Public Water Corporation

MIWR – GONU

MWRI - GOSS

Technical Guidelines for the Construction and Management of Borehole Hand pumps

A Manual for Field Staff and Practitioners

April 2009

Developed in partnership with

unicef

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Ministry of Irrigation and Water Resources – Government of National Unity

Foreword

Significant progress in the provision of water and sanitation services in Sudan has been achieved in the last few years. This is attributed to the increased access to many remote villages as a result of the three major peace agreements, the Comprehensive Peace Agreement (CPA) between north and south Sudan, the Darfur Peace Agreement (DPA) and the Eastern Sudan Peace Agreement (ESPA), that were signed in 2005 and 2006 respectively. This access has allowed the Ministries of Irrigation and Water Resource (MIWR) of the Government of National Unity (GoNU), state governments and sector partners (including NGOs and the private sector) to expand water and sanitation services in many areas. This prioritizing of the expansion and sustainability of water and sanitation services in urban and rural areas throughout the county, including to the nomadic population has resulted in a steady annual increase in water and sanitation coverage for the citizens of Sudan.

With this expansion in implementation, the MIWR recognized the need to harmonize the various methodologies utilized by the various actors in the implementation of water and sanitation interventions. It was agreed that this could be best achieved through the development and distribution of Technical Guidelines, outlining best practices for the development of the 14 types of water supply and sanitation facilities in the Sudan. These Technical Guidelines, compiled in a systematic manner will undoubtedly set standards and provide guidance for all water and sanitation sector implementing partners.

The MIWR of the GoNU of the Sudan is grateful to UNICEF, Sudan for financial and technical support in the preparation of the Technical Guidelines.

I believe these Technical Guidelines will go a long way to improving WES sector programmes, allowing for scaling up implementation of activities towards achieving the MDGs for water supply and sanitation in Sudan.

Minister
Ministry of Irrigation and Water Resources
Government of National Unity, Khartoum

Date ………………………………………

Foreword

The historic signing of the Comprehensive Peace Agreement (CPA) in January 2005, culminated in the establishment of an autonomous Government of Southern Sudan (GOSS) and its various ministries, including the Ministry of Water Resources and Irrigation (MWRI). The CPA has enabled the GOSS to focus on the rehabilitation and development of the basic services. The processing of the Southern Sudan Water Policy within the framework of the 2005 Interim Constitution of Southern Sudan (ICSS) and the Interim National Constitution (INC) was led by the MWRI. This Water Policy is expected to guide the sector in the planning and monitoring of water facilities during implementation. The Water Policy addresses issues like Rural Water Supply and Sanitation (RWSS) and Urban Water Supply and Sanitation (UWSS). The Southern Sudan Legislative Assembly (SSLA) of GOSS approved the Water Policy of Southern Sudan in November 2007.

The importance of developing effective water supply and sanitation services is universally recognized as a basis for improving the overall health and productivity of the population, and is particularly important for the welfare of women and children under five. Considering the current low coverage of safe drinking water supply and basic sanitation facilities as a result of the protracted civil war in the country during the last five decades, there are enormous challenges ahead. With the unrecorded number of IDPs and returnees that have resettled in their traditional homelands and the emergence of new settlements/towns in all ten states of SS, the demand for water and sanitation services is immense. There is need for implicit policies, strategies, guidelines and manuals to ensure provision of sustainable supply of quality and accessible water and sanitation services.

The preparation of these WES Technical Guidelines at this stage is very timely, as it enables us to further develop our strategies and prepare action plans for the implementation of the Water Policy. It will also allow us to strengthen existing best practices as well as to test new experiences that will create room for future development.

During the development and finalization of these guidelines for water supply and sanitation facilities, we have consulted WASH sector partners at State level and partner non-government agencies through successive consultative meetings, and appreciate their contribution, which has assisted in finalizing these documents.

The MIWR of the GOSS is thankful to UNICEF, Juba for financial and technical support for the preparation of these Technical Guidelines.

We call upon our WASH sector partners to give us their continuous feedback from the field for the improvement of these guidelines and manuals. We believe that successful implementation and future sustainable service provision will depend on effective coordination and close collaboration among all partners including government, non-government and beneficiary communities.

Mr. Joseph Duer Jakok,
Minister of Water Resources and Irrigation
Government of Southern Sudan, Juba
Date ……………………………………….

Acknowledgements

Special thanks go to Mr Mohammed Hassan Mahmud Amar, Mr Eisa Mohammed and Mr Mudawi Ibrahim, for their directions on GONU's sector policy; Engineer Isaac Liabwel, on GOSS's water policy; Mr Sampath Kumar and Dr. Maxwell Stephen Donkor, for their direction on the WASH sector from the UNICEF perspective, and for the provision of relevant documents & information, and facilitating & organizing a number of forums to discuss draft documents.

The author would also like to thank WES and UNICEF staff of North Darfur, North Kordofan, South Kordofan, Sinnar, Gedaref, Kassala, Red Sea and Blue Nile States; the staff of DRWSS, and UWC in Central Equatoria, Western Bahr el Ghazal, Warap and Upper Nile States; and the staff of UNICEF Zonal Offices responsible for the arrangement of meetings with sector partners and successful field trips to the various facilities.

Many thanks to Emmanuel Parmenas from MWRI, and Mr Mohammed Habib and Mr Jemal Al Amin from PWC, for their contribution in collecting documents and information at the national and state levels, facilitating field trips and contacting relevant persons at state level and to the latter two for their support in translating documents and information from Arabic into English.

The completion of this document would not have been possible without the contributions and comments of staff of SWC, PWC, MIWR, MCRD, MWRI, MOH in GONU, MAF, MARF, MOH MHLE, MWLCT and SSMO in GOSS, UNICEF, National and International NGOs like Oxfam GB, Pact Sudan, SNV, SC-UK, and Medair, and review workshop participants at state and national levels and members of technical working groups.

Acronyms

APO	Assistant Project Officer
BS	British Standard
CBO	Community Based Organization
CPA	Comprehensive Peace Agreement
DG	Director General
DPA	Darfur Peace Agreement
DRWSS	Department of Rural Water Supply and Sanitation in State Ministry of Physical Infrastructure in Southern Sudan
ES (Es)	Effective Size
ESPA	Eastern Sudan Peace Agreement
GONU	Government of National Unity
GOSS	Government of Southern Sudan
IRC	International Reference Center (International Water and Sanitation Center)
MCRD	Ministry of Cooperatives and Rural Development of GOSS
MIWR	Ministry of Irrigation and Water Resources of GONU
MPN	Most Probable Number (Faecal coliform counts per 100ml)
MWRI	Ministry of Water Resources and Irrigation of GOSS
NTU	Nephlometric Turbidity Unit
PM	Project Manager
PVC	Polyvinylchloride
PWC	Public Water Corporation (new name for former National Water Corporation)
RPO	Resident Project Officer
RWD	Rural Water Department
SSMO	Sudanese Standard and Measurement Organization
SWC	State Water Corporation
SWL	Static water level
TCU	True Color Unit
TDS	Total Dissolved Solids
UC	Uniformity Coefficient
UNICEF	United Nations Children’s Fund
WATSAN	Water and Sanitation
WES	Water and Environmental Sanitation
WHO	World Health Organization

Document Summary

This summary provides a brief overview of the document and is only meant as a quick reference to the main norms. Reference to the whole document is advised for accurate implementation.

Norms

- Borehole drilling should only begin after all stakeholders have agreed on the roles and responsibilities of each actor.
- Geophysical survey must be conducted to select good potential sites for drilling before boreholes are drilled.
- Minimum diameter of a borehole: 6 inch.
- Outer diameter of borehole casing: minimum 4.5 inch.
- Water quality should comply with Sudanese/WHO guidelines.
- Disinfection of the borehole is required prior to commissioning of the water supply system. Communities need to be informed about this as there might be unsubstantiated flow of false information in regard to disinfection (chlorination of water).
- Once a borehole is completed, a report must be filed with the PWC/SWC in North Sudan or the MWRI in Southern Sudan for updating their database.
- Types of hand pumps:
  a) For shallow wells up to 15m depth – Direct Action Pumps
  b) For wells up to 45m depth– IM2 or Afridev hand pumps. Afridev hand pumps are appropriate for aggressive water. The connecting rods and connecting nuts should be made from stainless steel.
  c) For wells more than 45m and less the 90m depth – Extra deep well IM2 or Dubba hand pumps similar to the ones used in Southern Sudan, should be installed
- Hand pump specification should be checked for its appropriateness to the quality of water in the borehole.
- Number of people to be served at 20 liters per person per day (l/p/d)
  a) 250 people in North Sudan
  b) 250-500 people in South Sudan
  c) 500 people during emergencies at 15 l/p/d
- Distance to water points should not be more than 1000m and 500m during normal and emergency times respectively.
- Note: factory tests show direct action pumps and IM2 (up to 45m depth) yield 35 liters per minute while field experience shows a yield of 17 liters per minute
- Note: Be aware of different groundwater problematic zones in certain parts of Sudan.

