are fitted with in-line chlorine dosing pumps, while batch chlorination is still being carried out at other sites – we plan to standardise chlorination procedures across the camp. One of the challenges noted has been mixing the chlorine HTH powder, which does not dissolve easily (possibly because the high temperatures in South Sudan cause it to expire early) and thus produces inconsistent results.

2. Rehabilitation of tapstands

The original tapstands were, understandably, built quickly in an emergency context – many are now showing signs of “wear and tear”; in many cases drainage is poor (complicated by the impermeability of the black cotton soil); and most of the fences were dismantled by the community. Solidarites and Medair have already begun a programme of rehabilitating the concrete aprons, drainage and fencing. In parallel with this we will be seeking to empower the community to manage and maintain their local waterpoints. Promoting voluntary work is a challenge in the camp after two years of paying wages by NGOs, so success will depend on whether or not the community feel any sense of ownership.

3. Reduce running costs

The current network is expensive to run with high ongoing costs for operating staff (we currently have a team of 54 people⁴ running water supply in the camp); diesel (consumption of about 1500 litres/ week); and maintenance. However, possible improvements have already been identified which may reduce O&M costs:-

- Installation of new submersible pumps

Replacing the submersible pumps in the PAE boreholes with a pump better suited to the depth/ yield of the borehole. All 5 PAE boreholes were fitted with a Grundfos SP8A-50 pump. This is optimised for deep boreholes, producing 8 m³/hr at a head of 200 m. However, the boreholes in Batil camp are much shallower than this with the pump typically installed between 70 – 80 m. At these depths, the pumps installed are a long way off the peak performance point. From the Grundfos pump range the most appropriate pump is the SP14A-25 – this is the same diameter (so can be installed in the 5” borehole casing) and uses the same motor (7.5 kW). One of these pumps was installed at the beginning of June in PAE4 borehole. Initial results are encouraging with yield increasing by 30%. Fuel consumption should remain more-or-less constant for the same size motor, hence we

⁴ 4 technicians; 36 operators and guards; 10 handpump chlorinators and 4 chlorine monitors

expect a significant (23%) drop in fuel consumption for the same output. After monitoring performance and water levels at PAE4, we will then install these pumps in the other high-yield boreholes in Batil.

- Installation of solar system

This has already been trialed in Gendressa and Kaya by Oxfam. We plan to install two systems in Batil before the end of 2014 – though generators will be kept as a back-up.

- Reduce the number of generators

It is planned to install electrical cable from BH15 to BH16 (about 200 m) so that the two small pumps can be run simultaneously from a single generator. This should also reduce fuel costs (and the number of operators required). Currently the Zordan generators are over-sized for the SQ5-70 pumps.

4. Capacity building of staff

We will continue to train refugee staff within Batil, so that they can take on more responsibility for minor repairs to the network; repair of handpumps; and basic servicing of generators.

Appendix A – Water demand per zone

Water demand per zone							12	4.5	6	15	15	15	15	5	
Storage area							Number of hours each BH is operated per day								
Storage area	Shelters	% camp population	demand (m3/day)	number of times tank filled per day	storage	proposed storage tanks	BH15&16	BH26	BH45	PAE1	PAE2	PAE3	PAE4	BH10	
S1	1115	10.7%	106.7	1.5	70.0	T70					7.1				
S2	784	7.5%	75.0	1.1	70.0	T70						5.0			
S3	1182	11.3%	113.1	1.4	80.0	T70 + T11 (BH10)						6.2		4.0	
S4	1038	9.9%	99.3	1.4	70.0	T70							6.6		
S5	1016	9.7%	97.2	1.2	80.0	T70 + T11 (BH26)		8.3					4.0		
S6	1618	15.5%	154.8	2.2	70.0	T70	12.9								
S7	1675	16.0%	160.3	2.3	70.0	T70			10.7						
S8	1337	12.8%	127.9	1.6	80.0	T70 + T11 (BH45)			11.3		4.0				
S9	686	6.6%	65.6	1.5	45.0	T45				4.4					
			10451	1000	635.0	12 storage tanks	12.9	8.3	11.3	15.1	11.1	11.2	10.6	4.0	
Water pumped per day (m3)							155	37	68	226	167	168	159	20	1000
Water pumped per day (%)							15.5%	3.7%	6.8%	22.6%	16.7%	16.8%	15.9%	2.0%	100.0%
Fuel per day (litres) - based on 1.2 l/hour for Zordan generators & 3.1 l/hour for Olympian generators							15.5	9.9	13.6	46.7	34.4	34.7	32.9	4.8	192.6
Conclusions:															327 USD/day
1	Demand highest in S6, S7 - extra storage site (S9) proposed in zone 6 to support TS28,29,30														119,495 USD/year
2	Under this scenario 73% of water is supplied from the 4 PAE BHs; remaining 27% from the 5 smaller pumps (which may eventually be converted to solar power). Handpumps not included														
3	S8 could potentially be supplied by PAE2 instead of BH45.														
4	Due to the low yield of BH26, it will probably be necessary to continue pumping from PAE4 to the SW														

