Water resource management in humanitarian programming in Darfur:

The case for drought preparedness

Report of the UNEP mission to review water resource management at IDP camps and host communities in Darfur during February & March 2008

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Cover photo: water collection from a wadi bed near to Masterei in West Darfur in the dry season.

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Acronyms

BC	Basement Complex
DFID	Department for International Development (of UK Government)
ENTEC	Environmental Technology Task Force
FAO	Food and Agriculture Organisation of the United Nations
GWWD	Groundwater and Wadis Directorate (of Ministry of Irrigation)
HDW	Hand Dug Well
HIC	Humanitarian Information Centre
IDP	Internally displaced person
IRC	International Rescue Committee
IWRM	Integrated Water Resource Management
MOU	Memorandum of Understanding
NGO	Non-governmental Organisation
NS	Nubian Sandstone
NWC	National Water Corporation
OCHA	United Nations Office for the Coordination of Humanitarian Affairs
OW	Observation well
PW	Production well
SECS	Sudanese Environmental Conservation Society
T	Transmissivity
TOR	Terms of Reference
UNAMID	African Union/United Nations Hybrid operation in Darfur
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNHCR	United Nations High Commission for Refugees
UNICEF	United Nations Children's Fund
URS	Umm Ruwaba Series
USAID	United States Agency for International Development
VR	Volcanic Rocks
WES	Water and Environmental Sanitation

Summary

This report summarises the findings of a review of water resource management in IDP camps and host communities in Darfur undertaken by UNEP in February and March 2008. It has been subject to consultation at meetings with the Water Sector in Nyala, El Fasher, and Khartoum and the draft report was widely reviewed within the Darfur water sector by UNICEF, WES and NGOs implementing programmes in the areas covered in the report. The work builds on the Tearfund report "Darfur: water supply in a vulnerable environment" and it assesses progress made since that report.

This report has assessed information relating to IDP camps and host communities but stresses that an integrated approach addressing water needs for all users in Darfur is needed. IDP camps are generally located adjacent to host communities; taken together these are referred to as "communities" in this report. Where IDP camps are on the edge of large cities the word camps is retained. Darfur's large cities have been subject to particularly rapid population expansion and drought risks need to be addressed with their surrounding areas, camps and settlements as a whole.

Good progress has been made on groundwater monitoring at IDP camps and communities in 2007-8. Some 49 ground water level loggers have been installed and at least a further 15 wells are monitored with manual dipping. This work has been led by UNICEF, GWWD, WES and Oxfam. UNEP welcomes the recommendations made in UNICEF's report ""Darfur's IDPs Groundwater Resources: capacities, depletion risks and contingency planning" which builds on data collected from groundwater monitors and other sources.

The report confirms the assessment that the principal risk associated with groundwater depletion in Darfur is the risk of acute depletion at camps and communities that are vulnerable to the impact of a year of low rainfall. The vulnerability of communities is a function of the water demand (population and water use), local geological conditions, rainfall and surface water flow. Camps on Basement Complex geology have little capacity for groundwater storage so the groundwater supplies are dependent on annual recharge from a nearby wadi. If there is a good hydraulic connection with the wadi and the wadi has a good volume of alluvial storage then the water resources in the camp are likely to be resilient to a year of low rains (Mornei would be a camp in this category). If however, the camp is not connected to a wadi (such as Dereig or Otash) then the camp is dependent on the little storage available in the fractures and weathered zones of the Basement Complex beneath the camp alone and so would be vulnerable to groundwater depletion in a year of low rains. Between these extremes are a range of camps where the extent of connectivity and recharge from wadis to the aquifers beneath the camps is partial and not well known. The focus of the groundwater monitoring programme has been to identify these hydraulic connections that indicate the recharge mechanism for the aquifers at these camps, and therefore indicate the level of vulnerability to groundwater depletion in a year of low rains.

The following camps and communities are identified as potentially vulnerable to groundwater depletion. These camps should be priorities for effort on improved water resource management:

North Darfur: Abu Shouk, Al Salaam, Kebkabiya Town, Kutum Rural, Tawila Town, Kutum Town, Saraf Omra Town, Kassab, Zamzam, Mellit.

South Darfur: Otash, Dereig, Kalma, Kass Town, East Jebal Marra, Muhajirya – South Camp, Beleil.

West Darfur: Kereinik, Seleah, Kulbus, Abu Surug, Umm Dukhun, Golo AU.

The changes in this list since the Tearfund report are the addition of Zamzam and Mellit. This list represents a screening of camps made from desk reviews and consultations with hydrogeologists working in Darfur. The list is a live document and should be developed as more information becomes available.

1 *'Darfur: water supply in a vulnerable environment', Tearfund 2007. www.tearfund.org/darfurwatervulnerability or www.tearfund.org/darfurwatersummary*

2 *http://www.wes-sudan.org/reports/Darfur%20IPs%20Groundwater%20Resources%20Final.pdf*

Table S.1. Recent annual rainfall records compared with average and lowest on record (mm)

Location	Average rainfall 1978-2007	Lowest annual rainfall recorded (year)	2004	2005	2006	2007
El Fasher	194	73 (1983)	118	317	239	265
Nyala	384	140 (1947)	432	487	467	457
Geneina	427	124 (1984)	442	636	419	508

This report makes the case for the implementation of a drought preparedness strategy as follows:

- The massive displacement in Darfur has caused unprecedented concentrations of population to depend on groundwater resources in areas of particularly variable rainfall.
- The crisis has coincided with four years of generally above average rains so groundwater recharge has been good.
- This good rainfall cannot be relied on to continue.
- Some camps are in areas away from good recharge and so have increased vulnerability to groundwater depletion.
- Therefore, a drought preparedness strategy is needed that assesses and mitigates the impacts of a year of low rains at camps with high populations and poor aquifers.

Table S.1 shows how rainfall at the state capitals compares with both the average rainfall and lowest on record. On only two occasions has recent rainfall been below the average, and only one of these by a significant margin.

In order to mitigate the impact of drought at vulnerable IDP camps the following four stage strategy for drought preparedness is proposed:

1. **Extend current initiatives in hydrological analysis**: Continuing the improvements in the quality and coverage of hydrological data collection, management and interpretation at potentially vulnerable camps.

2. **Prepare interim drought preparedness plans for the event of failure of the 2008 rains**: These will improve drought resilience pending implementation of drought mitigation works. Interim drought preparedness would include activities such as drilling in areas with good yields and tankering.

3. **Design and implement drought mitigation works** (sand dams, check dams, etc.) during the 2008-2009 dry season and 2009-2010 dry season.

4. **Drought preparedness plans to address residual risk**, which will remain high in some cases, following completion of drought mitigation works.

This strategy is presented for further review, development, adoption and implementation by the water and sanitation sector in Darfur, as one component of a broader water and sanitation strategy.

Development of water resource management needs to address long term post conflict scenarios of IDP return in addition to the risk of drought during the period of displacement. Water resource infrastructure would need to be appropriate for agricultural and environmental rehabilitation and recovery in the areas where the environment has been eroded due to the concentration of population during the years of the conflict. This needs to be part of a wider water resource strategy supporting areas of projected return and for rural populations including nomadic groups.

For lasting benefit in Darfur this work must be undertaken in a collaborative manner and with due attention given to institutional development and capacity building with government and civil society. The work will be undertaken in collaboration with UNICEF, WES and other stakeholders and will be part of the development of the broader UNEP/UNICEF IWRM programme. Integrated Water Resource Management (IWRM) is a consultative multi-sectoral approach to water resource management that acknowledges the complexity of governance structures in Darfur by including formal and traditional government in addition to technical water professionals and civil society.

Recommendations for water resource managers: This report includes an edited version of the 20 technical recommendations for improved water resource management at camps – updating the recommendations made in the Tearfund report "Darfur: water supply in a vulnerable environment". This report also includes the camps specific recommendations from the Tearfund report. In conjunction with the analysis provided by UNICEF, and consultation with the wider water sector, a protocol for good practice in water resource management at camps should be developed.

Technical support and next steps: This report provides commentary on interpretation of groundwater monitoring data rather than detailed analysis of individual camps. Work on individual camps will be undertaken with focal point agencies supported through the DFID-funded UNEP technical help desk. This will provide more detailed analysis of each of the potentially vulnerable camps and comprises the first of the four steps towards drought preparedness described above.

Chapter 1

Introduction and purpose

1.1 Project background

This report summarises the findings of two UNEP missions to Darfur covering the three state capitals in February and March 2008. The missions included site visits to Otash, Kalma, Abu Shouk, Al Salaam camps and the Haloof dam. The first mission focussed on reviewing groundwater monitoring and consultation with UN and NGOs in Nyala and El Geneina. The second mission had a greater focus on consultation with government in all three states.

This report has assessed information relating to IDP camps and host communities but stresses that an integrated approach addressing water needs for all users in Darfur is needed. IDP camps are generally located adjacent to host communities; taken together these are referred to as "communities" in this report. Where IDP camps are on the edge of large cities the word camps is retained.

This project has been undertaken by UNEP with substantial support from UNICEF and Oxfam, who have collected the data discussed in Section 3 and 5 and have facilitated discussions and visits in the field. DFID has provided funding for UNEP to manage a joint programme with UNICEF on Integrated Water Resource Management in Darfur. The first component of that work is to provide a technical helpdesk on water resources with a focus on water security for displaced populations. This report is prepared under that component of the project ahead of the formal agreement with UNICEF, but with support and a spirit of cooperation from UNICEF. All parties have stressed the need for a collaborative effort – between UN agencies, with government, NGOs, and civil society and community water user groups.

The current initiative in Darfur builds on two studies undertaken by Tearfund in 2007. *Darfur: Relief in a vulnerable environment*[3] called for groundwater monitoring to be undertaken by implementing agencies on one in five production wells, and for a more detailed assessment to be made of water resource security in IDP camps in Darfur. The more detailed assessment *Darfur: water supply in a vulnerable environment*[4] was undertaken in February to March 2007 and circulated as a draft report in May 2007. The key finding of this report was that rather than long-term draw down of aquifers, the principal risk to groundwater resources at IDP camps was the risk of failing supplies in a year of poor rains at particularly vulnerable camps. The report identified 21 camps that appeared potentially vulnerable on the basis of their geology and population, and made recommendations for improved assessments of water resources at these camps. After a protracted period of consultation during which implementation of groundwater monitoring began in earnest, the report was finalised reporting that groundwater monitoring was being undertaken in Darfur. These reports were funded by DFID, UNHCR, and USAID and were given technical support by UNEP. UNEP drew attention to these issues in the Post Conflict Environmental Assessment in June 2007.[5] Prior to the current initiative, UNICEF commissioned a hydrogeological consultancy in 2004 and a consultation with government agencies produced recommendations for groundwater monitoring at IDP camps in Darfur. Agreements with government agencies made at this time provide a useful basis for developing the current initiative. UNICEF have commissioned a report *Darfur's IDPs Groundwater Resources: capacities, depletion risks and contingency planning*. UNEP welcomes the recommendations made in UNICEF's report including recommending additional camps for groundwater monitoring. This report is complementary to that by focussing on drought mitigation. The UNICEF report became available in draft form after this mission.

The analysis of potentially vulnerable camps and communities builds on site visits to the same camps communities and cities, and to Mornei, in 2007 and analysis undertaken at that time for the Tearfund report. This has been developed with considerable input from GWWD and WES who provided advice about water resources at different camps. The pro-

[3] *'Darfur: Relief in a vulnerable environment', Tearfund 2007 www.tearfund.org/darfurenvironment*
[4] *'Darfur: water supply in a vulnerable environment', Tearfund 2007. www.tearfund.org/darfurwatervulnerability or www.tearfund.org/darfurwatersummary*
[5] *'Sudan Post-Conflict Environmental Assessment', UNEP 2007 p 111. Details of UNEP`s programme in Sudan can be found at: http://postconflict.unep.ch/publications.php?prog=sudan*

Figure 1. A production Borehole in Kalma Camp managed by CARE

posed approach to drought preparedness has been presented at sector coordination meetings in Nyala, El Fasher and Khartoum and bilateral discussions with water stakeholders, and developed on the basis of these discussions. Regrettably, only a brief presentation could be made at the sector meeting in Geneina but, as with other state capitals, useful discussions were held with government water stakeholders.

This mission discusses the first period of data collection from the current initiative on water resources, but does not provide a community-by-community analysis of what the data indicates at each community. The purpose of the discussion of data here is to promote awareness of the importance of interpretation of data and provide some case studies. Some general observations on the data are made. Details of the proposed collaboration between UNEP, UNICEF and other sectoral stakeholders are outlined

1.2 Water resource management in camps and communities: the case for drought preparedness

The hydrogeology and hydrology of Darfur is highly heterogeneous. Blanket generalisations of whether Darfur is water rich or water scarce therefore mask the reality that people in any given location may face. Rain falls in Darfur for only about four months in the year, so storage of water in aquifers is crucial for water supplies to endure through the dry season. Most of central Darfur however, is underlain by a type of geology that makes a very poor aquifer (the Basement Complex – largely comprising hard crystalline rocks like granite and schist), so although exceptional areas with more water exist, central Darfur should be seen as having poor water resources. Exceptional areas of good water resources would include the large wadis and areas of sandstone geology such as Geneina, and the highlands of Jebel Marra.

The hydrogeological system of Darfur predominantly depends on the water falling as rain on to Jebel Marra and the surrounding hills and draining radially through the large wadis. Aquifers for camps lying on Basement Complex geology may be replenished by water leaking out of the alluvial sands into the fractures of the Basement Complex rock, if sufficient hydraulic connectivity and gradient exist. Aquifers beneath camps further from the wadis may not be recharged by the water stored in the wadi sands.

Table 1. Recent annual rainfall records compared with average and lowest on record (mm)

Location	Average rainfall 1978-2007	Lowest annual rainfall recorded (year)	2004	2005	2006	2007
El Fasher	194	73 (1983)	118	317	239	265
Nyala	384	140 (1947)	432	487	467	457
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Mornei is an example of an IDP camp and host community beside a large volume of groundwater stored in a large alluvial aquifer. The wadi runs adjacent to the camp and has a large volume of wide sands upstream. This gives Mornei good resilience to drought through the dry season.

At the opposite end of the spectrum, Otash and Dereig in Nyala are not connected to large wadi storage systems and so are dependent on the storage in the aquifers directly under the camps alone. There is a small channel (khor) in Otash but without significant volumes of storage. This leaves these camps too dependent on the rain that falls directly onto them, and therefore particularly vulnerable in a dry year.

Between these extremes lie a number of communities where the degree of hydraulic connection between the aquifer under the camp and any nearby wadi is unknown. An example would be Kalma where the recharge paths from Wadi Kalma and Wadi Nyala are unproven. Hydrogeological assessments are needed that comprise analysis of data collected about groundwater levels, wadi flows, pumping and rainfall records in order to assess the extent to which water stored in these wadis would seep into the aquifer beneath Kalma in a year of poor rains. This is why the listed camps are described as being potentially vulnerable to drought. After further data collection and hydrogeological analysis the risk should be more clearly defined.

Darfur has some of the highest levels of variability in rainfall in Africa. In North Darfur, of the 20 driest years since records began in 1917, 16 have occurred since 1972. However, despite this apparent increase in frequency of drought the years of the crisis have generally coincided with good rains.

Table 1 shows the annual rainfall at the state capitals for the last four years against the average for the last thirty years and the lowest on record for comparison. In only two cases has the annual rainfall been lower than average and in only one case by a significant margin. These good rains however cannot be expected to last and drought preparedness is now an urgent priority for the management of water supplies at camps.