1. Introduction

1.1 The purpose of this document:

The Ministry of Irrigation and Water Resources (MIWR), GONU, and the Ministry of Water Resources and Irrigation, (MWRI), GOSS, are responsible for the policy and strategy development, coordination, planning, management, monitoring and evaluation of water supply and sanitation facilities in the country. In order to reduce disparities, improve standards, accelerate implementation and to standardise design and costs, the two ministries agreed to harmonize the methodologies utilised in the implementation of WATSAN interventions Currently, there is no standardised document providing Technical Guidelines for implementation by WES or other water and sanitation agencies and this is detrimental to the longevity of structures and the sustainability of interventions.

In 2006 MIWR and MWRI decided to develop Technical Guidelines for the construction and management of rural water supply and sanitation facilities. These Guidelines are a collection of global and national good practices in water and sanitation that have been collated. The process of the development of the Technical Guidelines is outlined in Annex 7.

These simple Guidelines are primarily intended as a reference for field staff and practitioners in the water and sanitation sector challenged by situations and conditions in the field.

Updating of the Guidelines is recommended biennially; to ensure newer and better practices are incorporated as they are developed/ introduced. Water and sanitation sector implementing partners should contribute in providing feedback to the MIWR and MWRI as necessary during the updating.

1.2 Mobilization of stakeholders

Identifying and mobilizing potential stakeholders is an important step in the realization and sustainability of a rural water supply system. Various stakeholders play various roles at different stages of a project cycle. Roles and responsibilities can be assigned using participatory techniques like participatory rural appraisal. Involvement of the community (including women) in decision making at all stages of the project will promote sustainability. For example in , site selection, distance to water points, community contribution for the construction, operation and maintenance of the water service, selection of the village health committee (for the management of water , sanitation and hygiene promotion activities in their villages) and village mechanics (that could be trained?) The community should also be involved in the technical aspects of the water service being provided such as technology choice, choice of preference design, platform and drainage apron.

Local authorities also play a significant role in the facilitation of the implementation of the water supply system. Problems that may arise during the implementation of the water supply system such as for example, land ownership, could be easily solved if the local authorities are brought on board and are involved in the decision making process.

Problems can only be identified by the active involvement of the stakeholders in the decision making process. The long process involved in getting community engagement will be decreased if the implementing agency uses a demand-driven approach.

In Southern Sudan, the roles and responsibilities of stakeholders in regard to operation and maintenance and hygiene promotion are outlined in separate guidelines which are available for reference.

1.3 Technology options

There are a number of global technology options available for improved rural water supply systems. However, not all can be applied everywhere. In rural North Sudan, and Southern Sudan, the common choice is borehole hand pumps or motorized pumps (water yards); hand dug well hand pumps, Hafirs (with a combination of filtration systems and hand pumps), and from developed springs.

These Technical Guidelines focus only on borehole hand pumps. The following general design considerations are recommended for the application of this technology option.

2 Design considerations

2.1 General

In order to ensure the supply of improved and adequate water to communities within the design period of any water supply system, due consideration should be given by the designers and planners to the following parameters:

- **The population number**: A reliable forecast of the expected number of people utilizing this service is important. This can be extrapolated from the current population figure and the growth rate and/ or any other factors that might affect the numbers to be served.
- **Population served by a hand pump**: one hand pump serves 500 persons in emergency and 250 person in normal situation.
- **The design period of components**: The design period of each component should be identified and their implementation period agreed upon at the beginning of the planning stage as the life span of the different components varies. Components can be implemented in phases depending on the availability of resources. Components like boreholes could initially be designed for 20 years more or less, and hand pumps should be designed for the same period with a regular replacement of components.
- **The per capita water demand**: The per capita daily water demand should be in line with the government development strategy. In Sudan, the current daily water demand is set at 20 liter per capita per day (l/c/d). The Government of Sudan aims to reach to 50 l/c/d by 2015. As achieving 50 l/c/d requires huge amount of budget allocation, it is advisable to maintain the minimum per capita of 20 l/c/d for some time to come in the future.

- **The quality of water**: The quality of water (in terms of physical, chemical and bacteriological content) has a significant impact on public health. Since this varies considerably from region to region in Sudan, the fluoride, sulphate and nitrate content in the groundwater sources needs to be examined as it may be higher than the rates allowed by the (name of the authority) in Sudan. According to Sudanese law, water from all boreholes drilled has to meet the water quality standard before hand pumps can be installed.
- **Distance to improved water supply facilities**: To the extent possible, the distance of the water supply facility should not be greater than **500m** during emergencies and **1000m** during normal times from the village or dwellings.
- **Choice of various technology options:** Without compromising the quality, quantity and sustainability of the system, a low-cost option should be prioritised.
- **Geophysical Survey:** Borehole drilling must be preceded by a geophysical survey at the potential site to reduce the risk of encountering dry boreholes.
- **Hydrogeological classification of aquifers**: The knowledge of hydrogeological classification of aquifers in the various parts of the country and the quantity and quality of the groundwater in the various aquifers is vital. This is detailed below.

2.2 Hydrogeological classification of the aquifers of Sudan

The knowledge of the hydrogeological classification of aquifers in the various parts of the country and the quantity and quality of the groundwater in the various aquifers is vital, for an informed decision on the design of the water treatment system to be used. According to hydrogeological information from 1989, Sudan's hydrogeological units are divided into three main groups:

A) Porous rocks of relatively high to low hydrogeological importance
B) Fractured rocks of relatively medium to low hydrogeological importance, and
C) Porous or fractured rocks with very low hydrogeological importance.

A) Porous rocks of relatively high to low hydrogeological importance: This group is divided into three sub-groups:

1. **Continuous aquifers of sub-regional to regional extent which are confined or unconfined and consolidated or unconsolidated:** Nubian Sandstone and Gedarif Formations are categorized under this subgroup, whose saturated thickness is generally high; permeability varies but it is generally high; water quality is generally good and hydrogeological importance and potential is great.

   Areas under this subgroup are: South Kordofan, North Kordofan, Gedarif, Khartoum and Northern States, North Darfur, Baggara Basin of South and West Darfur, South Darfur, Western Bahir el Ghazal, Northern Bahir el Ghazal and Unity States (refer to map 1: Sudan Hydrogeological Map).

2. **Continuous and sub-continuous aquifers of local to regional extent:** Um Ruwaba, Gezira, El Atshan, Butana, Nawa and Undifferentiated Paleozoic Formations are

categorized under this subgroup which are consolidated or unconsolidated; with saturated thickness medium to high; and permeability low to high. The water quality varies though it is generally good and hydrogeological importance and potential is medium to great.

Areas under this subgroup are: All Southern Sudan except Western Bahr el Ghazal, West Equatoria and Central Equatoria.

3. **Continuous or sub-continuous aquifers of local to sub-regional extent**: Alluvium, Wadi fills and swamp deposits are categorized under this subgroup, which are unconsolidated and their saturated thickness generally small; permeability varies and the water quality is generally good; hydrogeological importance is generally great and the potential is variable.

   Areas under this subgroup are: In Southern Sudan, they are sub-continuous and are found in Lakes and Central Equatoria States.

B) Fractured rocks of relatively medium to low hydrogeological importance: This unit is characterized by local aquifers restricted to fractured zones. It could be unconfined or confined. The permeability varies and it is generally low. The water quality is generally good. Thermal saline waters may occur. Its relative importance is medium to low and the potential is generally low. Undifferentiated volcanics are categorized under this unit.

Areas under this hydrogeological unit are: Gedarif, Eastern part of Eastern Equatoria, Jebel Mara area in Darfur and some pocket areas in North Darfur, (refer to map 1: Sudan Hydrogeological Map)