Appendix B - HDPE welding procedures

Diameter = 3"

Length = 6m; Nominal Pressure = 10 Bar

Outer Diameter = 90mm; Wall Thickness = 5.1mm; SDR = 17.6; Bead Thickness = 1.0mm

1	Plug in the heating mirror; set the temperature to 219 degrees
2	Shaving the Pipe Shave the HDPE pipe using the facing tool by slowly increasing the pressure <i>Do not increase the pressure too much as this will damage the facing tool</i>
3	Remove the facing tool Carefully check the alignment of the pipes and adjust the clamps to ensure joint is flush Bring the pipes together and set the pressure to 9 Bar (= 5 + X bar)
4	Once the heating mirror has reached 219 degrees, open the trolley and insert the heating mirror
5	Bead Formation Close the trolley at pressure 9 Bar (= 5 + X bar) for 11 seconds
6	Heating Up Reduce the pressure to 4 Bar (= X bar) for 51 seconds
7	Change-Over <i>The following needs to happen fast (within 5 seconds) =</i> Open the trolley and remove the heating mirror Bring the pipes back together at LOW pressure
8	Pressure Increase SLOWLY increase the pressure to 9 Bar (= 5 + X bar) (within 5 seconds)
9	Cooling Time Wait for 7 minutes Make sure the pressure does not decrease too much
10	Reduce the pressure to zero Open the clamps and remove the welded pipe

NOTE: X = the inertial pressure (the pressure required to just move the pipe). For **one 3" pipe** the inertial pressure is **X = 4 Bar** (based on field test); *whenever pipe strings are welded together the inertial pressure needs to be determined and entered into the above formulae to determine the new pressures to be applied.*

PROCEDURE FOR WELDING HDPE PIPE

Diameter = 4"

Length = 6m; Nominal Pressure = 10 Bar

Outer Diameter = 110mm; Wall Thickness = 6.3mm; SDR = 17.6; Bead Thickness = 1.0mm

1	Plug in the heating mirror; set the temperature to 217 degrees
2	Shaving the Pipe Shave the HDPE pipe using the facing tool by slowly increasing the pressure <i>Do not increase the pressure too much as this will damage the facing tool</i>
3	Remove the facing tool Carefully check the alignment of the pipes and adjust the clamps to ensure joint is flush Bring the pipes together and set the pressure to 11 Bar (= 7 + X bar)
4	Once the heating mirror has reached 217 degrees, open the trolley and insert the heating mirror
5	Bead Formation Close the trolley at pressure 11 Bar (= 7 + X bar) for 11 seconds
6	Heating Up Reduce the pressure to 4 Bar (= X bar) for 63 seconds
7	Change-Over <i>The following needs to happen fast (within 6 seconds) =</i> Open the trolley and remove the heating mirror Bring the pipes back together at LOW pressure
8	Pressure Increase SLOWLY increase the pressure to 11 Bar (= 7 + X bar) (within 6 seconds)
9	Cooling Time Wait for 9 minutes Make sure the pressure does not decrease too much
10	Reduce the pressure to zero Open the clamps and remove the welded pipe

*NOTE: X = the inertial pressure (the pressure required to just move the pipe). For **one 4" pipe** the inertial pressure is **X = 4 Bar** (based on field test); whenever pipe strings are welded together the inertial pressure needs to be determined and entered into the above formulae to determine the new pressures to be applied.*