The exception to the pattern of above-average rains in the crisis is the El Fasher rainfall in 2004, which was well below average, but this would have occurred prior to the full impact of increased demands around El Fasher, and also had the benefit of the increased recharge from the Haloof Dam before it was destroyed in a flood in 2005. The Haloof Dam has the potential to provide significant additional water resources to Abu Shouk and Al Salaam camps. This dam is a typical example of a drought preparedness measure that may be needed at other concentrations of population.

A further aspect of the variability in rainfall relates to the spatial distribution of any single rainfall event. There is a high degree of variability between the rainfall records at different locations across Darfur. This means that rainfall is localised and so any given area may receive more or less at a given time. This variability can be seen from how 2004 was a dry year in El Fasher but an average year for Nyala and Geneina. Hence, the rainfall at the state capitals should not be assumed to apply across the entire states.

Chapter 2

Hydrogeological context

2.1 Rainfall

Darfur has low and variable rainfall. Records exist since 1917 in El Fasher and since 1946 in Geneina and Nyala. These are the only gauges recognised by the Sudan Meteorological survey though others exist. The records from these three gauges are shown Figures 1 to 6 and discussed below.

The overall trend in rainfall appears to show a recovery since the low point in the 1980s, however of most significance is the increased frequency of drought. 16 of the 20 driest years on record in North Darfur have occurred since 1972. Climate models indicate that both rainfall and droughts increase under the impacts of climate change, but more localised research is needed to determine the interaction between global climate dynamics and Darfur which would also appear to be influenced by the lower rainfall caused by deforestation.

Examination of the rainfall records for 2007 at the three state capitals (see Figures 4 to 6) demonstrates:

- Rainfall at all three locations was above average.
- As usual, rainfall at El Fasher (265 mm) was the lowest of the three, and that at Geneina (508 mm) was the highest. Nyala's total was 457 mm.
- The rainfall patterns at the three locations were quite different:
  - o 56% of El Fasher's rainfall was concentrated into a few days in late August (149 mm between 21 and 26 August).
  - o Over 40% of Nyala's rainfall fell before July 1st. This supports anecdotal observations of early rainfall in South Darfur encouraging early crop growth, only for later drought to damage the crops.
  - o At Geneina the rainfall was spread more evenly through the season, with some rain falling on most days in August.

2.2 Runoff

Under present conditions, surface water flow data in Darfur are sparse, but some observations have been recorded at a number of Oxfam sites. It is understood that more detailed data may be available for Wadi Nyala.

2.3 Groundwater resources

Darfur's largest groundwater resources are contained in the large sedimentary basin aquifers such as – the Nubian Sandstone in North and South Darfur, the Umm Ruwaba Series sandstones and mudstones in South Darfur, and the Paleozoic sandstone in West Darfur. These sedimentary basins extend down-gradient from Darfur into Kordofan and other Sudanese regions, and also into Libya, Egypt and Chad. These aquifers have a very large total storage capacity and can therefore sustain water supplies to deep boreholes irrespective of dry years. However, these aquifers are absent from most of the central part of Darfur where most of the large IDP camps are located. Important examples of these aquifers are around Geneina (Desi Basin), to the west of El Fasher (Shagara Basin), in the south of South Darfur (Bagara Basin) and the North of North Darfur (Sahara Basin). Typical borehole yields in sedimentary basin aquifers would be 1 to 10 l/s.

The next most important aquifers in Darfur are the wadi alluvial aquifers, which are largely composed of sands with high permeability, a shallow water table and high storativity (storage per unit volume of aquifer). The most important resources of this type exist in the Wadi Azum system in West Darfur, where the aquifer can be up to 40m deep. Wadi Nyala is another example, with sand up to a depth of about 20m. The size of the available groundwater resource at any given location depends largely on the aquifer geometry (width and depth) and the area of the upstream catchment which provides annual recharge. In general, an aquifer 6-10 m deep should be able to sustain a borehole supply through a dry season, but many of Darfur's wadi aquifers are too shallow and hold groundwater for only a portion of the dry season. Typical borehole yields for wadi alluvial aquifers would be 1 to 20 l/s.

The volcanic rocks (e.g. lava and ash deposits) of the central Jebel Marra massif occupy a relatively small but important area in Darfur. The fractured lavas (e.g. basalt) hold small amounts of groundwater in the harder rocks, and the ash deposits contain some groundwater in their pore space. The high altitude (up to 3,000 m) of Jebel Marra area ensures that these rocks receive the highest rainfall in Darfur and this, combined with the strong relief, gives rise to high water table gradients. There are numerous permanent springs in the area. The hydrogeology of the volcanic rocks is not yet well known. The mobility of minerals in the volcanic rocks results in the chemical quality of the groundwater being sometimes unsatisfactory. Typical borehole yields for volcanic aquifers would be 0.5 to 5 l/s.

The least favourable hydrogeology in Darfur is found in the rocks of the Basement Complex – hard, fractured and weathered crystalline metamorphic rocks such as granite and schist. These rocks are very widespread and underlie most of central Darfur, including most of the IDP camps with water supply problems. Until the 1980s, the Basement Complex in Sudan was largely undeveloped for groundwater, but with the help of geophysical surveys to help select suitable borehole locations, and pneumatic-percussion drilling rigs to drill wells quickly in hard rocks, the exploitation of the Basement Complex for village water supply became possible. Even so, there is still little documentation of the hydrogeology of the Basement Complex in Sudan. Typical borehole yields for basement complex aquifers would be 0.1 to 1 l/s.

The low bulk permeability of the Basement Complex rocks, and their low storage capacity, make it difficult to estimate the sustainability of borehole water supplies, especially in times of drought. Recharge to the Basement Complex largely depends on infiltration from the beds of wadis. Therefore, the sustainability of water supplies from boreholes in Basement Complex rocks will largely depend on the boreholes' proximity to a wadi system bringing recharge from a sufficiently large area upstream.

These wadi systems comprise an upper layer of arable soil over sands, and are characterised by high to very high permeability, a shallow water table and high specific storage capacity (i.e. storage per unit volume of aquifer). Provided the aquifer is deep enough and the upstream catchment area is sufficiently large, the supply should be able to survive at least one dry season. However, many wadi alluvial aquifers in Darfur are relatively shallow and hold groundwater for only a portion of the dry season.