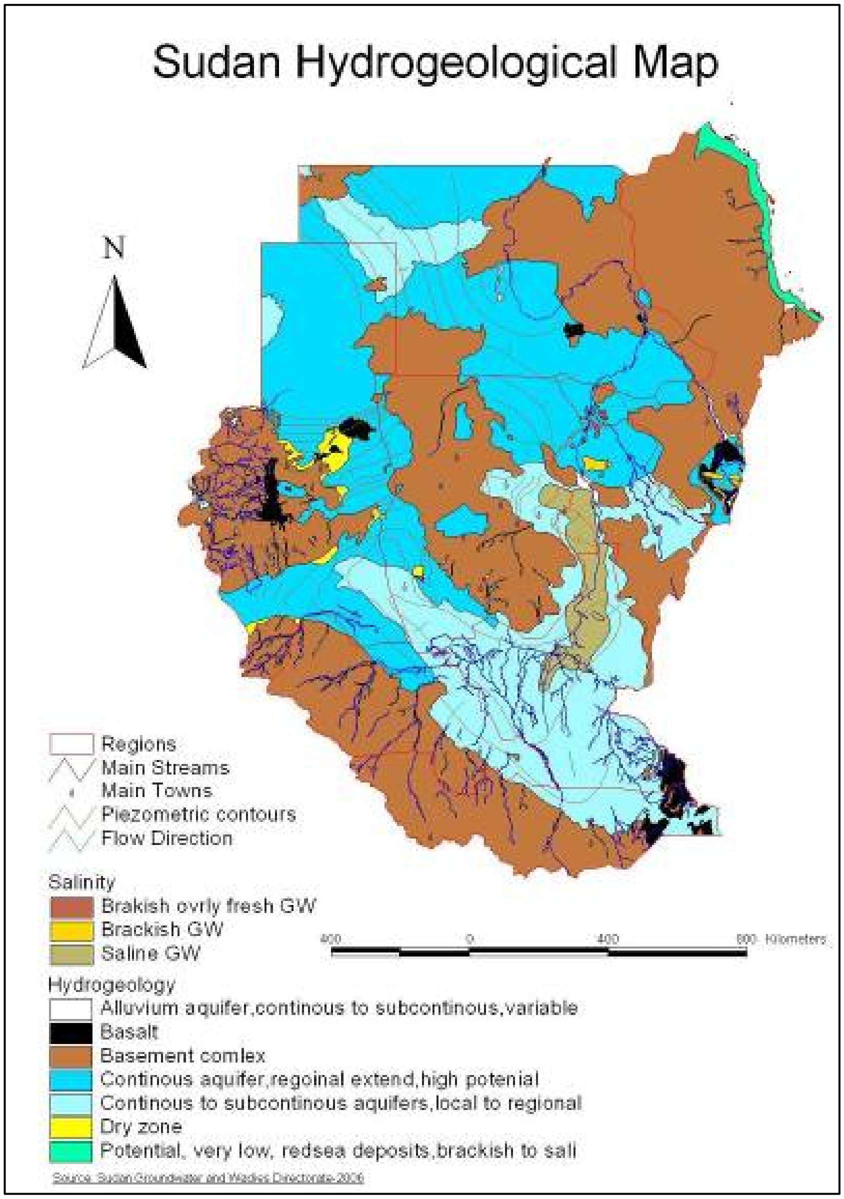
C) Porous or fractured rocks with very low hydrogeological importance: This unit is subdivided into two subgroups:

1. The Red Sea deposits are categorized under this subgroup, which are local aquifers that may be confined or unconfined. They are found in thin arentic beds or lenses consisting of consolidated or unconsolidated sediments. Their permeability is low to very low. The water quality varies and near the coast it is often brackish or saline. The relative hydrogeological importance is generally low and potential is low as well.

2. Undifferentiated Basement Complex and acid intrusions are categorized under this subgroup which are rocks that are generally non-water bearing. Water occurs in fractured or weathered zones. Local perched perennial or ephemeral aquifers may occur as well as thin saturated layers at depth and hydrogeological importance and potential is low.

   Areas under this unit are: Blue Nile, Nuba Mountatins, Western Equatoria, Central Equatoria, Eastern Equatoria, Western Bahr el Ghazal, West Darfur, Eastern States and some Northern part of Sudan (refer to map 1: Sudan Hydrogeological Map).

Practical problematic situations that are related to groundwater in different parts of Sudan are expressed in terms of high salinity, fine sand, loss of circulation, running sand & caving, thick mud-stone and other problems that will occur during drilling of boreholes like the presence of boulders. Areas affected with these problems are indicated in Table 2. The salinity zone has been indicated in map 1: Sudan Hydrogeological Map.



Map1: Sudan Hydrogeological Map

High Salinity	Fine sand	Loss of circulation	Running sand & caving	Thick mudstone	Others e.g. Boulders
-Sud Basin (Jonglei) (Some parts of Northern Upper Nile, Renk County) Latitude 8-13 Longitude3130-33 Umm Rawaba	-EnNhud Basin Nubian Sandstone, Northern Upper Nile	-Baggara Basin South Kordofan (Moo), South Darfur in Umm Rawaba Formation, West EnNhud Nubian Formation,	-Basement complex	-Nubian Sandstone Fula Depression Fula West Omdurman Arak and Debban North State	-Boulders Upstream and midstream of Red Sea Wadis emerging from escarpment (high mount) Sinkat

Formation, Unity State		Kapoyta area in Eastern Equatoria			Jabeit Port Sudan area
-East Kordofan Basin East Kordofan, White Nile, Latitude 13-14 Longitude 3130-3230 (Tendalti)	-Haskanita East Darfur, Umm Rawaba	-East Kordofan Basin Umm Rawaba Formation	-Umm Leuna Northern Darfur	-Gedarif Basin Mudstone below volcanic rock Darfur	-Nuba Mountain Waids Upstream
-Blue Nile Basin Jezira Formation, West Managil, Abuguta, North Central Gezira State, South of Khartoum 'between Niles', East of Nile Khartoum	-Baggara Basin	-Blue Nile Basin Sennar (North West) Nubian	-Nubian Formation Umm Hashaba Northern Darfur West Darfur Kulbus Wadi Sediment (100m)	-Malaha West Darfur Targmbout Nubian	-Jebal Marra Volcanic and upstream of wadis of Jebal Marra
-Gedarif Basin Southern part of the basin South of Gedarif	-Blue Nile Basin (Singa near river)	-Central Darfur Basin (Dabal) West Kordofan East Darfur	-Khartoum East Nile Um Dwit Nubian		-Basalt sills South of Khartoum and Omdurman
-Aroma	-South Darfur (Nubian)	-West Omdurman			-Basalt
-Delta Toker Downstream	-Khartoum East Nile, Kadarw (Nubian), Bageer (Nubian)	-Jezira State Umm El Gora (East of Blue Nile) (Nubian)			-Shagra Basin El fashir well field (180-250m)
-Red Sea Formation Red Sea at the shore line, downstream of alluvial in wadis in Red Sea m. system		-West Kordofan El Sederat Latitude 130858 Longitude 273488			-River Atbara (Boulders)
-Sinkat (Wadi sediment)					-Alluvium
-Basement (Dali & Mazamom) 6400ppm					

Table 2: Groundwater problematic Zones – Sudan[1]

3 Guidelines for the selection of borehole hand pumps

A borehole hand pump has the following main components: A borehole (the source of water); a platform with a drainage apron and soak away pit (protection from surface water infiltration and contamination); and a hand pump (the water lifting device). The method of borehole design and construction has been described in sections 5 and 6 respectively. It is of vital importance, however, to consider the following points during the selection of hand pumps:

[1] Source: Information Center (Kilo 10) Groundwater and Wadis Directorate, Ministry of Irrigation and Water Resources, August 2007

a) Depths of static and dynamic water levels and discharge of the well: This knowledge is important to determine the appropriate type of the hand pump to be procured.

b) Quality of water: Depending on whether the water is corrosive or non-corrosive, appropriate riser pipes and connecting rods could be identified. In case acquiring appropriate riser pipes and connecting rods is not possible, knowing the quality of water will help to establish an informed, appropriate and time-bound maintenance procedure for the GI riser pipes and connecting rods. In Sudan, in general, most of the groundwater quality parameters[2] are as follows:

Water temperature:	30 – 40^{0}C
pH:	6.5 – 8.5
Total hardness:	200 – 300 mg/l
Total dissolved solids:	500-1000mg/l and at some places >1500 mg/l
Sand content:	The water is moderately charged with sand particles

c) Ease of operation and maintenance: The pump design should allow for village level operation and maintenance.

d) Local capacity for operation and maintenance: The building or strengthening of community capacity to manage, operate and maintain their water supply systems is important.

e) Availability of spare parts: Spare parts should be available locally at affordable prices. The responsibility for the supply of spare parts should be agreed upon during the planning stage of the project. Whether taken on by WES, private sector, CBO or local administration, issues to be considered include effectiveness, cost implication and sustainability of the supply. In Southern Sudan, the supply chain of spare parts has been dealt with under separate guidelines which are available for reference under the title of Operation and Maintenance.

f) Government policy on standardization of hand pumps. Standard hand pumps recommended by the GONU through the MIWR/PWC are IM2 including deep well IM2 pumps. In Southern Sudan IM2 and Afridev have been adopted for shallow wells and Dubba for deep wells. This might change through time, however, as and when new pumps are introduced, tested and proven to be more appropriate.

4 Borehole design

4.1 General considerations in borehole design

The design of the borehole aims to achieve the following:

- **Structural stability to prevent borehole collapse**: The design will depend on the stability of the aquifer strata. For example, a borehole in fissured hard rock need only be cased over the thickness of the overburden. The remainder can be left open, as the

[2] Source: NWC, Water Supply Design Criteria and Equipment Standardization

formation will not require support. A borehole in unconsolidated formations will, however, require casing and screens to prevent collapse.

- **Prevention of ingress of fine material**: Fine material (such as sand) in the water is undesirable. It may damage the pump and it will silt up the well. Therefore a combination of screens, gravel packs or geotextiles are used to prevent material from the aquifer formation entering the borehole.
- **Low hydraulic resistance to flow into the borehole**: Resistance to flow of water from the aquifer into the well will restrict well yield. The correct screen length, position, slot size of aperture and material will minimize losses due to friction, encrustation and corrosion. It is necessary to ensure that the screen is placed against the proper aquifer zone.
- **A reasonable lifespan**: A borehole should last for 20-30 years, and many last longer. The correct selection of casing/screen materials should ensure that the borehole will not collapse or severely corrode within that time.
- **Good quality water**: The borehole must be sealed at the top to prevent surface water from contamination by the borehole water or saline water from saline zone. This is usually achieved with a cement slurry or cement/bentonite grout seal.