Figure 2. El Fasher Annual Rainfall (mm) and 10 Year Average

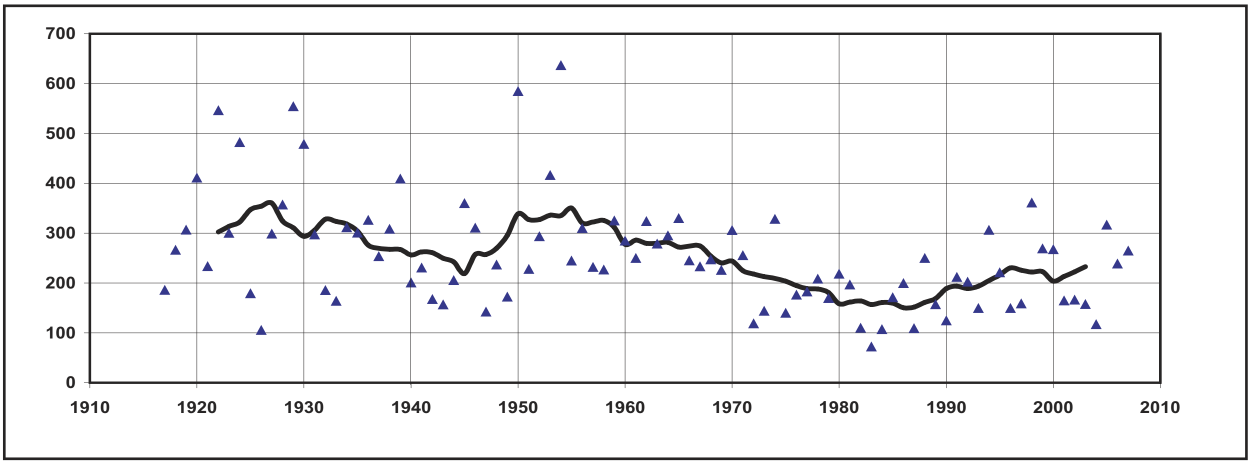


Figure 3. Nyala Annual Rainfall (mm) and 10 Year Average

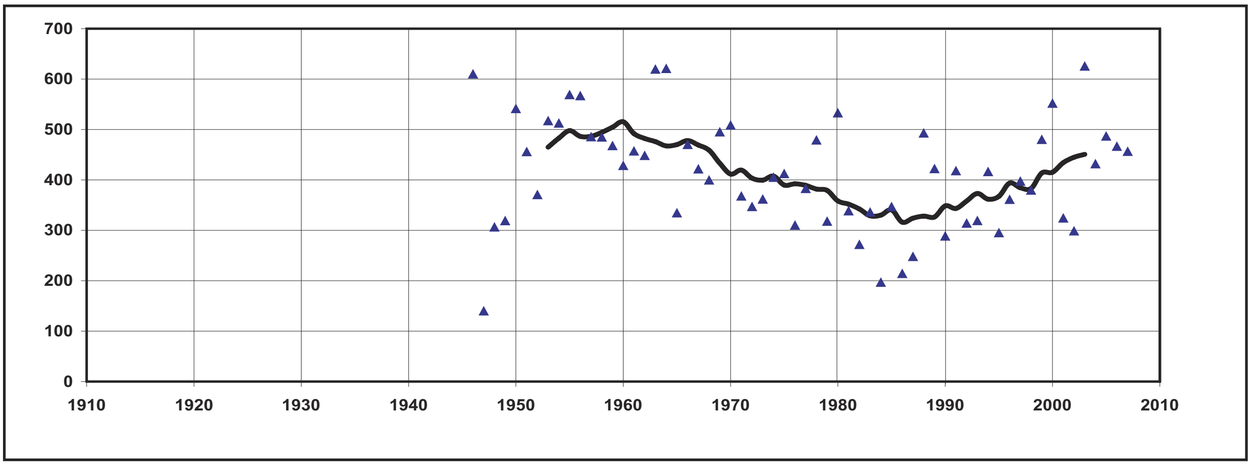


Figure 4. Geneina Annual Rainfall (mm) and 10 Year Average

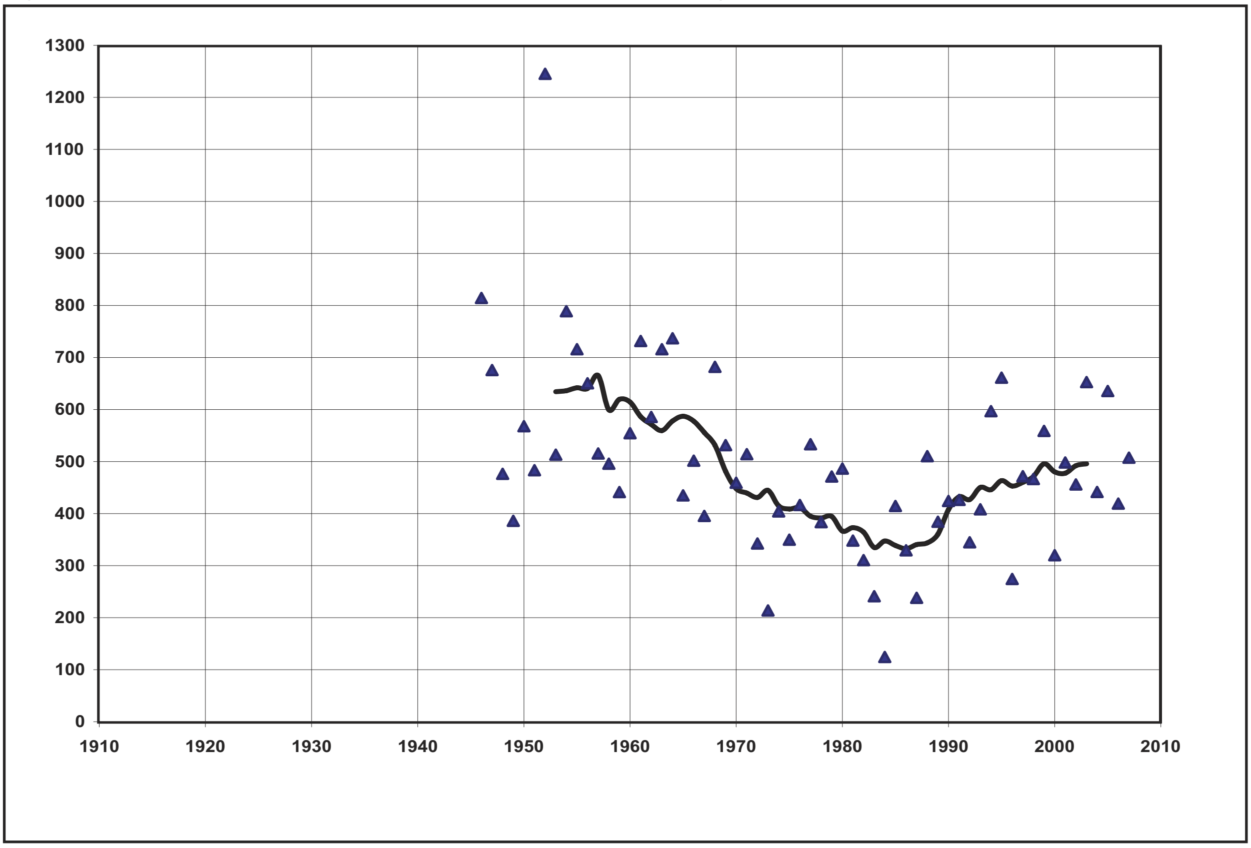


Figure 5. Daily rainfall (mm) El Fasher 2007

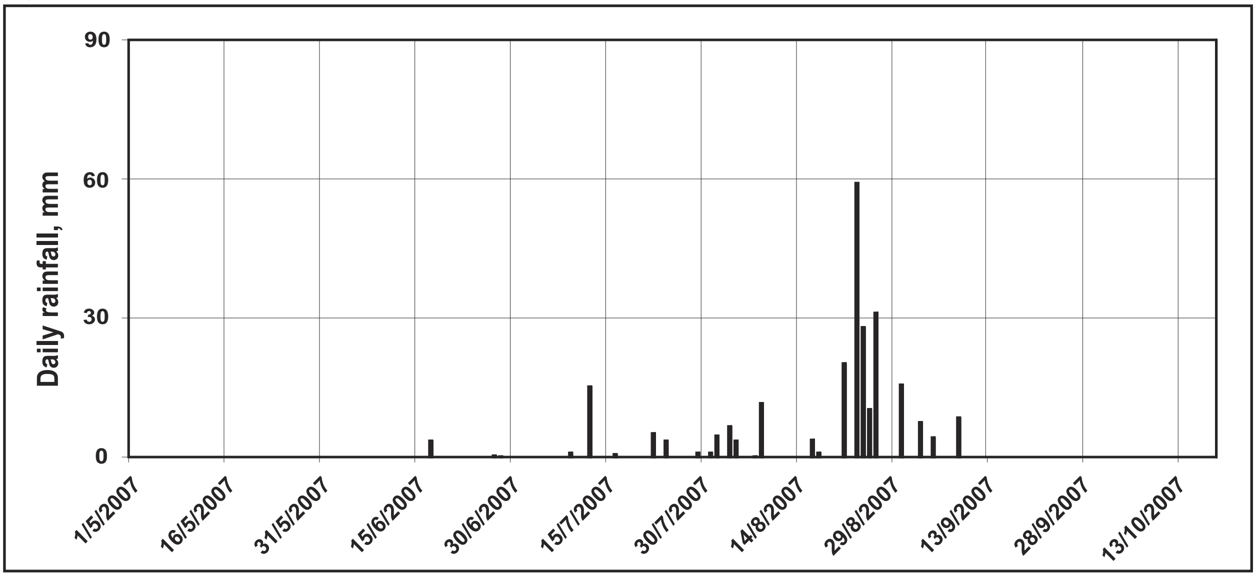


Figure 6. Daily rainfall (mm) Nyala 2007

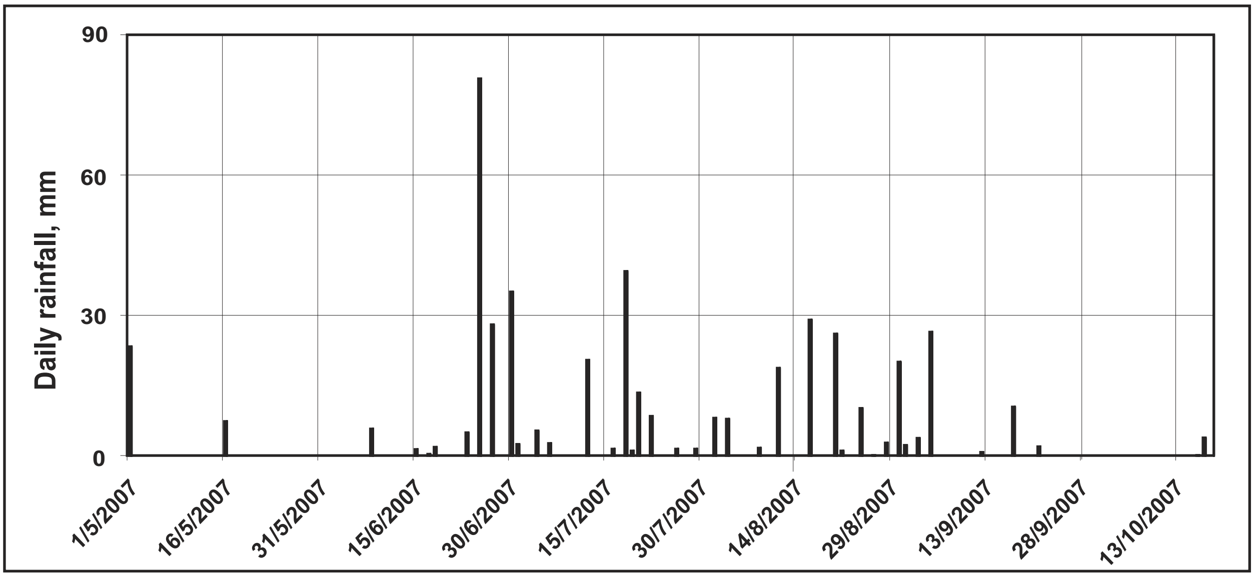
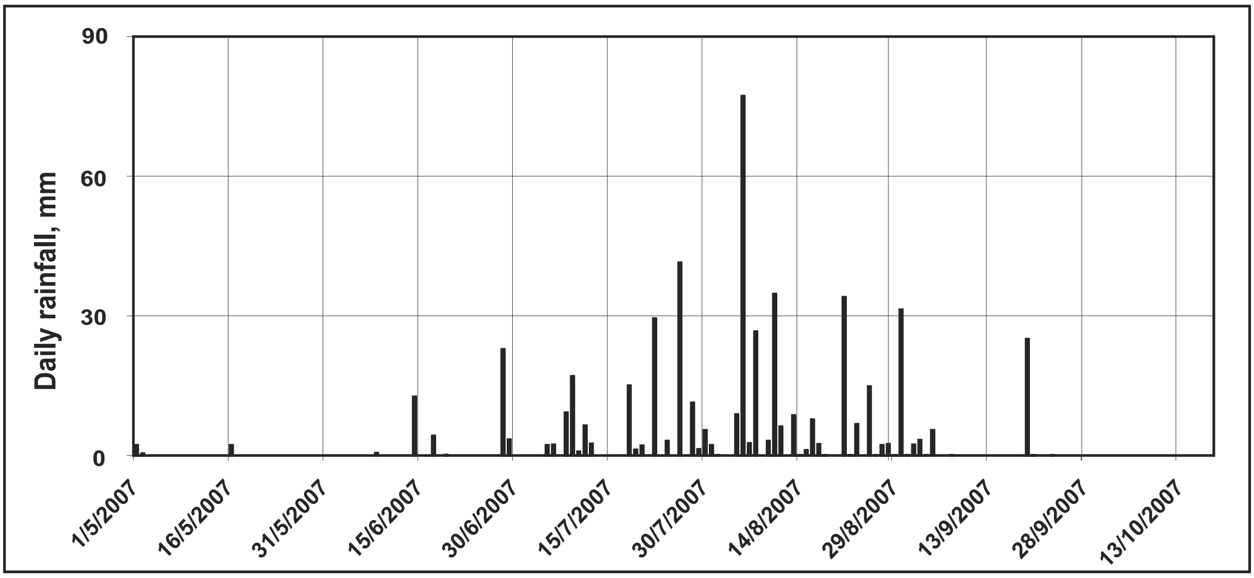


Figure 7. Daily rainfall (mm) Geneina 2007



Chapter 3

Progress review

Since the second Tearfund report (*Darfur: water supply in a vulnerable environment*) drew attention to the lack of groundwater monitoring in Darfur, considerable progress has been achieved:

- Some 49 water level loggers have been installed in wells, and manual dipping has been undertaken in at least 15 further wells. The known monitoring sites are listed in Tables 1, 2 and 3, dealing with North, South and West Darfur respectively.
- Plans have been made for the installation of an additional number of loggers and for more manual dipping.
- Rain gauges have been installed at several sites, and more are planned.
- Initial datasets have been derived from most of the wells mentioned above, and preliminary interpretation of the data has already helped in our understanding of how the aquifers respond to pumping and to recharge.
- The initial datasets have also helped to show how future monitoring should be managed.

Details of the loggers installed are shown below in Table 2 to Table 4.

In summary, there has been good progress in:

- Logger installation
- Manual dipping
- GPS Co-ordinates
- Surface water observations
- NGO engagement

There has been less progress on:

- Wellhead surveys
- Flow meters
- ID Codes
- Household water use surveys
- Data management

Figure 8. A “dipper” for manual measurement of water in a well. The sensor is on the end of a tape dropped down the well for a manual reading to water depth.

Figure 9. A logger (left) which records water levels and remains in the well. A dipper is being held down the well (right).

The prioritisation of work on installation of loggers was entirely appropriate given the urgency of data collection. Now that a funded programme to develop an integrated strategy on water resource management is being established, the full range of activities may be given more attention.

Table 2. Ground water logging and dipping - North Darfur

Site	Location	Logger #	Latitude	Longitude	Altitude m	Installed	Last reading	Depth m	Diam inch	Initial SWL m	Logger depth m	Well type	Comments	Aquifer
UNICEF LOGGERS														
Zamzam 1	El Fasher	147	13.48758	25.30942	715	13/09/2007	26/11/2007	63	4.5	23.7	40	OW	WL fell continuously over period	BC/Alluvium
Zamzam 2	El Fasher	145	13.47919	25.30719	714	13/09/2007	26/11/2007	60	5.5	27.3	45	OW	WL rose continuously over period	BC/Alluvium
UWC	El Fasher	146	13.61997	25.35114	730	18/09/2007	05/12/2007	40	4.5	18	35	HP	WL rose over period	BC
Mashtal	El Fasher	151	13.611	25.33844	736	18/09/2007	25/10/2007	50	4.5	32.2	45	HP	Logger shows no change in WL, but manual data show WL rise. Logger not functioning?	BC
Dababeen	Kutum	154	14.20142	24.64594	1121	24/09/2007	29/10/2007	10	5.5	4.8	9.2	OW	WL very stable over recorded period - between 4.2 and 4.4m	BC
El Soug	Kutum	148	14.2035	24.64797	1124	24/09/2007	29/10/2007	35	4.5	7.6	30	HP	WL rose then flatlined	Alluvium/BC
El Wadi	Kutum	149	14.19914	24.64269	1123	24/09/2007		23	8.6	5.3	15	OW	No data available yet	Alluvium/BC
Kassab	Kutum	153	14.23067	24.65728	1126	24/09/2007	02/12/2007	28	4.5	12.2	25	HP	WL rose continuously over period	BC
Shagra	El Fasher	152	13.59506	25.22433	742	22/09/2007		256	6.6	66.5	90	OW	Complicated pattern, overall WL fall, may be some recharge	NS
Shagra	El Fasher	150	13.6255	25.22528	732	29/09/2007		260	6.6	37.6	55	OW	Complicated pattern, may be some recharge	NS
OXFAM LOGGERS														
Abu Shouk Dinka Camp	El Fasher		13:38:52.0	25:20:50.5	? / 745	07/06/2007		80	4.5	34.15	69	PW	Data not yet available	BC
Abu Shouk ICRC BH	El Fasher		13:39:40.1	25:20:39.6	? / 741	07/06/2007		?55	4.5	36	50	PW	Data not yet available	BC
Abu Shouk WES I21	El Fasher		13:40:13.6	25:21:17.6	780 / 754	05/06/2007	18/11/2007	?	5.5	35.7	50	PW	Logger set too high to record total drawdown. Some recharge in October.	BC
Haloof Observation BH	El Fasher		13:40:55.4	25:21:50.1	771 / 751	05/06/2007	18/09/2007	57	5.5	33.8	45	PW	Several recharge events recorded, overall rise	BC
Ameiria Wasst BH3	Kebkabia				1085.9	20/06/2007	02/12/2007	50	5.5	12	48	PW	High drawdown; rose to peak late Sept	BC
El Salam/Wadi HP2	Kebkabia		13:38:56.7		1110	19/06/2007	02/12/2007	70	4.5	14	50	HP	Data not yet available	
El Salam/Wadi HP2	Kebkabia				1103	03/06/2007		60	4.5	14	50	PW	Formerly MW, now abandoned - saline	BC
El Shahied HDW	Kebkabia				1138	19/06/2007	26/11/2007	8	2m	2	4	HDW	Steep rise, fluctuating peaks, then recession	
America Garib HP28	Kebkabia				1057	05/06/2007		30	4.5	10	27	HP	Data not yet available	
Wadi Bargo N, BH4	Kebkabia				1075	06/06/2007		34	5.5	8	30	PW	Data not yet available	
Dipped wells														
Abu Shouk, Bir Yaqoub	El Fasher												Data not yet available	BC

Table 3. Ground water logging and dipping - South Darfur

Site	Location	Logger #	Latitude	Longitude	Altitude m	Installed	Last reading	Depth m	Diam inch	Initial SWL m	Logger depth m	Well type	Comments	Aquifer
UNICEF LOGGERS														
Kondowa W55	Nyala	128	12.02781	24.93522	614	28/07/2007		10	8.6	2.5	8	OW	Logger stolen	Alluvium
Al Neem Forest	Nyala	132	12.04114	24.86939	664	28/07/2007	03/12/2007	12	78.5	2.4	10	HDW	Early rise, later fall	Alluvium
Wadi Gani (3)	Kass	131	12.50064	24.283	940	30/07/2007	10/12/2007	20	8.6	4.6	16	PW	Rises - peaks ~13th Sep - falls	?Alluvium/BC
Wadi Gani (4)	Kass	129	12.50486	24.28094	941	30/07/2007	24/10/2007	23	8.6	11.3	17	PW	Recovery to ~17 Sep, then falling	?Alluvium/BC
Otash	Nyala	136	12.09401	24.90814	681	04/09/2007	03/12/2007	42	4.5	17	17(??)	OW	V. little daily recovery	BC
Otash	Nyala	133	12.10285	24.91164	683	04/09/2007	03/12/2007	39	4.5	14.4	22	OW	No decline over 3 months!	BC
Al Salam	Nyala	130	11.934	24.947	627	03/09/2007	??	36	4.5	12.4	17	OW	No data provided	BC
Al Salam	Nyala	134	11.936	24.941	628	03/09/2007	28/10/2007	23	4.5	15.8	24	OW	?Logger failed? - no logger data	BC
Sakaly	Nyala	135	12.007	24.881	663	05/09/2007	04/10/2007	36	4.5	4.6	12	OW	Can't determine true peaks	BC
Sakaly	Nyala	127	12.007	24.887	665	05/09/2007	03/12/2007	45	4.5	11	18	OW	WL Falling	BC
Dipped wells														
Beleil 1	Nyala (SE)		11.99337	25.04180	612	19/07/2007	15/08/2007	36		11.8	n/a	PW	rising over period	?Alluvium/BC
Beleil 2	Nyala (SE)		11.99100	25.04277	612	19/07/2007	15/08/2007	42		12.5	n/a	PW	rising over period	?Alluvium/BC
Dereig 1	Nyala (NE)		12.07505	24.92885	658	18/07/2007	29/09/2007	60		38.8	n/a	PW	Mainly falling	BC
Dereig 2	Nyala (NE)		12.07610	24.93011	693	18/07/2007	29/09/2007	54		38	n/a	PW	Mainly falling	BC
Dereig 3	Nyala (NE)		12.07610	24.92884	675	18/07/2007	29/09/2007	63		36.4	n/a	PW	Mainly falling	BC
El Salam 1	Nyala		11.93692	24.94129	630			45				PW		
El Salam 3	Nyala		11.93626	24.94544	632	28/07/2007	18/08/2007	42		15.5	n/a	PW	Rose by 1.3m over period	BC
El Salam 4	Nyala		11.93624	24.94697	631	21/07/2007	28/07/2007	40		15.1	n/a	PW	Rose by 0.5m over period	BC
Mosey 1	Nyala (S)		12.03409	24.90514	640	28/07/2007	15/09/2007	18		12.6	n/a	PW	Rose by 2.4m over period	?Alluvium/BC
Wadi Bargo N, BH4	Kebkabia		13:38:45.04	24:06:41.22	1075	06/06/2007		34	5.5	8	30	PW	Data not yet available	
Dipped wells														
Abu Shouk, Bir Yaqoub	El Fasher												Data not yet available	BC

Table 4. Ground water logging and dipping - West Darfur

Site	Location	Logger #	Latitude	Longitude	Altitude m	Installed	Last reading	Depth m	Diam inch	Initial SWL m	Logger depth m	Well type	Comments	Aquifer
UNICEF LOGGERS														
Reyad Camp	Geneina	103	13.46128	22.44194	808	30/06/2007	05/10/2007	42	5.5	30.2	41	OW	Rose by over 6m, peaked about 10 Sept.	Sst
Ardamata Camp	Geneina	104	13.47758	22.49858	789	18/08/2007		5.75	4.5	3.63	5	OW	No data available yet	?Alluvium/BC
KD Camp, Wadi Aribo	Zalingei	142	12.90517	23.54811	887	21/08/2007	12/11/2007	25	5.5	21	15	OW	Several recharge events, overall rose by 0.45m, peaked 5 Sept, fell by 1m	BC
Hai El Thawra	Zalingei	138	12.90767	23.47856	882	21/08/2007	12/11/2007	35	4.5	11.5	20	OW	Rose by 0.74m	BC
Mornei BH 2	Mornei	141	12.95744	22.8875	721	29/08/2007	06/11/2007	18.6	6.6	2.4	14	OW	Mostly fell by 1.7m, several recharge events	Alluvium
Kereinik BH	Kereinik	143	13.36403	22.87461	788	30/08/2007		37	4.5	7	30	OW	No data available yet	BC
Kulbus	Kulbus	137	14.3701	22.4679	950	28/10/2007		36	4.5	6	32	OW	No data available yet	BC
Salam B		144	12.11806	22.60555	609	30/10/2007		30	4.5	4	11	OW	No data available yet	BC
Um Shalaya BH	Um Shalaya	139	13.11947	22.97497	753	09/11/2007		30	4.5	9	22	OW	No data available yet	BC
OXFAM LOGGERS														
Um Dukhun HP4	Um Dukhun		11:08:14.5	22:58:09.42	518	29/07/2007	04/10/2007	35	4.5	8.55	14	HP		BC
Um Dukhun Garib HP294	Um Dukhun		11:09:31.2	22:57:05.00	533	29/07/2007		33	4.5	8.5	13	HP		BC

Chapter 4

Drought preparedness in potentially vulnerable camps and communities

This work has a focus on the demands for the IDP camps because this population is placing new demands on the aquifers – beyond those that history has proven they can support. However, the humanitarian imperative demands that water security for host communities are also addressed. Water demands at camps are more complex than those described in texts on emergency responses such as the Sphere project. This is because of the arid context in which people are used to being sparing with water demand, but also the water demands associated with livelihoods which are over and above the minimum supplies provided in an emergency context.

Whilst drought preparedness at camps is rightly part of Darfur's "emergency response" this work must not be seen in isolation from larger scale water resource management activities, and the development of the drought preparedness strategy for these communities should be seen as supporting agricultural and environmental recovery and development demands once the IDPs have returned. This work will need to be matched by efforts on government capacity building, community based management, water supply for livelihoods and recovery planning. This needs to be part of a wider water resource strategy supporting areas of projected return and for rural populations including nomadic groups. These issues will be addressed under the IWRM programme.

4.1 Potentially vulnerable camps and communities

The following list of camps has been identified as being potentially vulnerable to groundwater depletion in the event of a dry year. The work is based on an analysis of the size of the new population i.e. IDPs and on the local geological and hydrological conditions. These camps are identified as being priorities for groundwater monitoring so that the level of risk of groundwater depletion may be better established and mitigation measures can be developed where necessary.

This list should be seen as a "work in progress" and camps and communities may be added where stakeholders recommend. Camps should be deleted from the list when improved analysis can be undertaken and this identifies reliable sources of aquifer recharge. This should be seen as part, rather than the whole, of a process of developing drought preparedness. The changes in this list since the Tearfund report are the addition of Zamzam and Mellit.

Table 5 provides an introduction to recharge mechanisms at selected vulnerable camps in Darfur. It should be noted that this is a desk study, so is presented as preliminary information in need of field verification.

4.2 Additional areas

In addition to the potentially vulnerable camps other areas require a strategy for water resource management. The priorities would be:

- Large towns on Basement Complex geology – Nyala, El Fasher;
- UNAMID camps;
- Rural populations in arid areas (such as camps in North Darfur and the Northern part of West Darfur: Umm Baru, Kondobe, Sirba, Kuma etc.);
- Large populations on Basement aquifers with wadis nearby and large populations on other aquifers – Zalingei, Buram, Ed Daein, Mornei, Geneina, Gereida;
- Rural populations in less arid areas.

Nyala and El Fasher need to be assessed for drought preparedness as a collection of populations including the camps. These towns will be assessed in collaboration with GWWD, NWC, WES, UNICEF, and implementing agencies in the camps under the IWRM project.

UNICEF have commenced monitoring of the Shagara basin to the west of El Fasher. This aquifer supplies El Fasher via a pipeline so monitoring is appropriate here. Other sites that are used as sources of water for large supplies should also be monitored.

Table 5. IDP camps and settlements potentially vulnerable to groundwater depletion

Camp / Community	Geology	Population IDP / Total	Geology	Comments
North Darfur				
Abu Shouk	BC	54,141 54,141	Water supply is from fractured basement aquifer. Construction of Haloof dam will increase recharge to the aquifer. Presently 12-15 wells are dry. Monitoring is required to assess the effect of the dam on groundwater recharge in Abu Shouk area.	
Al Salaam	BC	48,788 47,788	Low recharge potentials of the BC aquifer and no apparent wadi catchments area and variable rainfall. Monitoring is required.	
Zamzam	Wadi / BC	49,824 49,824	The aquifer is predominately fractured basement overlain by thick superficial sediment. Wells located on what appears to be a buried channel linked with Wadi El Ku receive recharge. A surface depression ponds water beyond the rainy season and promotes recharge through the buried channel. Wells away from the buried channel are likely to receive less recharge and are subject to more rapid decline in water levels.	
Kebkabiya Town	Wadi / BC / VR	42,926 63,254	Sustainable high runoff from high lands of Jebal Marra results in recharging the shallow alluvium aquifer. Groundwater depletion towards end of the dry seaon may occur. Saline zones are not uncommon in the wells tapping fractured basement–volcanic rocks. Groundwater and surface water monitoring is needed.	
Kutum Rural	Wadi / BC / NS	40,284 95,479	This is an area of dispersed settlements included on the list due to its particular aridity. Away from the catchments and wadis recharge is low. Wells in the Nubian Sandstone outlier are of low, but sustainable yield. There is little recharge to the Nubian Sandstone aquifer.	
Tawila Town	Wadi / BC	32,846 39,902	This site lies at Wadi Tawaila which is a branch of Wadi Golo/El Ku. Recharge of the deep aquifer of the Shegara basin, mostly originates from Tawaila area. Recharge as much as 3.5m has been recorded in previous years. Recharge potential is moderate to high. Monitoring of groundwater levels and flood stages is required.	Poor security
Kutum Town	Wadi / BC	26,418 43,944	The alluvium basin of Wadi Kutum receives annual recharge from run-off which originates from the highlands and flows to the south east. Water production rates are high. Monitoring is needed.	
Saraf Omra Town	Wadi / BC	24,110 54,800	Due to presence of shallow and permeable wadi deposits and high recharge, depth to groundwater shallow, as the name (Saraf) implies. More wells (hand pumps) can be drilled and monitored.	Poor Security
Kassab	Wadi / BC	23,102 23,102	High water availability. The aquifer is part of Wadi Kutum alluvium basin. Recharge potential is high. It shares with Kutum Town the same source(s) of recharge.	
Mellit Town	Wadi / BC	9,830 26,855	Basement terrain mostly of granitic rocks. They have little fracturing and are of low groundwater storage capacity. Potential groundwater recharge is limited due to a lack of adjacent catchment areas, high variability and low rainfall/runoff. Wadi Mellit is incised through a narrow channel, especially close to the town and only provides limited recharge. This is reflected by the low yield and/or dryness of the drilled wells – a high rate of drilling failure.	
South Darfur				
Otash	BC	63,304 63304	No apparent catchment and recharge concentration surface area, notwithstanding sub-surface flow through fractures. Monitoring is required.	
Dereig	BC	25,561 25,561	No or little recharge by surface runoff. Recharge potential is poor. Additional drilling is not advised. Groundwater monitoring is required.	
Kalma	Wadi / BC	78,730 78,730	The aquifer recharge mechanism, especially from Wadi Nyala has not yet been analysed. Groundwater monitoring is recommended to continue and to extend it to Wadi Nyala area.	
Kass Town	Wadi / BC	95,908 125,253	Recharge potential is high. Water availability (produced) is low compared to the large number of IDPs in the camp. This puts the aquifer under stress. Monitoring activities are recommended to include upstream and downstream wells. High fluoride levels are reported in Kass.	
East Jebal Marra	Wadi / BC / VR	76,813	The alluvial aquifer that overlies the basement rocks is thin. Recharge to groundwater can take place through fractures on the bare rocks. Runoff is fast because of the high gradient. Groundwater recharge is rated as moderate to low.	
Muhajirya	Wadi / BC	44,124 125,253	The camp lies on the lower reach (delta) of Wadi El Ku. Only in years of good rains and floods does Wadi El Ku reach beyond Muhajirya. Recharge of the coupled shallow alluvium-fractured basement aquifer is affected by this variability of runoff.	
Beleil	Wadi / BC	22,947 22,947	Beleil is at the lower reach of Wadi Nyala. The downstream aquifer of Wadi Nyala is rich and prone to high recharge annually, despite lowering of the water table to critical depths in late summer months. Monitoring is required and should be analysed together with Kalma.	
West Darfur				
Golo AU	Wadi / BC / VR	16,000 25,471	Very low produced water, despite the apparently high recharge from the wadi's runoff and possibly the base flow initiated from volcanic ashes (cone) on the Jebel Marra. Extra wells can be drilled to increase water yield (at least 10l/c/d) to cope with the high IDP population.	
Umm Dukhun	Wadi / BC	32,992 55,540	The coupled alluvium/fractured basement aquifer probably secures high water production. Recharge potential is moderate to high. Fluoride concentration in the groundwater is high. Monitoring is required for both water quantity and quality.	
Kereinik	Wadi / BC	35,455 37,457	High water production. Recharge potential is moderate. Monitoring is required.	
Seleah	Wadi / BC	22,031 58,738	Coupled alluvium/wadi aquifer with possible high recharge potential from Wadi Saleah and high rainfall in the area. High concentration of fluoride. Monitoring is required.	Recent major conflict
Kulbus	Wadi / BC	15,879 25,584	The Kulbus area has limited groundwater storage capacity in the fractured rocks. Geophysical surveys are required to locate productive wells. Recharge potential is low. The current groundwater production rate is high. Monitoring to groundwater behaviour and recharge is required.	
Abu Surug	Wadi / BC	18,618 18,618	The main aquifer is fractured basement rocks. Recharge to groundwater is limited and constrained by the limited catchment area and narrow khors and wadi. Geophysical methods can be used to identify potential groundwater sites for drilling extra wells to increase the water supply to the camp. Groundwater monitoring is required.	Recent major conflict

The water demands for UNAMID deployment should be managed in conjunction with the overall multi-sectoral demands for water in Darfur. To achieve this, an assessment of the relative benefits of a UNAMID role on the IWRM fora in Darfur should be made. In addition, UNAMID should coordinate with UNEP and UNICEF in order to align the management of their environmental and water resource footprints with mainstream UN programming.

Similarly, large towns with other geologies will be assessed in subsequent stages of the work. The large sandstone aquifers in Gereida, Geneina, Buram and Ed Daein will provide a reasonable resilience to drought in the towns. Some organisations are beginning to monitor sites in sandstone such as Shengil Tobia and Ed Daein. This is good practice, and needs to be matched with appropriate data management, interpretation and liaison.

Wadi Azoum provides a large volume of storage for Zalingei so overall supplies should be reliable. In Zalingei however, areas away from the wadi may be short of water in a drought year. Therefore a drought preparedness plan should be prepared for the town as a whole.

Rural areas will be addressed under the IWRM project. Priority for drought preparedness should be given on the basis of environmental vulnerability and population. The work should form part of integrated drought cycle management planning.

4.3 Way forward

A four-stage process is required to develop drought preparedness at the potentially vulnerable IDP camps.

1. Continuing the improvements in the quality and coverage of hydrological data collection, management and interpretation at potentially vulnerable camps.

2. Interim drought preparedness plans for the event of failure of the 2008 and 2009 rains.

3. Design and implementation of drought mitigation works (e.g. sand dams, check dams etc.) during the 2008-2009 dry season and the 2009-2010 dry season.

4. Drought preparedness plans to address residual risk, which will remain high in some cases, following completion of drought mitigation works.

These steps are expanded as follows:

1. Continuing the improvements in the quality and coverage of hydrological data collection, management and interpretation at potentially vulnerable camps. This will require three components:

   1.1 **Improved water resource management at camp and state level.** The recommendations in Appendix A provide details of the work required at camp level at the level of data management and interpretation. These recommendations have been made in the Tearfund report *Darfur: Relief in a vulnerable environment*. UNICEF endorses many of these recommendations and adds more location-specific recommendations in the report *Darfur's IDPs Groundwater Resources, capacities depletion risks and contingency planning*. The important features of this work are to improve data collection relating to groundwater levels, rainfall, surface water flow and water usage. Household water use surveys are required in order to establish actual water use. Data management needs to be improved with appropriate records keeping, identification of boreholes and loggers and transfer of data. Interpretation needs to be improved with analysis of data by qualified hydrogeologists at each camp on a six-monthly basis. The list of camps potentially vulnerable to drought should be reviewed and updated on the basis of the analysis developed. This report focuses on issues relating to water quantity, but water quality should also be addressed. Camps face risks to water quality from both chemical composition of the water which is a function of the geology and from biological contamination relating predominantly to excreta disposal. The ongoing nature of this work should be combined with a programme of capacity building within WES and GWWD.

   1.2 **Drought preparedness assessments.** Building on the data collected and analysis undertaken at camps under step 1.1, one-off local assessments need to be made. Drought preparedness assessments will include analysis of hydrological and hydrogeological data of the type presented in UNICEF's report and as shown in Section 5. Analysis for this work will need to draw on data from:

- Hydrological and hydrogeological data and assessments;
- Field visits;
- Previous assessments;
- Advice from Darfur-based hydrogeologists;
- Geophysical surveys;
- Remote sensing, if appropriate.

Outputs from the assessment will include:

- Assessment of drought risks – and consequently the camps will be retained or removed from the list of vulnerable camps;
- Recommendations for improved hydrogeological analysis – location of wadi gauges, groundwater monitoring sites etc;
- Recommendations for development of drilling programmes;
- Feasibility analysis of drought mitigation works – sub-surface dams, check dams, rainwater harvesting etc.

Following consultations within implementing agencies the following approach is proposed for the work:

- Camps are grouped into clusters of two to four on the basis of location and the lead water agency for water and sanitation.
- Generic TOR for assessments are drawn up by UNEP/UNICEF/WES/GWWD under the IWRM programme and modified for location as required in consultation with the implementing agency and other local water stakeholders.
- UNEP facilitate by either funding the work under the IWRM programme or by brokering funding with donors.
- UNEP assist with the selection of suitable consultants to work with WES/GWWD in undertaking the assessments of the clusters of camps. The work is managed by the lead water and sanitation agency.
- An emphasis must be made on collaboration between internationally recognised hydrogeological expertise and Darfurian hydrogeologists in order that the contribution of both parties is brought to the work and capacity building of local institutions is made a priority.
- Reports are presented and shared with the water stakeholders across Darfur.

1.3 **Study on water use for livelihoods.** In order to better understand water demands at camps, assessments of water use are needed at household level. This is as per recommendation R.12 in the Tearfund report (see Appendix A). The need for this has been highlighted by the Oxfam water use survey of Abu Shouk and Al Salaam camps[2]. Information from these surveys needs to be synthesised by a study that addresses patterns of water demand for livelihoods. This needs to be used to develop a better understanding of the overall demands at camps. This work should be undertaken with similar work on the use of other natural resources at camps as being coordinated by the Environmental Technology Task Force (ENTEC). More details of ENTEC are available from the Universities of El Fasher and Nyala, Nyala Peace and Development Centre,

[6] *Oxfam, Abu Shouk and Al Salaam Water Resource and Water Usage Survey Report, March 2007*

Sudanese Environmental Conservation Society (SECS) UN-HABITAT and UNEP.