The following may also be considered when designing a borehole hand pump:

- The expected depth of the well is usually determined by the hydrogeological structure of the area where the well will be drilled. It is important to identify the appropriate drilling method to be employed in order to achieve the required depth of the well.
- If a uniform diameter of well is required to be maintained, the drilling should be done to accommodate casings of outside diameter 5.5 (or 4.5) inches of PVC pipe. However if a telescopic method of drilling is required, the drilling should be done to accommodate surface casings of diameter 5.5 inches of PVC pipes to a required depth and casings of diameter 4.5 inches of PVC pipes in hard rock. In both cases casings should be extended by one full length of casing pipe (about 3m) above ground for the safety of the borehole from any possible damage until the installation of the pump is complete.
- An apron/platform should be constructed around the top of the lining (at least 1m radius).
- Hand pump specification should be checked for appropriateness to the quality of water in the borehole.
- Position of the screen as per conditions and designs of section 4.2.should be ensured.
- Disinfection of the borehole is required prior to commissioning of the water supply system. Communities need to be informed about this as there might be unsubstantiated and false flow of information in regard to disinfection (chlorination of water).
- Surface water diversion ditches should be provided to protect against inundation.
- Waste water from the hand pump/borehole needs to be drained away from the platform through a proper drainage apron and soak away pit, evaporation beds (where infiltration is difficult due to texture of the soil) or to nearby individual/ community garden.
- With community consensus, the area around the borehole drainage apron should be fenced for the longevity of the system.

4.2 Practical borehole design considerations for Sudan

The first step in designing of boreholes is in understanding the various hydrogeological conditions of the aquifers in Sudan particularly in the area in which the borehole is to be drilled. Various borehole designs have been illustrated for different aquifer systems in Figures 1, 2, 3, 4, 5 and 6 in the following pages.

Stratified aquifers: In stratified aquifers (both confined and unconfined) of non-homogenous formations, screen sections are positioned against each reasonably permeable/thick individual stratum within the aquifer. Slot openings of the different sections of the well screen are also chosen according to the gradation of the material of the different strata by sieve analysis of corresponding samples obtained as shown in Figure 1. Two rules should apply as shown in Figure 4:

- If fine sand material overlies coarse sand it is necessary to extend not less than 25 cm of screen with the slot size designed for the fine material down into the coarse layer below.
- The slot size of the screen section to be installed in the coarse layer should not be more than double the slot size for the overlaying fine layer. Any deviation from these two rules will result in pumping sand.

  Some feasible areas for design application: Nubian and Um Rwaba Aquifers in Northern and Central Sudan and Renk Sedimentary Aquifer in Upper Nile State, near the river banks, all channels in Central Equatoria along the Nile.

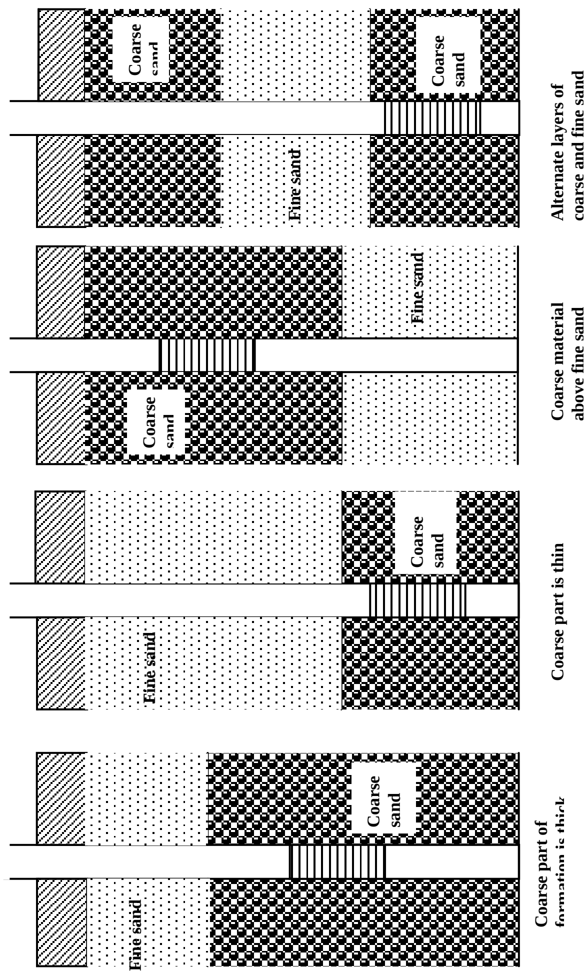
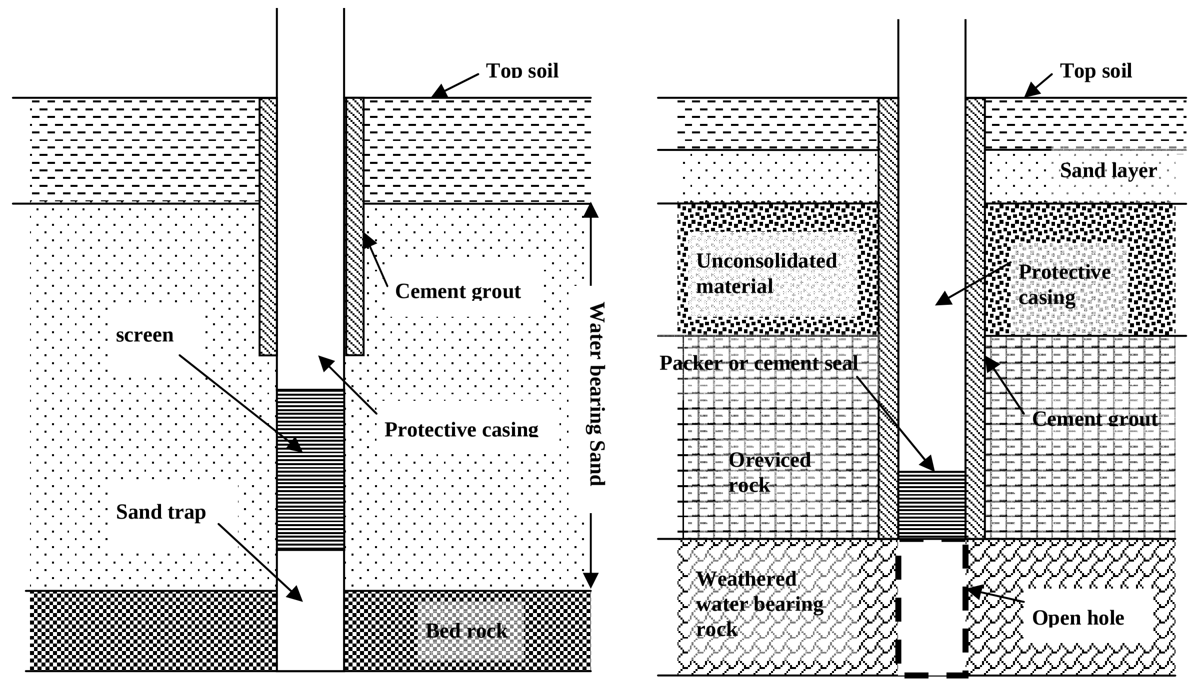


Figure 1: Suggested positioning of well screen in various stratified water bearing sand formation

Shallow aquifers in Wadi fill deposits: Best result can be obtained for well drilling within a wadi coarse (in the case of non flowing Wadis) or the terraces along its bank by completing the well up to bed rock and screening the bottom portion of the water bearing thickness as shown in Figure 2 (a). The top protective casing pipe should be cemented from ground surface to about 3m above the top of the screen.

Some feasible areas for design application: Wadi Kaja (Northern Darfur), Wadi Nyala and Bulbul (Southern Darfur), River Atbara, River Gash, Khor Sallum, Wadi Arab, Khor Arab (Eastern States), Wadi El Milak (Northern States), Red Sea Wadis, Nuba Mountain Wadis, Blue Nile Wadis, North Kordofan Wadis and North of Western Bahir el Ghazal



a) Well design in Shallow Wadi Course Deposits

b) Well Design in Fractured Rock Basement

Figure 2

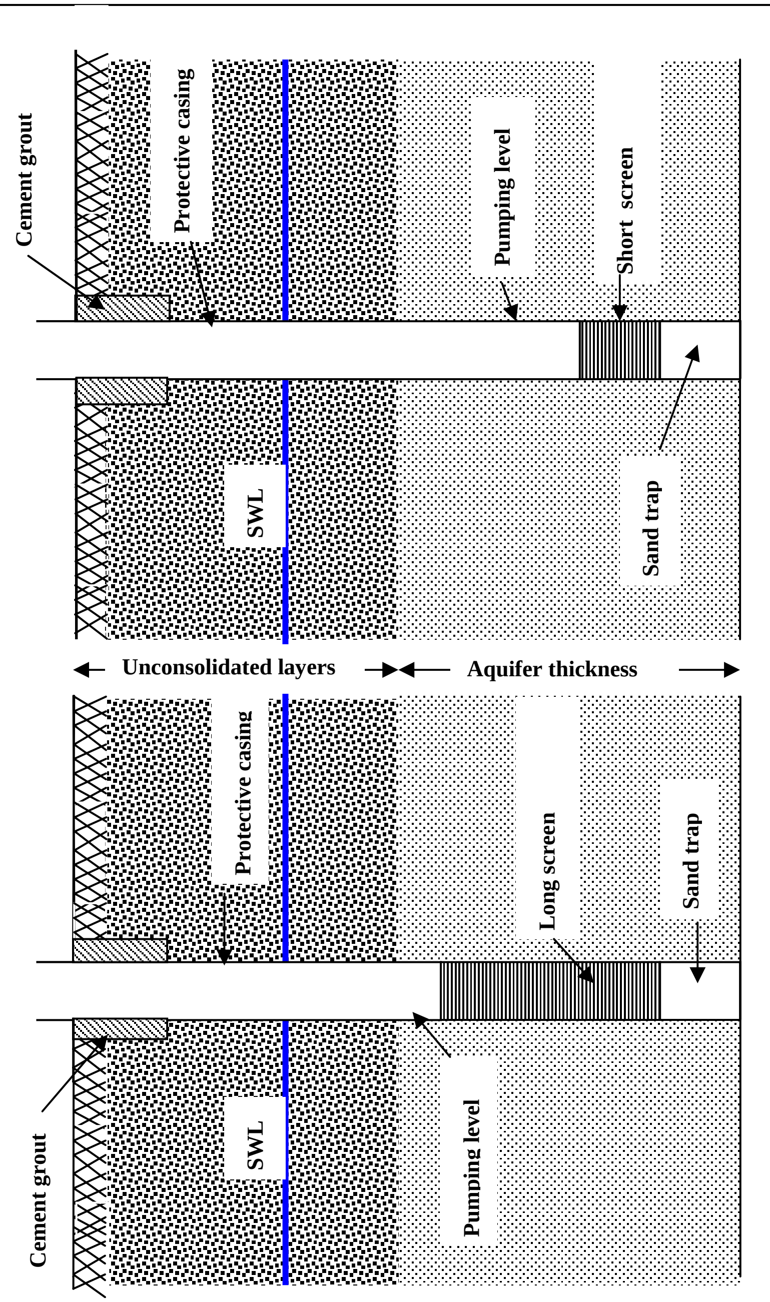
Shallow aquifers in weathered basement: Experience has shown that fair amount of groundwater is available in consolidated weathered or fractured basement rocks. The intake portion of the well is usually an open borehole of an adequate depth in the fractured water bearing formation as shown in Figure 2 (b). The protective upper casing should be completely cemented from top to bottom using packer or cement seal to protect the intake portion from the cement grout to leak downward.

Some feasible areas for design application: Um Keddada District (Eastern Darfur), Nuba Mountains (South Kordofan), El Mazroub Area (North Kordofan), Sodari District (Northern Kordofan), Northeast of Kerma (Northern Region), South El Damazine (Central Region), Butana District (Central and Eastern Region), Red Sea, Tambura in Western Equatoria, Kagwada in Central Equatoria, in parts of Lakes State

Water table/unconfined aquifers: For water table wells, two designs can be applied: either by using a long screen as much as possible to allow for horizontal flow of water at low entering velocity as shown in Figure 3 (a); or screening the bottom portion of the water bearing thickness to allow for more available drawdown as shown in Figure 3 (b). Both designs are satisfactory but the latter is preferred for cost effectiveness. Another reason for screening the bottom portion is that it is a custom that water table wells are usually pumped with water levels maintained slightly above the top of the screen.

Some feasible areas for design application: The Nubian Basin of Northern Darfur close to the intake area, Baggara Basin (Western Kordofan), Damgamad (Sug El Gamal) Basin (Western Kordofan), El Nahud Saata Basin (Western Kordofan), Umm Ruwaba Basin (Eastern Kordofan), Nubian Basin (Northern Kordofan), Nubian Basin underlying Gezira Formation (Khartoum State): and Jonglei, Lakes, Warap and Upper Nile States in Southern Sudan

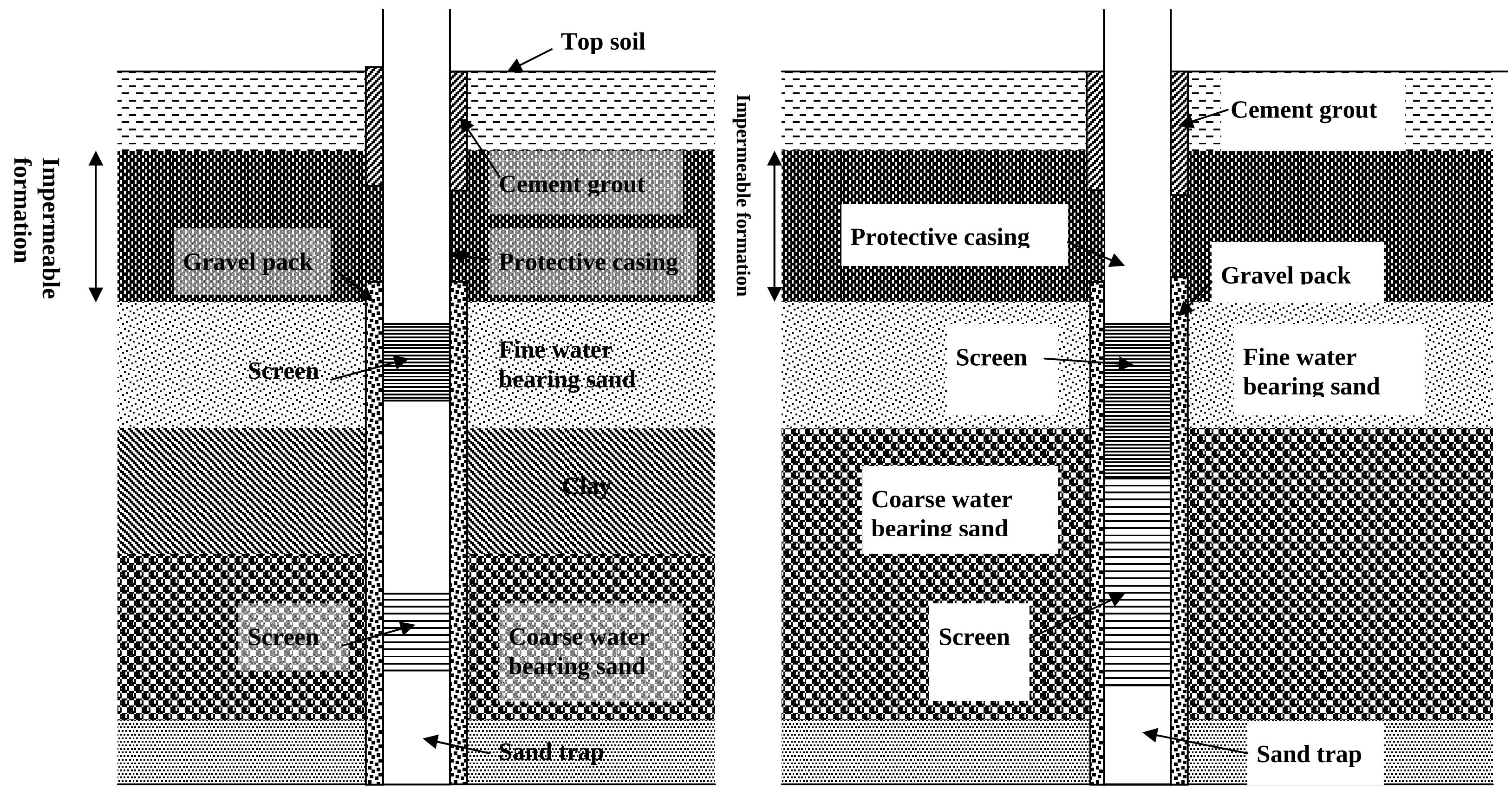
Figure 3: Water Table Aquifer Design



a) Well Design for Water Table Aquifer with Long Screen Section for Horizontal Flow at Low Velocity