2. **Interim drought preparedness plans for the event of failure of the 2008 rains.** These will improve drought resilience pending implementation of drought mitigation works. Interim drought preparedness would include activities such as drilling in areas with good yields, tankering, and engaging the community in the management of water use.

3. **Design and implementation of drought mitigation works** during the 2008-2009 dry season and 2009-2010 dry season. Drought mitigation works will include engineering works such as:

- Drilling plans to enable optimum strategic use of groundwater resources;

- Rainwater harvesting – water from small catchments is retained and stored;

- Surface water dams – these are dams that store water above ground. In arid areas they suffer from water loss due to the high evaporation and siltation;

- Sub-surface dams – these dams that are buried in the wadi bed to restrict water seeping downstream through the sand. They maintain a higher water table in the wadi sands upstream of the dam.

- Sand dams – these are dams that are both below and above the wadi bed. The area behind (upstream) of the dam becomes filled with sand and the water table in this now deeper layer of sand is retained at a higher level during the dry season.

- Recharge dams appear to be similar to surface water dams, but their main function is to retain water in a wadi or khor in order to allow infiltration to the aquifer to take place over a longer period – and therefore a greater amount of aquifer recharge in total. These dams may operate both as surface water dams and recharge dams. The Haloof dam is an example of a dam that operates in both of these ways.

- Check dams, which look similar to sand dams and cause the wadi flow to be held back so more recharge of the aquifer takes place. They can be classified as small recharge dams. A number of them could be used in succession. Water flows over the top of them when in flood. They are appropriate where there is not a good site for a larger recharge dam.

  The private sector is more likely to have appropriate capacity and experience for the construction of larger pieces of infrastructure. Surface dams, for example, should not be assumed to be appropriate for traditional community based programming, particularly because of the safety implications of not completing dams before rains commence. Similarly, the design of hydraulic structures should be undertaken with assistance of specialist advice. Therefore, different parts of the drought preparedness work will require different procurement strategies and should be evaluated on a case-by-case basis.

4. **Drought preparedness plans to for residual risk**, which will remain high in some cases, following completion of drought mitigation works. This work will develop contingency plans that address the multiple impacts of drought. Developing these plans will require a combination of multi-sectoral technical and social analysis, community and government participation. The methodology will be developed as part of the IWRM process. This work will have to link in with wider drought preparedness planning for Darfur.

This four-stage programme for drought preparedness is summarised in Table 6 below.

Table 6. Four-stage plan for drought preparedness

Step	Activities	Timeline
1. Improved local hydrogeological assessments	1.1 Implementation of recommendations on water resource management: groundwater monitoring, wet and dry season household water use assessments, rainfall recording, surface water recording, ongoing analysis of camps potentially vulnerable to groundwater depletion.	Immediate
	1.2 Local assessments and design of drought preparedness work.	Spring, Summer, Autumn 08
	1.3 Study on water use for livelihoods following on assessments by implementing agencies.	Summer, Autumn 08
2. Interim drought preparedness plans	2.1 Prepared as part of local assessments in collaboration with water stakeholders and communities.	Spring, Summer 08
3. Drought mitigation works	3.1 Implementation of mitigation works – check dams, sub-surface dams, rainwater harvesting, drilling etc.	Dry Seasons 08-09 and 09-10
	3.2 Subsequent evaluation of impact of works in wet seasons following construction.	
4. Drought preparedness plans	4.1 Drought preparedness plans revised following implementation and evaluation of mitigation works.	

Chapter 5

Review of hydrogeological data

This report does not attempt to provide a comprehensive review of the data obtained to date. Instead, it is intended to draw attention to some features of the monitoring data and provide examples of the need for well informed interpretation of groundwater data. Examples are shown from different types of monitored well – including an observation borehole, a production borehole, a large-diameter dug well, and a hand pump – from all three states, and from three aquifer types.

iOxfam Haloof Observation Well, Abu Shouk/Al Salaam camps, El Fasher

Figure 10 shows the data obtained over a few days in June 2007, before the onset of the rains. The well is located immediately beside a small wadi, and about 50 metres from an important production well operated by Oxfam. The initial water level at the start of monitoring was 33.8m below ground. The graph shows that the production well is pumped about three times a day, and that the water level in the observation well is drawn down each time the nearby well is pumped. The drawdown is typically about 0.25-0.3m in each pumping episode. The well recovers partially when the pump is switched off, and the cumulative drawdown in a typical day is about 0.5m, but can reach 0.7m (as on 9/6/07). Pumping normally begins at about 5 am, and the well appears to recover fully overnight – if it didn't, the water level would be expected to fall every day.

By taking the highest water level in each day (normally around 5 am), the long-term trend can be observed, as in Figure 9, below.

Figure 11 shows several interesting features:

- Several (at least ten) individual recharge events are obvious. On each occasion, the water level rises quite sharply, by several metres, peaks, and then falls quite rapidly until another recharge event occurs.
- Each recharge event must coincide with flow in the nearby wadi.
- After the recharge, the water level decline reflects the dissipation of the groundwater 'ridge'

Figure 10. Oxfam Haloof observation borehole, El Fasher, North Darfur – Eight days

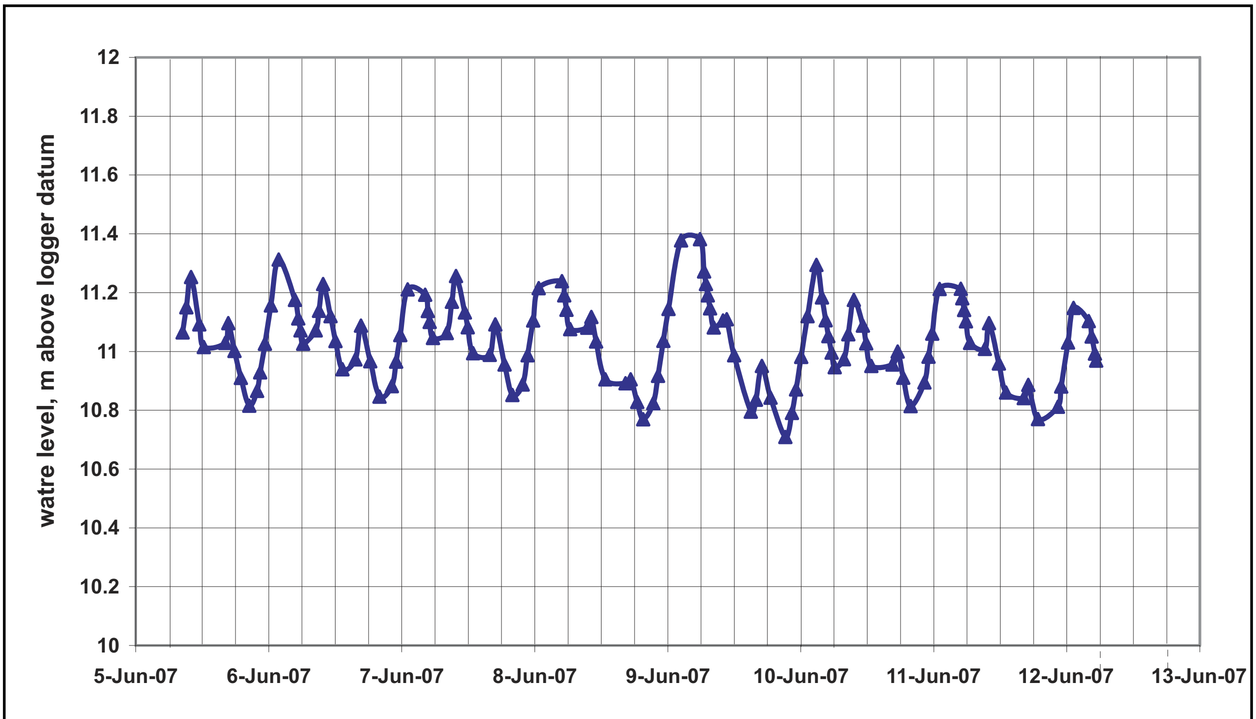
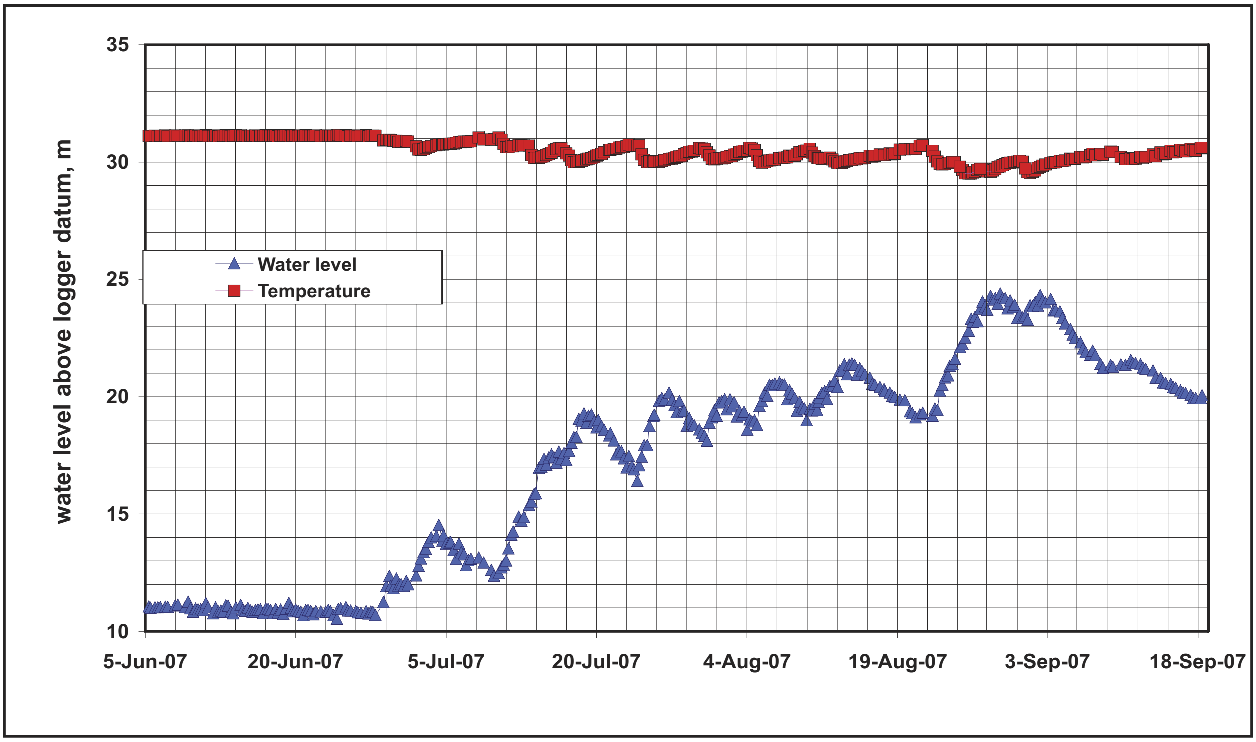


Figure 11. Oxfam Haloof Observation Borehole, El Fasher, North Darfur – Three months



beneath the wadi, as the water moves laterally into the surrounding aquifer (weathered Basement Complex).

- A comparison of the graph with the rainfall data for El Fasher Airport reveals that some of the recharge events did not coincide with rainfall at the airport. This again illustrates the spatial variability of rainfall in Darfur, and shows that the wadi flow (and hence the groundwater recharge) depends on rainfall to the north and west, in the headwaters of the wadi system.

- The recharge shown in July 10-20 (water level rise of about 7 metres) correlated poorly with rainfall at El Fasher (15.2mm on 12 July) but correlated better with rainfall at Nyala (over 60mm between July 12 and 18).

- However, the second main recharge period (23-30 August) correlates well with El Fasher rainfall (about 150mm between 21 and 26 August).

- Figure 11 also shows small changes in the groundwater temperature, which is routinely recorded by the loggers. It shows that each recharge episode reduces the temperature slightly, by 0.5-1°C, as the rainwater is slightly colder than the groundwater. The water temperature soon recovers.

ii. UNICEF Logger 129, Kass Well 4, South Darfur

Figure 12 shows the data obtained over most of August 2007. This logger is installed in a production well.

Figure 12 shows the response of the water level to pumping, with draw-downs of as much as 10 metres, and very rapid recovery of the water level when pumping stops. It also shows a rather smooth and gradual rise in the water table, amounting to about one metre in August. This is in response to groundwater recharge, but there are no obvious 'steps' corresponding to particular rainfall events.

Figure 13 shows the groundwater levels in the same well over a longer period, omitting the pumping effects. It shows a gradual rise in water level through August and most of September, with a peak around 18 September, and a gradual fall thereafter.

Many of the other water level datasets (not illustrated here) show a similar pattern, with small variations in the date of the water level peak.