b) Well design preferable for water table Aquifer with short screen at bottom

Figure 4: Well design in Non-Homogeneous Formation

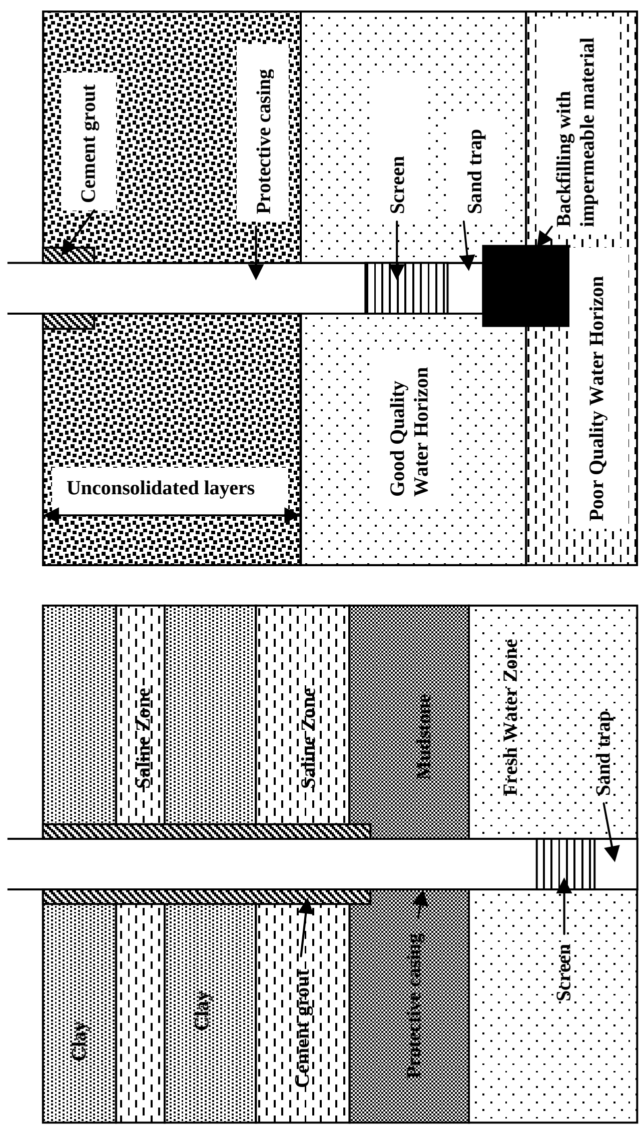


a) Well Design for Non-Homogeneous Formation of individual stratum

b) Well Design for Non-Homogeneous Formation of Fine Sand overlying Coarse Sand

Aquifer with upper saline zones: In such conditions the upper saturated layers of saline water should be completely isolated by cement grout from the lower fresh water bearing layers as shown in Figure 5 (a). This operation dictates the use of electric logging to verify and supplement the descriptive logging of the different strata penetrated in terms of depth and thickness and water quality contained in the various layers. The most permeable bottom half of lower fresh water bearing thickness needs to be screened with optimum screen area selected according to the sieve analysis of the corresponding respective samples taken from the good water bearing horizon.

Some feasible areas for design application: Area south of Um Ruwaba (Eastern Kordofan), area west of White Nile, area between the Blue and White Nile, Western Area of the Central States, Gadarif district with thick upper basalt rocks; and , Sedimentary Aquifers of Unity State – Bentiu and Rubkana areas and northern part of Upper Nile State, in Southern Sudan.



b) Well Design With Lower Poor Water Quality

a) Well Design With Upper Saline Zones

Figure 5: Well design in Different Saline Water Quality Situation

Aquifers with lower saline zones: In case water of poor quality or high saline content is expected to be found in the lower part of an aquifer, the well should be completed to a depth which will avoid the undesirable water as shown in Figure 5 (b). Any part of the hole that may be drilled in the part of the aquifer containing poor water quality should be completely backfilled so that the water will not migrate upwards when the well is pumped. The backfilling should be from impermeable material and well tamped solidly so that it supports the casing without settlement.

Some feasible areas for design application: Atbara Basin (Northern States), Toker Area (Eastern States).

5 Borehole drilling and installation

Borehole drilling and hand pump installation process will involve the following: Hydrogeological/geophysical survey, drilling of a borehole, developing of a borehole, pumping test (if required), water quality testing, installation of casings/screens, gravel packing (if required), sanitary sealing of a borehole, platform and drainage apron construction, disinfection of the well, hand pump installation,

Hydrogeological/Geophysical Survey.

The survey can only give an indication of where groundwater may be found and how much there might be. Hydrogeological survey may include the review of the hydrogeological setup of the area, examination of the outcropping rocks, detection of suitable geological structure, availability of exposed/buried channels etc.

There are a number of choices for geophysical survey where the choice or combination of choices is determined by hydrogeological conditions. These include: electromagnetic survey, grounded electrical resistivity survey, seismic refraction survey, magnetic survey etc. It is advised that a hydrogeologist is consulted for specific situations. Electromagnetic and grounded electrical resistivity surveys are recommended for their simplicity and relatively cheaper cost.

Electromagnetic survey: The electromagnetic method is based on the variation in electromagnetic conductivity of different rock formations. Since it can be carried out using portable equipment, it is a useful method for quick location of fractures and faults that may bear water. Promising sites identified by the electromagnetic method can be verified by a grounded electrical survey.

Grounded electrical resistivity survey (or electric logging): This method involves applying an electric current to the ground through electrodes. Any sub-surface variation in resistivity is measured and correlated with possible water bearing zone. The equipment for this type of survey is relatively portable.

Logging

Electric logging is a geophysical operation that serves to verify and supplement the description of the hole. It consists of the record of the apparent resistivity of the surface formation and the spontaneous potential in terms of depth below the ground surface. These two properties are related indirectly to the character of the subsurface formation and to the quality of water contained in them.

Dry formations show high resistivity. But when they are saturated with water, their resistivity is reduced to a different degree in each material. This is because water is a good conductor of electricity and its presence within the voids of the formation provides a conductive medium that lowers the resistance of the dry formation. The degree of reduction depends on the level of minerals dissolved in the formation water which affect the electrical conductivity of the water.

Clay formations show relatively low resistivity whilst sand saturated with fresh water shows relatively high resistivity. Gamma Ray Logging is sometimes used to indicate shale and clay beds by measuring the natural radiation of Gamma rays from certain radioactive elements that occur in varying amounts in a subsurface formation. Changes in radiation are commonly associated with differences between the types of materials making up successive strata. Clay and shale contains more radioactive elements than limestone, sandstone and sand. Therefore in most cases Gamma Ray Logging is a more distinct indicator of clay and shale formation than electric logging. Gamma Ray Logging can also be conducted whether the borehole is cased or not. The best way of interpreting a well logging is by correlating the curves with drillers' lithology log of the penetrated strata. With this correlation, it is possible to get the tangible information that formulates the optimum well design.

The sites identified by the geophysical survey should be ratified for suitability by the users before any drilling activity is started. In general, if the geophysical survey is done for a number of sites, it should guarantee at least 80% successful productive boreholes.

Drilling of a borehole:

Taking into consideration the formations identified by the hydrogeological/geophysical survey and understanding the hydrogeological conditions of the area, the next step is to select an appropriate drilling method and drilling rig. Table 2 shows the different methods in use and their appropriate application.

Table 2: Well drilling methods

No	Method, well diameter and depth	Suitable formation for drilling	unsuitable formation for drilling	Advantages	Disadvantages
1	Hand-drilled wells Diameter: 100-200mm Depth <30m	Clays, sands, fine gravels Example: in Warap State	Rock formations, cobbles, boulders	Low capital cost, portable equipment	Limited depth, limited range of suitable formations
2	Jetted wells Diameter: 50-200mm Depth <40m	Clays, sands, fine gravels	Rock formations, cobbles, boulders	Very quick and easy in right conditions, low capital cost, portable	Limited depth, limited range of suitable formations, water required to drill
3	Percussion (cable tool) Diameter: 100-1100mm Depth up to 600m	Soft rock, sands, gravels, silts and clays Example: in Eastern Equatoria, Central Equatoria, and Western Equatoria	Running sand, flint (or chert), hard rock, boulders	Reasonable capital and running costs, simple maintenance, good sampling during drilling, up to 30m/day in soft rock	Experienced driller needed, temporary casings needed in loose formations, slow in hard rock may be 2m/day
4	Direct circulation rotary drilling Diameter: 100-750mm Depth >1000m	Soft rock, metamorphic and igneous rock	Running sands, fractured rock, some shales, boulders	Little drill casing needed, 100-150m/day in soft ground, 10-20m/day in rock	High capital and operating costs, high demand on skill, maintenance and spares, drilling fluid can damage aquifer
5	Reverse circulation rotary drilling Diameter: 400-1750mm Depth up to 350m	Unconsolidated sediments, soft rock	Hard rock, boulders	80-100m/day in unconsolidated sediments, drill casing not needed	Heavy drilling equipment, large quantity of water needed for drilling
6	Down-the-hole hammer Diameter: 100-450mm Depth up to 400m	Hard rock Example: in Eastern Equatoria, Central Equatoria, Western Equatoria and Western Bahir el Ghazal	Sands, gravels, clays,, soft rock, loose boulders	Up to 5m/hour in hard rock, good sampling during drilling	High skill, capital and maintenance

Adapted from Hamill and Bell, 1986 and depth indicated are those expected under normal conditions

To summarise, a borehole can be drilled either by Percussion Drilling or Rotary Drilling. In selecting the appropriate size and type of drilling rig consideration must be given to cost implications, the time lag before water is pumped out of the ground, and the logistical, technical and administrative support required to maintain the drilling activity.

Table 3: A comparison of drilling rig size and complexity[3]

Drilling rig size and complexity	Advantages	Disadvantages
Large and complex	Capacity in reserve to drill a range of formations and to overcome drilling difficulties. Can drill to depth, if necessary	Relatively more expensive to operate and maintain. Large rigs require more support vehicles and more people. In rough and/or wet terrain a large heavy rig may have problems moving about and getting access to sites.
Lightweight	Cheaper and easier to operate and maintain. Easier to move about and get access to awkward sites. Feasible to airfreight	A lack of capacity to drill deep boreholes (beyond about 100m), to overcome drilling difficulties, to cope with hard rock drilling. Boreholes may not be truly vertical (but usually straight enough for most pump installations)

The suitability of a rig for a particular job will partly depend on its lifting capacity and, for a rotary rig, the torque it can impart to the drill bit. When rotary drilling is selected and down to the hole (DTH) method is applied the borehole should be drilled using compressed air as a drilling media.

Figure 6: Borehole drilling in Juba, Southern Sudan

[3] Engineering in Emergencies

The drilling contractor should record the drilling cutting samples (lithology log) in the borehole completion report using the format suggested in the annex. For boreholes drilled in hard rock, sampling can be done at change of formation and the it should be labeled accordingly.

Installation of casing and screen pipes

Casing and screen pipes should be installed after drilling a borehole as per the hydrogeological formation of the borehole, following the instructions provided in the section 4.2 for blind and screen casings. A proper casing guide shoe should be fitted to the bottom of the casing before lowering. It is important to install a bottom up cup during installation of the polyvinylchloride (PVC) casing, to avoid fine sand and silt soil getting into the PVC.

Gravel packing:

In case gravel packing is required, it is usually chosen according to certain geologic conditions in order to provide a more permeable zone surrounding the screen by replacing artificially graded coarser materials. The net result from such a design is an increase in the effective diameter of the well, which also allows the use of a bigger slot opening to make the zone immediately around the well screen more permeable. The geologic conditions which tend to favor artificial gravel pack construction are as follows:

a. **Fine uniform sand aquifer**: Gravel packing should be used for this type of formation to allow a larger slot opening, allowing for greater open area, resulted in increasing the hydraulic efficiency of the well.
b. **Thick artesian aquifer**: In this type of aquifer where a long screen is required and where the pump is installed above the screened section of the well, a small diameter of screen can be installed and the annular space filled by gravel.
c. **Loosely cemented sandstone**: Poorly cemented sandstone aquifers usually contain fine-grained materials. In such formation it is better to design the gravel packing using artificially graded gravel or sand envelope to prevent sloughing of sand particles and to allow the use of large screen opening. Another reason for gravel packing of a loosely cemented sandstone aquifer is to give support for the screen in the loose formations that does not provide lateral support for the screen.
d. **Laminated formation**: Some aquifers consist of alternating thin-medium and coarse layers. In such a situation it is rather difficult to determine the position and thickness of each layer and to choose the proper lengths of each section of multiple slot screens corresponding to the stratification. It is most advisable to reduce the error by gravel packing of the well. The gravel grading should be based on the layer of the finest material in the water bearing section.

The calculation of gravel pack size and screen slot size needs to be graphically demonstrated. Gravel pack thickness should not be less than 3 inches. In Southern Sudan, the size of the gravel pack is between 1.5 and 2 cm for a borehole of diameter 6 inches.
Table 4 lists the different sizes of boreholes and outer diameter (OD) of casing.

Table 4: Required volume of gravel pack for different outside diameters of well screen and inside diameters of boreholes[4]

Outside diameter of well screen	Volume of gravel pack							
		ID of pipe or borehole						
		203 mm	254 mm	305 mm	406 mm	508 mm	610 mm	762 mm
		8 inch	10 inch	12 inch	16 inch	20 inch	24 inch	30 inch
4 inch	ft3/ft	0.27	0.47	0.70	1.30	2.10	3.05	4.85
102 mm	m3/m	0.03	0.04	0.07	0.12	0.20	0.28	0.45
6 inch	ft3/ft	0.15	0.36	0.60	1.20	2.00	2.95	4.70
152 mm	m3/m	0.01	0.03	0.06	0.11	0.19	0.27	0.44
8 inch	ft3/ft	-	0.20	0.45	1.05	1.90	2.80	4.60
203 mm	m3/m	-	0.02	0.04	0.10	0.18	0.26	0.43
10 inch	ft3/ft	-	-	0.24	0.86	1.65	2.60	4.40
254 mm	m3/m	-	-	0.02	0.08	0.15	0.24	0.41
12 inch	ft3/ft	-	-	-	0.62	1.40	2.35	4.15
305 mm	m3/m	-	-	-	0.06	0.13	0.22	0.39
16 inch	ft3/ft	-	-	-	-	0.80	1.75	3.50
406 mm	m3/m	-	-	-	-	0.07	0.16	0.33
18 inch	ft3/ft	-	-	-	-	0.42	1.40	3.15
457 mm	m3/m	-	-	-	-	0.04	0.13	0.29
20 inch	ft3/ft	-	-	-	-	-	1.00	2.75
762 mm	m3/m	-	-	-	-	-	0.09	0.26

Developing of a borehole

Drilling of a borehole is not complete until the borehole has been developed to give maximum yield, and sediments and cuttings are removed to produce clear water. Development is necessary to:

- Remove fine material from the aquifer in order to improve permeability in the immediate vicinity of the well screen.
- Remove the remains of any drilling fluid. (If the borehole is coated in bentonite mud, for example, its yield will be significantly reduced)

The development should be done immediately after the completion of drilling and installation of the casing.

A production pump should not be used to develop a borehole as it would be severely damaged by the abrasive material pumped. Standard methods for borehole development include surging and jetting. Boreholes drilled in hard rock formations must be developed

[4] Source: Groundwater and wells, second edition, Fletcher G. Driscoll, Published by Johnson Division, St. Paul, Minnesota 55112

with compressed air after the completion of the well and until such time as clean water (without drill cuttings or clay) is obtained.

The air lift method can be used for testing boreholes before the installation of hand pumps. After development the well should be pumped using compressed air to obtain a steady flow of water from well. The static and dynamic water levels in the borehole can be measured by electric water level indicators. Testing for sand content is also a requirement in the development of a borehole.

Pumping Test

After development, a pumping test is required, to determine whether it is possible to install a hand pump in the borehole. This is positive if the well produces a minimum of 1200 liters per hour. The test is done by installing a pump inside the well at a depth above the well screen. The following measurements must be taken: static water level before pumping; the rate of discharge; dynamic water levels at various intervals during the pumping period; the time the pump is started; the time any change in the discharge rate is noticed; and the time the pump is stopped.

- **Measuring pump rates**: Control of the pumping rate during the testing requires an accurate device for measuring the discharge rate of the pump and a convenient means of adjusting the rate to keep it at as nearly constant as possible. A valve in the discharge pipe provides the best control. The size of the discharge pipe and the valve should be such that the valve will be from one half to three fourths open when pumping is at the desired rate. The simplest and most accurate method of determining the pump rate is to observe the time required to fill a container of known volume.
- **Water level measurement**: The depth to water must be measured many times during the pumping test. Readings must be taken at close intervals during the first two hours of the test with the time between readings gradually increasing as the test continues: every ½ minute during the first five minutes after starting the pump, then every 5 minutes for an hour, and every 20 minutes for about 2 hours. Reading at hourly intervals is sufficient after the 2 hours, until the well reaches the state of equilibrium i.e. there is no change in drawdown. The best way of measuring the water level is to use an electrical sounder. This is an electrode suspended by a pair of insulated wires. A light or ammeter indicates a closed circuit and flow of current when the electrode touches the water surface. Data for factors such as the coefficient of transmissibility of the aquifer can be obtained from the pumping test. Step drawdown test is the most practical method of determining the factor that allows a proper understanding of the behavior of the aquifer.

Water quality testing

The quality of the water from the borehole should be tested for physical, bacteriological, and chemical contamination before commissioning for public consumption. The physical and bacteriological contamination can be checked at field level with portable equipments like H_2S vials, Oxfam/Delagua Water Testing Kit or similar. Chemical contamination should be verified by the Sudanese institute authorized to do this at state or national level. The quality of water should be checked against Sudanese/WHO guidelines for drinking water under normal conditions, or against Minimum Sphere Standards and /or Sudanese/WHO guidelines during emergencies. Guidelines for the quality of water in Southern Sudan are being developed for stakeholder reference.

A sample of water should not be less than 2 liters, preferably two samples from each borehole. The sample should be sent to the authorized institute in a clean and sealed water container, for chemical testing. Three samples of water in clean, sterilized and sealed plastic or glass containers, not less than 100ml each should be sent for bacteriological analysis. The guideline values for drinking water quality standard are attached in the annex.

Sanitary sealing of a borehole

In a completed well, polluted water from surface drainage or from formations other than an aquifer, can move downward through the annular space and contaminate the water being pumped from the well. It is advisable that the well casing should terminate above ground to allow surface water to drain away from the well in all directions. Provision must be made in the design of a well for grouting the well casing in the ground from the surface down to an adequate depth not less than 6 meters (depending on the geological and site conditions), to provide a means for sealing an opening outside the casing. A grouting method suitable to local condition should be applied.

Undesired bad quality water, from water bearing formation that is overlying good water horizons, should be completely sealed off in order to keep the good water aquifer free from harmful bacteria or other contaminating factors.

Platform and drainage apron construction

A platform and drainage apron should be constructed as shown in Figures 6 & 7, or modified as per consumer needs. Users should be consulted for the design of the platform and drainage apron to ensure proper usage and maintenance of the water point.

Figure 6: Platform and drainage apron construction for India Mark II hand pump

Hand pump installation

An installation manual must be ordered with the hand pump. Installation, as per the guidelines of the manufacturer, can begin when the quality of the water in the borehole is found to comply with the Sudanese/WHO standard. It is important to ensure that all standard hand tools are available with the team that is installing the pump.