Figure 12. UNICEF logger 129, Kass Well 4, South Darfur – One month

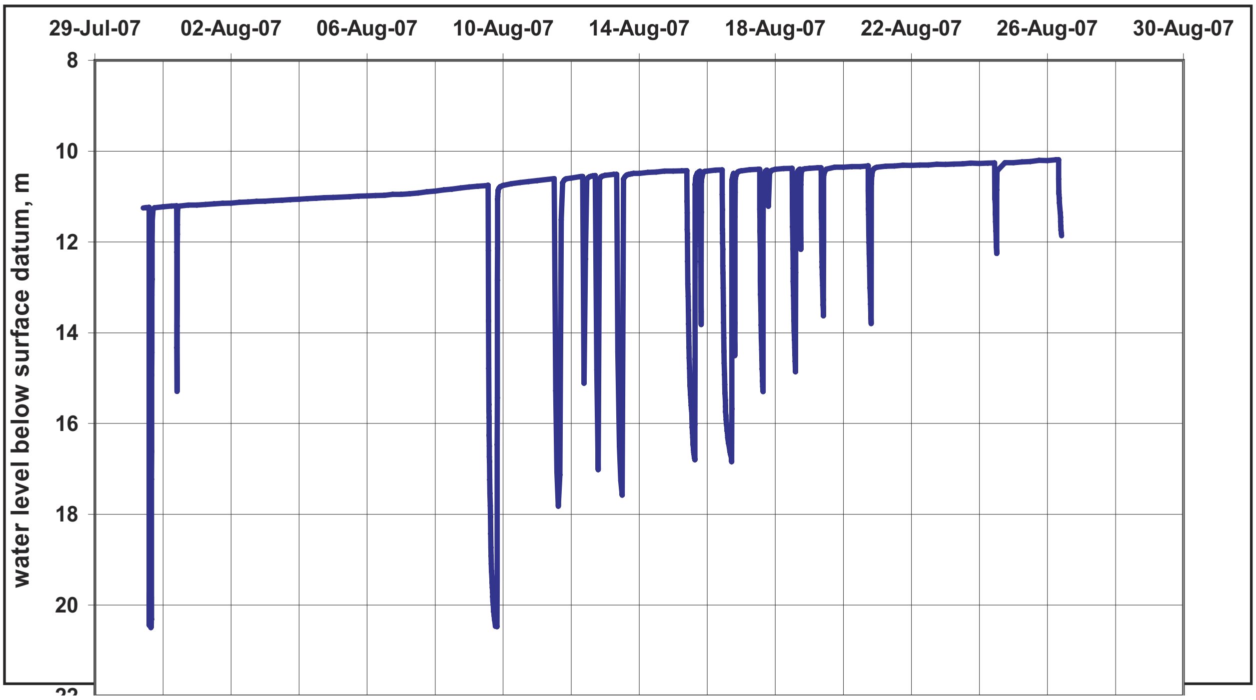
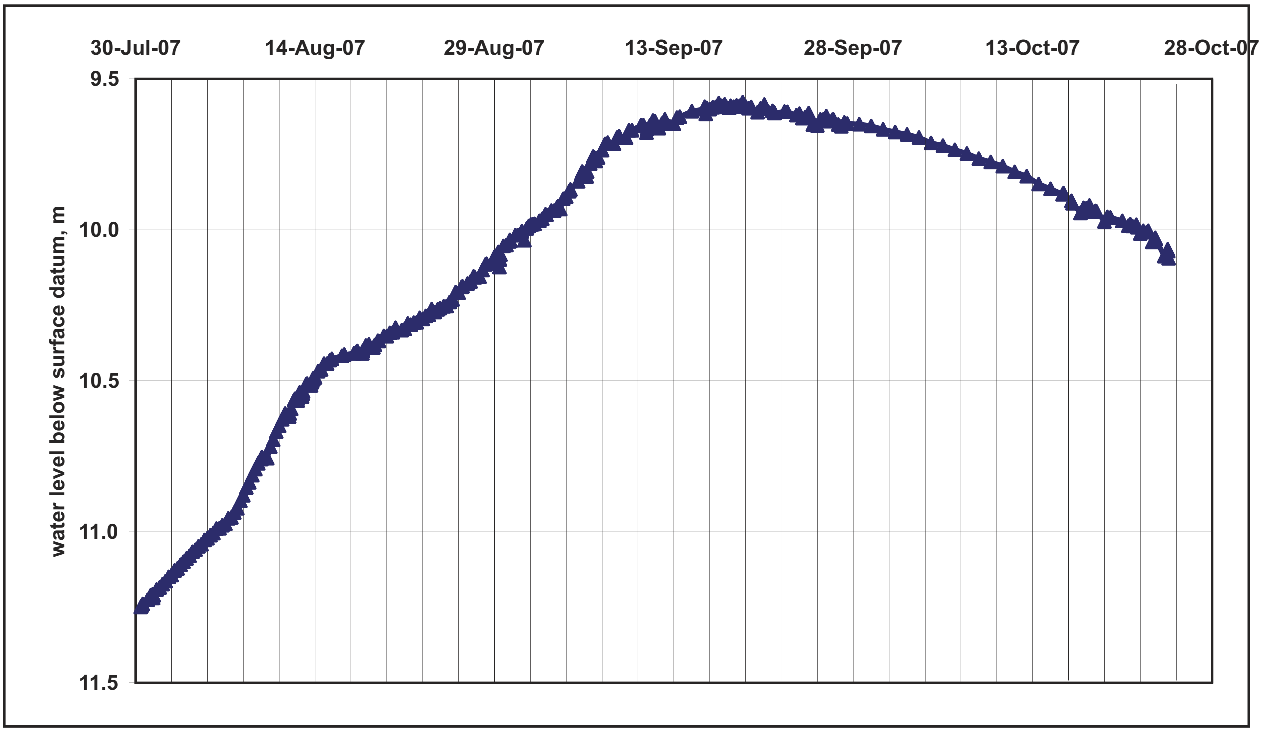


Figure 13. UNICEF logger 129, Kass Well 4, South Darfur – Three months



iii. Oxfam Logger, Al Shahied Dug Well, Kebkabia, North Darfur

Figure 14 represents the water level in a shallow dug well (8 metres deep) in North Darfur, over a four day period in June 2007. The graphs shows the response of the water level to pumping, which produces a drawdown of about 0.8m, and also shows that the water level recovers overnight when the well is not pumped.

Figure 15 shows the long-term record for the same well, excluding the pumping effects. There is a large recharge event beginning about 10 July and peaking at the end of July. The initiation of the recharge roughly corresponds to a rainfall event of 15.2mm in

El Fasher on 12 July, but the El Fasher rainfall record cannot account for the sustained recharge seen at this location in late July. This again illustrates the spatial variability of rainfall in Darfur.

Through July and August the graph shows a series of small recharge events which do not raise the water table much higher. This is probably due to the shallowness of the water table at this point – about 2-3m below ground. In these circumstances, the aquifer cannot absorb much more recharge, and the excess available water moves away downstream.

iv. UNICEF Logger 103, Er Reyad, El Geneina, West Darfur

Figure 16 represents the water level changes in a 42 m deep observation borehole in a

Figure 14. Oxfam Logger, Al Shahied Dug Well, Kebkabia, North Darfur – Four days

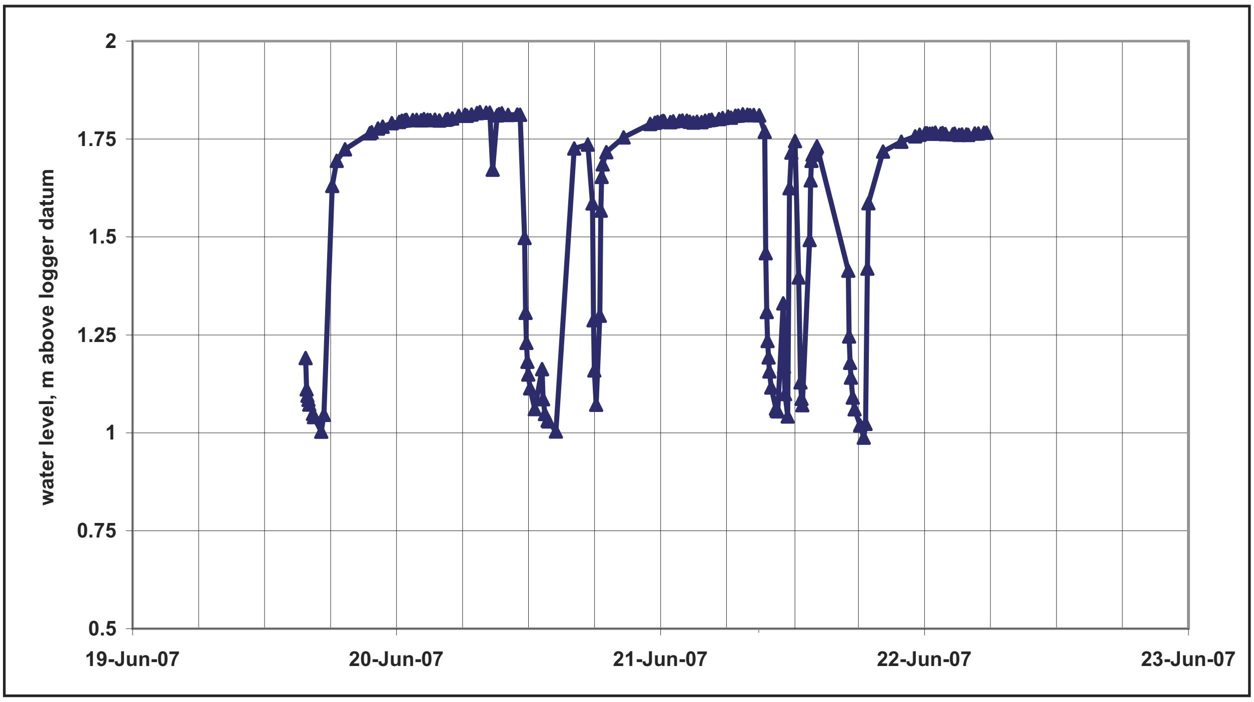
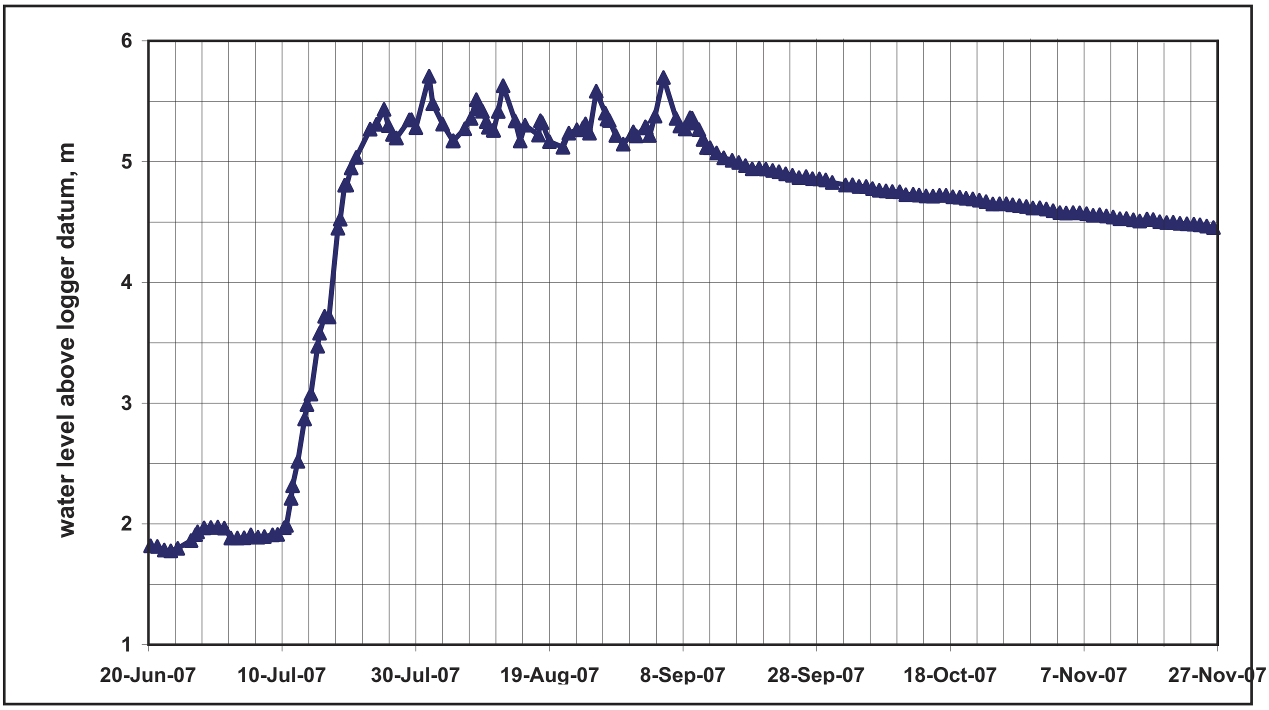


Figure 15. Oxfam Logger, Al Shahied Dug Well, Kebkabia, North Darfur – Five months



deep sandstone aquifer near El Geneina. The graph shows substantial recharge to the aquifer, beginning in late July. This graph shows the rate of recharge increasing markedly from about 6 August, with a further acceleration from about 17 August. Comparison with the rainfall record for El Geneina Airport reveals some correlation but there is probably a significant delay between maximum rainfall and the resultant rise in water level – the heaviest rainfall occurred on August 5 (77.2mm) and the sharpest rise in water level occurred on August 17 – a 12-day delay.

v. Oxfam Logger, Um Dukhun Hand Pump, West Darfur

Figure 17 represents the water level data recorded from a hand pump in this location in West Darfur

Figure 16. UNICEF Logger 103, Er Reyad, El Geneina, West Darfur – Four months

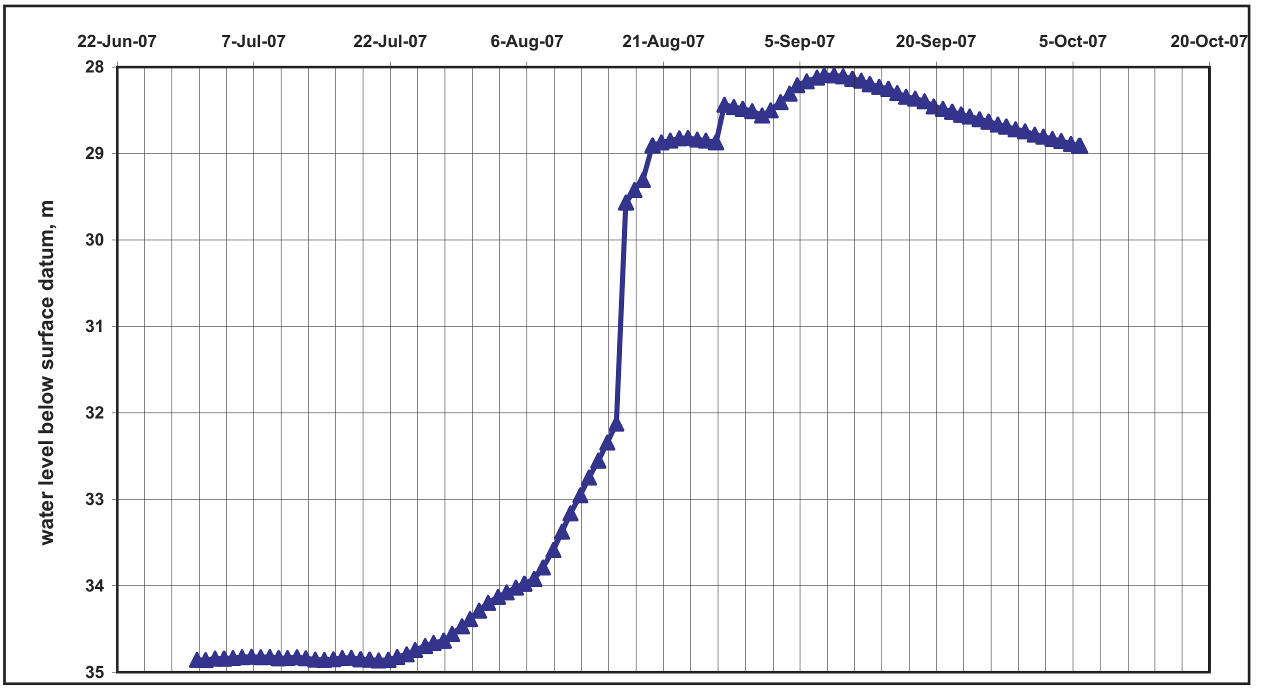
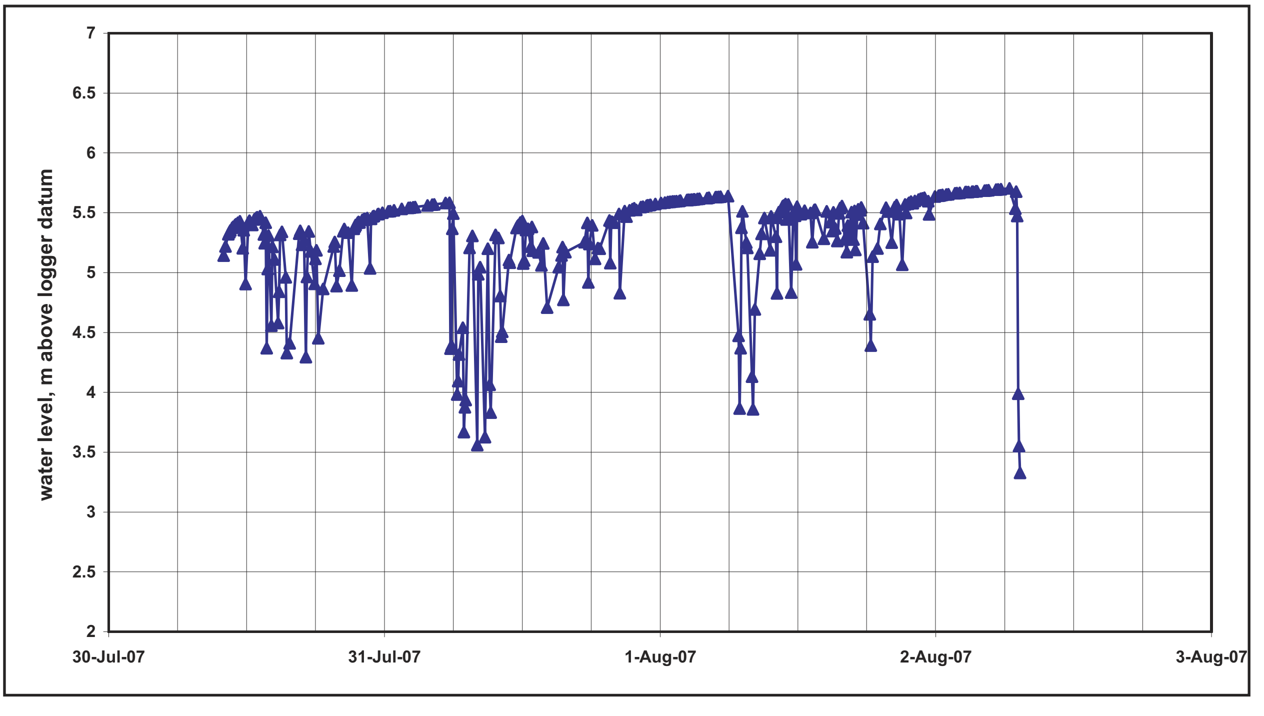


Figure 17. Oxfam Logger, Um Dukhun Hand Pump, West Darfur – Four days



over four days in July-August 2007. There are similarities with the records from other pumped wells, but in this instance the rate of pumping is much lower and the individual pumping episodes much shorter. This has resulted in a very 'spiky' pattern. It is clear that the water level recovers fully overnight, and even over the short period shown, it can be seen that there is a small rise in the rest water level, of about 0.1 m.

Figure 18 presents the longer-term water level record, excluding pumping effects, showing a gradual rise through August, a peak around mid-September, and the beginning of a fall into

Figure 18. Oxfam Logger, Um Dukhun Hand Pump, West Darfur – Three months

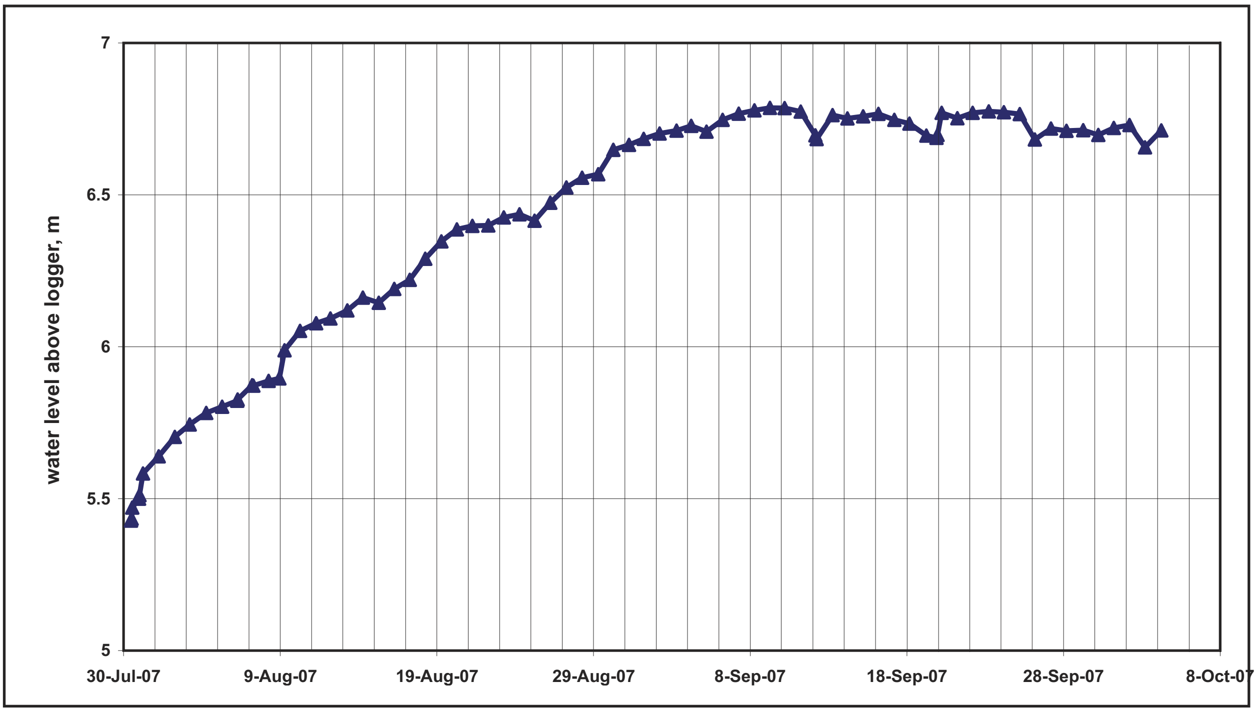


Figure 19. UNICEF Logger 147, Zamzam Borehole 1, North Darfur – Three months

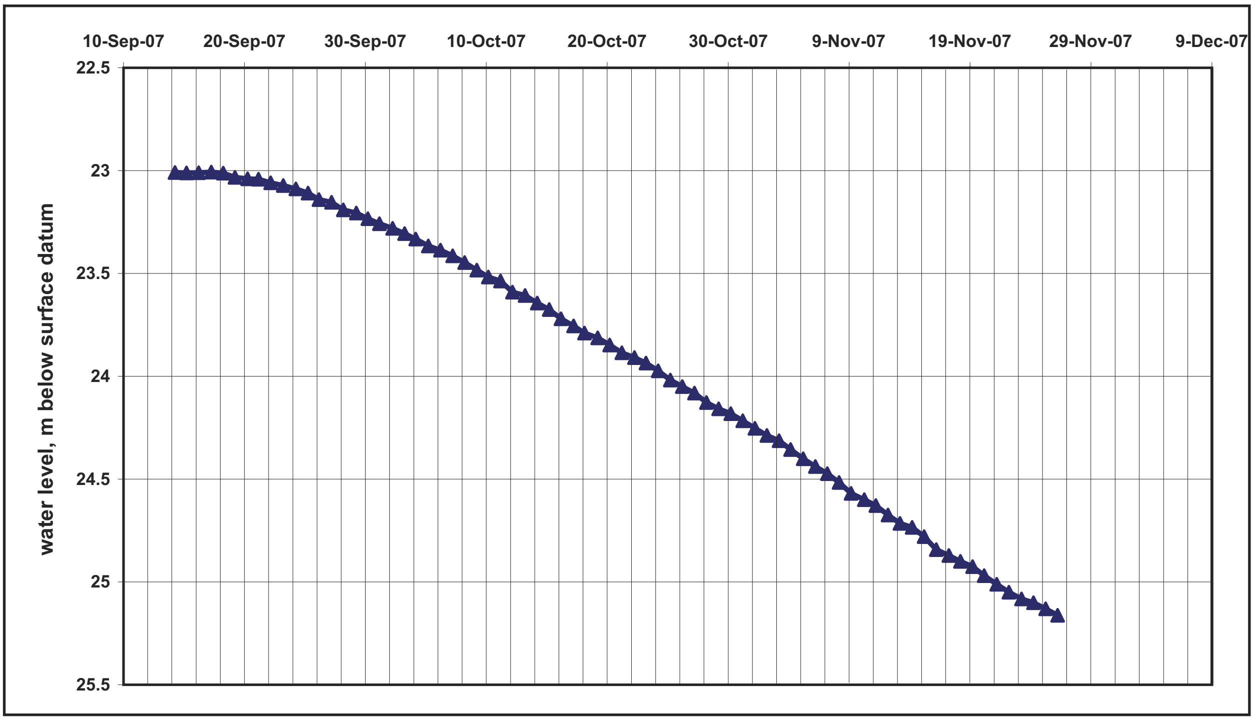
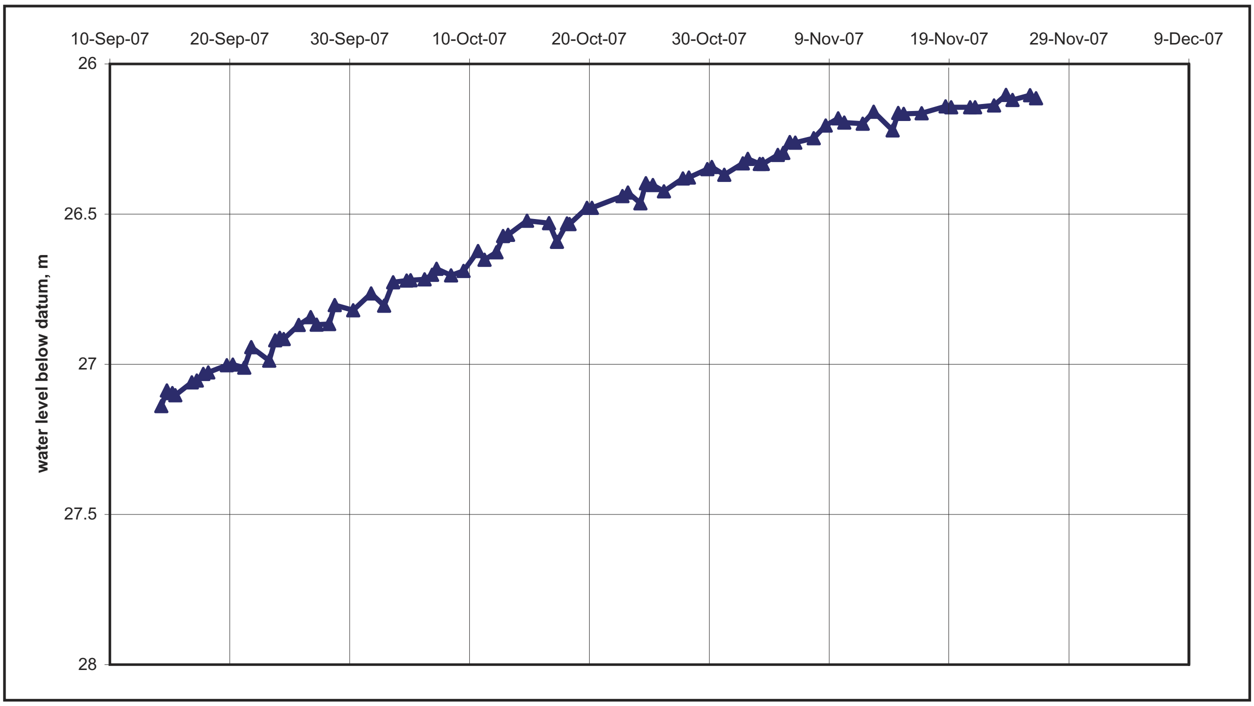


Figure 20. UNICEF Logger 146, Zamzam Borehole 2, North Darfur – Three months



October. The rise is gradual (some residual pumping effects cause slight indentations in the graph) and no individual recharge events can be made out at this scale.

vi. Unicef Loggers 147 and 145, Zamzam, North Darfur

Figure 19 presents water level data from a 63m deep borehole at Zamzam, south of El Fasher, close to Wadi El Ku. The borehole penetrated a significant thickness of wadi alluvium before entering the Basement Complex rocks. The significant feature of this graph is that the water level, which appears to have peaked in mid-September (also typical of several other wells) and then fallen steadily until late November.

Figure 20 is from Zamzam BH2, of similar depth (60m) and about 2 km away from the Wadi El Ku and drilled predominantly into Basement Complex. Obviously, there is a striking contrast with the graph above (Figure 17) – in this case the water level has risen steadily through September, October and November (the minor fluctuations are due to pumping effects). A more detailed explanation must await more detailed analysis, but it is suggested that the two graphs, taken together, illustrate that groundwater recharge has moved from the immediate vicinity of the Wadi El Ku (represented by Zamzam 1) outwards into the Basement Complex (represented by Zamzam 2). This shows how the groundwater level monitoring can reveal the direction of groundwater movement and thus help us to understand the larger groundwater systems.

5.1 Summary

The data available so far has revealed a wealth of information about the behaviour of the wells themselves, the aquifers in which they are located, and the recharge mechanisms on which they depend. As more water level data are collected, and additional data generated (e.g. wellhead levels, surface water observations, local rainfall measurements), even more insights will be obtained.

To date, the following comments can be made:

- The 2007 rainy season generated good quantities of groundwater recharge. In some wells, individual recharge events can be identified, and further study may enable correlation between rainfall and recharge events. It may even be possible to compare rainfall amounts with water level rises and derive approximate values of aquifer specific yield.

- Wadi flows are vital elements in the recharge pattern. The monitoring in some locations demonstrates how recharge begins in the wadis and khors and then disperses laterally into the Basement Complex.

- Recharge also occurs to the deep sandstone aquifers where wadi flow concentrates runoff into discrete locations.
- Drawdown data from pumped wells, and from observation wells near pumped wells, can be used to derive approximate values for aquifer transmissivity and (in observation wells) storage coefficient.

5.2 Advice on the interpretation of groundwater monitoring data

Interpretation is not simply a matter of upwards or downwards trends in groundwater level, but is about understanding volumes and routes of underground seepage and how the aquifers are replenished. The following practices are advised in the interpretation of groundwater data.

1. Check to see "which way is up" – i.e. are the water levels recorded as 'metres depth below datum (below ground)' or as 'metres height above logger'.
2. Plot out a few days' data in detail, to see how the well is behaving. For example:
   - Does it respond to pumping (in the well or in any nearby wells)?
   - Does it show evidence of other short-term fluctuations? The likeliest possibilities are responses to barometric changes (if the data are not corrected for barometric pressure) or to earth tides. Both these possibilities are likelier in confined (artesian) conditions.
3. From the examination of the short-term data, you can see how to select values from each day which will be representative of the long-term fluctuations – due to abstraction and recharge – which are our main interest.
4. Select values (usually once or twice a day) which most closely represent the static water level. In pumped wells, this will usually be just before the pump switches on for the main pumping period of the day. Often this is in the early morning after overnight recovery of the well.
5. Examine any extended pumping periods to see if the data can be analysed as for a pumping test, to derive aquifer properties. Note that analysis may give different values at different stages of the water table – as the aquifer thickness reduces by dewatering, the transmissivity will fall. The reduction in transmissivity and storage capacity as the water table falls is a key factor in vulnerability to a poor rainy season.

Chapter 6

Integrated water resource management

Integrated Water Resource Management is an approach to governance and management of water that establishes multi-sectoral water councils to address water resource planning. Technical specialists, government officials, traditional leadership, and civil society are all included in dialogue over water resource management. The purpose of this approach is that decision making addresses both technical and social issues in an informed and inclusive manner. Key features of IWRM therefore are that it is:

- Consultative: Planning of infrastructure is done in a way that includes periods of consultation and review by relevant stakeholders.
- Multi-sectoral: Water councils include different water interest groups e.g. agricultural, pastoral, domestic and private sector users
- Representative and inclusive: The councils include state government and traditional leadership and non-state actors, such as civil society, including women's groups and academics.
- Technically informed: Specialists such as engineers, hydrologists and hydrogeologists discuss water related issues with non-specialist water stakeholders and are able to both inform and listen to the concerns of the different interest groups.

6.1 UNEP and UNICEF in Darfur

UNEP is funded by DFID to support the formation of IWRM in Darfur. UNEP and UNICEF will work together to develop the partnerships needed in support of this work. This builds on the work of many organisations. UNICEF have taken a leading role in forming groundwater monitoring committees in the three Darfur states. These will form an important nucleus of the technical side of IWRM programming. UNEP and UNICEF are developing an MOU informed by the findings of this first mission of the IWRM project. The joint project workplan will focus on achieving the following through engagement with sector partners:

i. Improved drought resilience in host populations and IDP camps identified as potentially vulnerable to drought.

ii. IWRM principles and plans established in water sector programming including monitoring, assessment and demand management measures as necessary.

iii. Support and facilitation for drought risk assessments and mitigation feasibility design assessments.

iv. Stakeholder management and governance associated with proposed civil engineering works that arise from drought risk assessments

v. Support to work for the formation of consultative state water forums and governance arrangements taking account of existing structures and institutions.

Due to the particular conditions in Darfur this project has two areas that are unusual in conventional IWRM programming. Firstly, that councils are proposed at state levels rather than on the basis of catchment boundaries. This will be kept under review during the development of the process, particularly where councils relating to a given catchment within a state can be established or where working groups from each state can be established where a catchment crosses a state boundary. Secondly, there is a need to ensure that the formation of the councils is sufficiently consultative and representative, which takes time, and yet drought preparedness work can be undertaken rapidly. In essence this means that there is a "fast track" component of capital works that requires consultation ahead of the full formation of the councils. The approach planned here is to maximise the level of consultation at every opportunity and to use these opportunities for early consultation as trust building exercises for the formation of the councils.

7 *These outcomes reflect the revised project built on the original circulation of this report on 7 May 2008. UNICEF and UNEP agreed to work towards this revised workplan during periods of project development in July and November 2008.*

Figure 21. A traditional water point at Damra Bir Tuerra near Arara. This pastoralist community use this point for domestic needs and water their cattle in Wadi Arara.

6.2 Context – multiple levels of water governance.

The legal and institutional framework for IWRM will be discussed as part of the stakeholder analysis in the next stage of this project. However, the following comments are worth making here:

- NGOs have taken an active role in establishing local-level management structures for water and development issues. In some cases these are supportive of traditional peace-building structures, such as CARE's work in Kass. CARE deliver their programming through Village Development Committees (VDCs) in rural areas and through Watsan Umbrella committees in Camps. Both approaches involve a high level of community management and the VDCs support traditional peace-building institutions. Similarly, Oxfam are developing a programme of community based water resource management. UNEP intends to support this type of initiative and to learn lessons from them. Dialogue between different water management groups will be promoted so that best practice may be shared. The local differences between one area and the next will mean that it is likely that a number of models for water governance will develop.

- Sudan has experience of local water councils that is relevant to inform this work. Examples of this type of council include one from Nyala that was convened during the 1980s. These examples will inform the design of the current process.

- Sudan is one of the ten riparian states of the Nile, who through the work of the Nile Basin Initiative and Nile Basin Discourse are engaged in an International IWRM project. The focus of this groundbreaking work is to shift water management away from water allocation to benefit sharing. This relies on greater multi-sectoral consultation between nations and allows more efficient use of the water resources – to the benefit of all parties.

- UNICEF are sector lead in the UN humanitarian system for the coordination of water and sanitation.

- The work on IWRM builds on the assessment and recommendations made in UNEP's *Post Conflict Environmental Assessment for Sudan* of March 2007. This assessment makes the recommendation that IWRM be the guiding principle for the development of water policy in Sudan and recommends projects to integrate this approach in a number of degraded water basins in addition to Darfur.

In preparation for the IWRM stakeholder analysis, the following documents have been translated under the current work:

- Federal Water Act
- North Darfur Water Act
- West Darfur Water Act
- South Darfur Water Act
- Wadi Nyala Water Development And Utilisation Act
- Summary of environmental strategic plan – North Darfur
- Development of water resources – a key to peace in Darfur

An extensive bibliography of reports on water resource management was listed in the Appendix of the Tearfund report *Darfur: Water supply in a vulnerable environment*.

References

1. Tearfund, Darfur: Water supply in a vulnerable environment, 2007. www.tearfund.org/darfurwatervulnerability or www.tearfund.org/darfurwatersummary

2. UNICEF, Darfur`s IDPs Groundwater Resources: *Capacities, depletion risks and contingency planning*, 2007. www.wes-sudan.org/reports/Darfur%20IDPs%20Groundwater%20Resources%20Final.pdf

3. Tearfund, *Darfur: Relief in a vulnerable environment*, 2007. www.tearfund.org/darfurenvironment

4. Tearfund, *Darfur: Water supply in a vulnerable environment*, 2007. www.tearfund.org/darfurwatervulnerability or www.tearfund.org/darfurwatersummary

5. UNEP, Sudan Post-Conflict Environmental Assessment, 2007. http://postconflict.unep.ch/publications.php?prog=sudan

6. Oxfam, *Abu Shouk and Al Salaam Water Resource and Water Usage Survey Report*, March 2007.

Appendix A
Recommendations from *Darfur: water supply in a vulnerable environment*

Recommendations for water resource managers

The recommendations made here are modifications of the recommendations made in the Tearfund report *Darfur: water supply in a vulnerable environment.* They are modified on the basis of consultation with water sector stakeholders. This edition should be seen as part of a consultative process too. In addition to these general recommendations, UNEP endorses the camp specific conclusions and recommendations made in the same report, which are also reproduced below.

Suggested responsibilities are shown in brackets. These are presented as a starting point for allocation of responsibilities. UNEP would be interested in hearing of proposed changes to these allocations of responsibility during the consultation period.

R.1 **The following activities should be undertaken to improve resilience at the vulnerable and potentially vulnerable camps. This work would be coordinated most effectively by UNICEF's field offices.**

a. **Manual water level measurements (dipping) at production wells in vulnerable and potentially vulnerable camps. These measurements should be made after rainfall events, and intermittently in the dry season.**

b. **Installation of water level loggers on production wells and/or observation wells at vulnerable and potentially vulnerable camps.**

c. **Provision of rain gauges and training in installation and recording of rainfall data.**

d. **Data collected should be interpreted by an experienced and appropriately qualified hydrogeologist and reported on a six-monthly basis, one analysis being at the end of the rains. The outcome of this analysis should be shared with the wider humanitarian community including OCHA. These reviews should form the basis of planning expenditure on the following period.**

e. **Household water use surveys should be undertaken to assess actual water demand.**

R.2 After prioritising representative boreholes in the most vulnerable camps, groundwater level monitoring should be implemented on all boreholes (motorised boreholes and unused – but not dry – boreholes). Monitoring is not practicable on hand pumps due to the lack of access. Both production and observation wells should be monitored. It is important to monitor production wells in Basement Complex rock because the fracture systems are often unconnected – in which case an observation well may not reflect the drawdown at a nearby production well. (This is not the case for "normal" aquifers.) Once borehole performance is established, there will be some instances where monitoring may be reduced.

R.3 Contingency plans should be drawn up to respond to a poor wet season.

R.4 All water points should be mapped. OCHA-HIC have been very active in mapping facilities at camps and their work should be assisted as much as possible by agencies in the camps.

R.5 The relative elevations of the wellheads at all borehole (and hand pump[8]) sites should be established by precise levelling (i.e. not via GPS). This will enable monitoring data to be used to determine relative groundwater levels to be determined at each well. This will

[8] *Ground levels at non-monitored sites such as hand pumps may be useful where borehole records provide original water level data, and may help in assessing the vulnerability of such sites to depletion; otherwise, levelling of these sites is a secondary priority.*

show hydraulic gradients and hence indicate recharge mechanisms.

R.6 Every water source should have a unique identifier number.

R.7 All information (baseline data, monitoring data and operational notes) should be assembled in suitable paper files, and on maps, in addition to the UNICEF database. Information copied in this way is much less likely to be lost over time.

R.8 Drilling records and water level monitoring data should be copied to relevant government bodies.

R.9 Flow meters should be installed, calibrated and periodically checked, on the outflow from all motorised boreholes and all storage tanks, and daily records of output should be kept.

R.10 A single coordinator should be appointed to monitor water resources in each camp. Water managers should have reliable and complete information on:

a. groundwater monitoring data, rainfall and wadi flow data,

b. pumping records and flow gauge data,

c. water use from household survey data,

d. relevant background data, maps and reports,

e. interpretation of this data showing the status of groundwater vulnerability, and recommended mitigating actions where needed.

R.11 Inexpensive plastic rain gauges (two in large camps) should be installed to give some measurement of the rainfall. The duplication will help to ensure that data are not missed and also to give a check. It is acknowledged that this type of rain gauge does not give data which are acceptable for meteorological purposes. However, in the absence of rain gauges outside the state capitals, such gauges will give reasonably accurate data whereby one rainy season can be compared with another, and potential recharge estimated.

R.12 Water use surveys should be undertaken in wet and dry seasons.

R.13 A coordinated project is needed to ensure that the compilation of all available information on the water supply systems in the camps is complete.

R.14 A data collection exercise is needed to ensure that important historical hydrological records and reports are scanned and made available to implementing agencies.

R.15 An assessment of the effectiveness of the WES/UNICEF database as a management tool should be made, and recommendations made for integrating the database in water management and monitoring and evaluation of the water programme. The assessment should assess potential for internet access to the database, whereby water managers can enter and read data directly. This has the potential for making the database a 'live' document and a useful means of communication.

R.16 Unless emergencies occur, additional drilling in vulnerable or potentially vulnerable camps should be undertaken only after household water use surveys have been undertaken and the need proven. This recommendation is made in light of Oxfam's survey, which identified significantly higher water use than had previously been understood in the camps.

R.17 Provision for groundwater level monitoring should be included in the design of all new boreholes.

R.18 Existing AU and proposed UN camps should practice sustainable management of water resources as part of a larger do-no-harm approach to environment in Darfur. The inherent vulnerability of Darfur's environment and its central role in Darfur's traditional livelihoods give an urgency to this recommendation that would not exist in more resource-rich environments.

R.19 Observations of surface water flow should be made at vulnerable camps. As with groundwater monitoring, the purpose is to establish the extent to which wadi flow recharges the basement aquifer beneath the camp – therefore both water bodies need to be observed. A staff gauge should be installed (in a concrete pad) in each wadi in or near a camp. Records should be kept of:

a. dates, times and durations of wadi flows,

b. depth (on staff gauge) of maximum flood and at other times,

c. dates and durations of standing water in the wadi.

R.20 Best practice on water management at camps should be developed, recorded and disseminated on the basis of lessons learnt during the implementation of these recommendations in Darfur.

Camp-specific conclusions and recommendations

Abu Shouk / Al Salaam camps – conclusions

1. The water supply to Abu Shouk and Al Salaam depends substantially on hand pumps, 12-15 of which have run dry or reduced in yield over the past three years.

2. Most failed or failing hand pumps are in the raised Qoz areas, whereas most of the 'dependable' hand pumps, and the motorised pumps, are in the lower alluvial areas.

3. The failed and failing hand pumps have been drawing on groundwater storage in areas receiving little or no recharge in the wet season.

4. Dependency on the motorised pumps in the alluvial areas will therefore increase.

5. Lack of data on borehole water levels precludes a conclusion on the sustainability of the water supply as a whole (some areas are already drying). However, consideration of the likely available recharge and the variability of annual rainfall indicates that:

    - the supply may already be unsustainable in an average year, but only a period of groundwater level monitoring can confirm or refute this,

    - in a dry year (significantly lower than average rainfall in the wet season) the supply is likely to be unsustainable through the subsequent dry season.

6. Reconstruction of the Wadi Haloof dam would reduce the vulnerability of the camp water supplies.

Abu Shouk / Al Salaam camps – specific recommendations

C.1 A single coordinator should be appointed to monitor the water resources at the two camps.

C.2 Construction of additional boreholes in the alluvial areas should be considered.

C.3 Reconstruction of Wadi Haloof dam should be supported in principle, subject to appropriate hydrological and cost-benefit analyses.

Kalma camp – conclusions

1. The present water supply in Kalma Camp is understood to be adequate for humanitarian needs, and the camp residents are being supplied, on average, with slightly more than the target of 15 litres/head/day, although this has not been verified by household water use surveys.

2. The water supply depends heavily (over 40%) on four dug wells in the wadi alluvium which are privately owned and rented by the operating agencies. The supply from these wells appears to be sustainable in the long term.

3. In the medium term, it seems unlikely that the current rate of groundwater abstraction from

the boreholes in the Basement Complex can be replaced by annual recharge. Therefore, the supply is drawing on diminishing storage in the Basement Complex and is inherently unsustainable.

4. To replace boreholes in the Basement Complex which become dry (which is likely) it should be possible to drill new boreholes in the flood plain of Wadi Nyala.

Kalma camp – specific recommendations

C.4 Contingency plans in Kalma camp should include new boreholes close to Wadi Nyala.

C.5 An integrated water management plan is needed for Wadi Nyala, which will take account of the needs of both Nyala city and the nearby camps.

Otash Camp – Conclusion

1. The water supply in Otash Camp currently appears to be adequate for humanitarian needs, but in view of the absence of obvious sources of recharge, this situation appears unsustainable in the medium term. This camp is particularly vulnerable to the occurrence of a dry year.

Otash camp – specific recommendation

C.6 If water levels in Otash do not recover substantially in the 2007 wet season, contingency plans should be put in place for the possibility of some of the boreholes failing in the next dry season.

Mornei camp – conclusions

1. The groundwater resources at Mornei show no sign of significant depletion in spite of intensive abstraction since the establishment of the camp in 2004.

2. This is due to the relative abundance of groundwater, principally in the wadi alluvium along Wadi Barei and Wadi Azum, and the abundant recharge from floods in the wadis.

3. Problems with the water distribution system require some additional measures, e.g.:

1. rehabilitation or replacement of Well No. 6,
2. drilling additional wells on the north side of Mornei at sites identified by geophysical surveys – to increase capacity and allow reduced pumping hours in existing wells,
3. provision of additional elevated storage tanks, so that tap stands can be fed from storage rather than directly from the pumping mains,
4. replacing some low-yielding hand pumps by tap stands supplied from storage,
5. extension of the distribution mains, particularly in outlying areas of the camp.

Mornei camp – specific recommendations

C.7 Data loggers should be installed in Well No. 6, where the replaced or rehabilitated borehole should be designed to allow for it, and Well No. 7, at the upstream site, which shows the most drawdown. (The data loggers sent to WES Mornei are unsuitable because of the diameter of the probes (40 mm) and should be replaced by instruments with smaller probes).

C.8 WES should be supported to reconfigure the distribution system so that all the wells pump to storage, and all tap stands are supplied from storage. To allow this, additional storage capacity should be installed.

Appendix B. List of Contributors and Acknowledgements

Report Authors

The team comprised Dr. Hamid Omer Ali (Independent Consultant), Brendan Bromwich (UNEP) and Geoffrey Wright (Independent Consultant).

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Brendan Bromwich manages UNEP's programmes on environmental coordination and water resource management in Darfur. He was a contributor to UNEP's Sudan Post Conflict Environmental Assessment, and co-author of *Darfur: relief in a vulnerable environment*, *Darfur: water supply in a vulnerable environment* and *Sharpening the Strategic Focus of Livelihoods Programming in the Darfur Region.* He worked for 15 months in West Darfur on community-based water and sanitation projects that served both the nomadic and farming communities from 2004 to 2006. Prior to his work in Darfur he has worked as an engineering consultant specialising in strategic planning and water engineering. He worked on World Bank funded water and environment projects in China and Central Asia, and The Sultanate of Oman's master plan for the water sector, which developed a national strategy for groundwater and desalination development in an arid context over a 20-year period. In 2003 he co-authored a book on *Hydraulic Design of Sideweirs*. He holds a Master's degree in Civil and Environmental Engineering from Imperial College London.

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