Figure 7: Hand pump installation by women in Torit, Eastern Equatoria, Southern Sudan

Disinfection of the well

Disinfection is necessary initially during pump installation and if and when the well gets polluted. The well should be disinfected or sterilized with a chlorine solution yielding at least 50mg/l of active chlorine in all parts of the well. The chlorine solution may be prepared from calcium hypochlorite or sodium hypochlorite. In case bleaching powder is used for disinfection, 300g of bleaching powder should be mixed thoroughly in 15 liters of water and poured into the well.

The disinfectant should stay in the well for at least four hours at the specified concentration, after which water should be pumped out and discarded until the water smells strongly of chlorine. At this point, no more water should be pumped out for at least 24 hours, after which water should be pumped out and discarded until the taste of chlorine is just noticeable in the water. A sample of water should be collected in a sterile bottle and sent for bacterial analysis.

6 Borehole hand pumps

6.1 Types of hand pumps

Available hand pumps that are used worldwide can be categorized in two major classes:.

- Hand pumps for shallow wells, and
- Hand pumps for deep wells.

All hand pumps have the following components as shown in Figure 9 (typical set up for deep well hand pumps):

- Pump Head Assembly: The above ground mechanism operating the plunger.
- Cylinder Assembly: Contains plunger, check valve, etc which lifts the water upward in each stroke.
- Connecting Rod: Provides linkage between the pump head and cylinder.
- Riser pipe: Carries water from the cylinder to the water tank

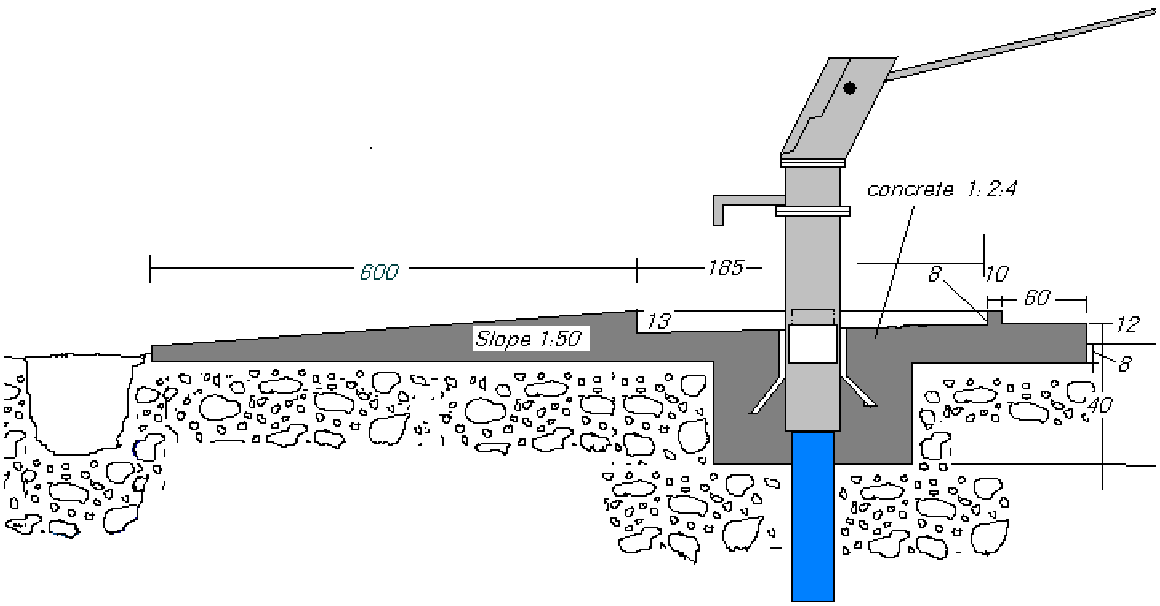


Figure **8** **Platform for India Mark - II Hand pumps**
Dimensions in Cm

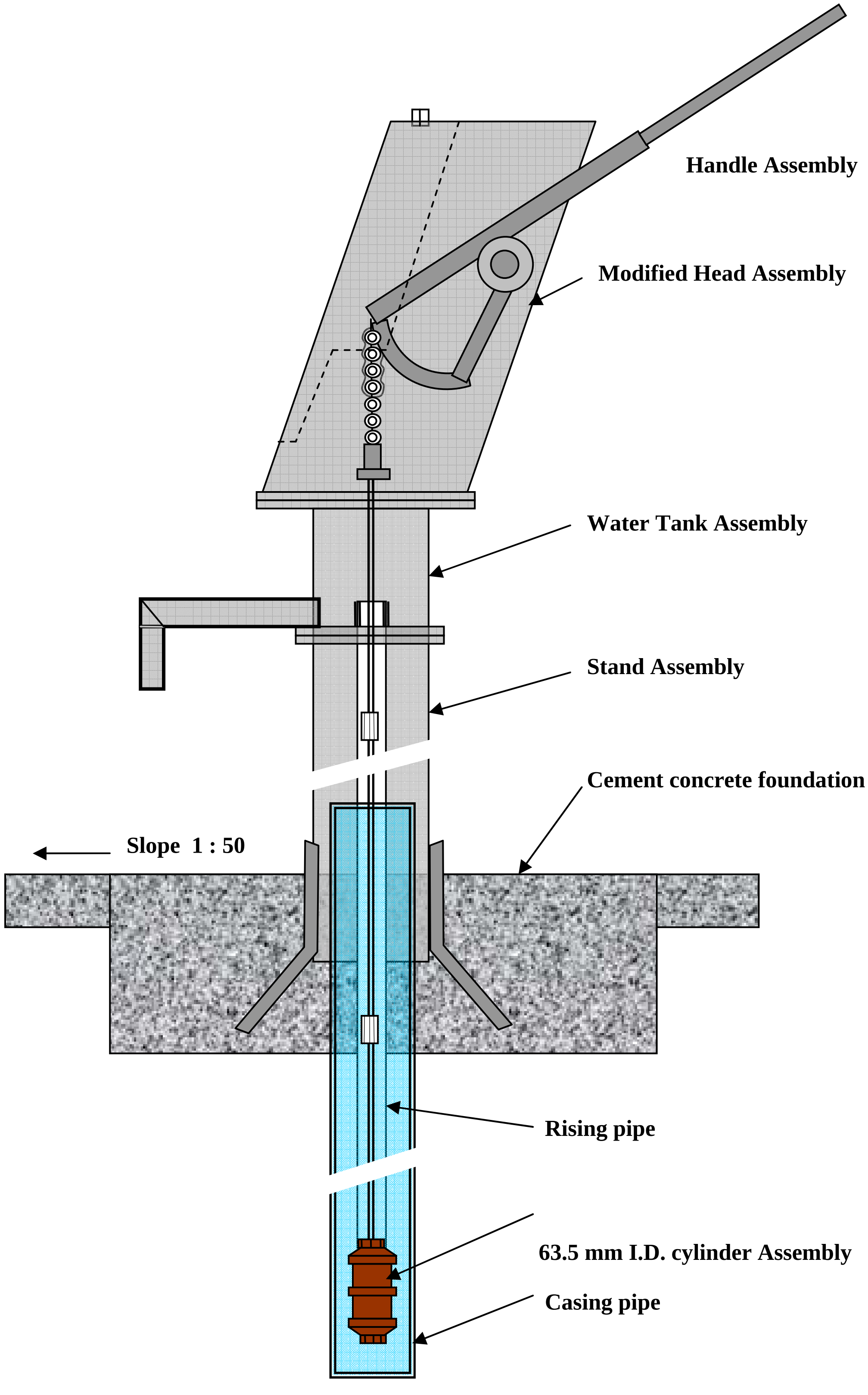


Figure 9: India Mark II Pump system details

Hand pumps for shallow wells can be used in wells of depth 12-15m. These include direct action pumps like Tara, Niara, etc.as options. These kinds of pumps are good for aggressive soil and water as the mechanism below ground is constructed from corrosion resistant components. These pumps can withdraw water up to 35 liters per minute. Typical pump head and cylinder assembly of these types of pumps is shown in Figure 10.

Figure 10: Direct action pump in use in Southern Sudan

Hand pumps for deep wells are further categorized into standard and extra deep well hand pumps. These hand pumps are for wells of depth 45m and 60m-90m respectively.

Hand pumps can also be categorized by Village Level Operated and Maintained (VLOM) and non-VLOM types. India Mark III, Afridev, Aquadev, Tara, Niara etc fall into the VLOM category, India Mark II is a non-VLOM type. The main difference between VLOM (eg. India Mark III) and non-VLOM hand pumps (eg India Mark II) is that the former allows the withdrawal of the cylinder components without the disassembly of the rising mains.

The difference between India Mark III and other VLOM hand pumps (like Afridev and Aquadev) is in the type of riser pipe. India Mark III has galvanized iron pipes while the others have PVC pipes with solvent cement joints.

India Mark II & III are good for non corrosive water while the other types of VLOM pumps are good for corrosive waters (except the galvanized connecting rods).

Table 5 below, lists the differences between the non-VLOM (India Mark II) and VLOM (Afridev) types.

Table 5: Comparison between the India Mark II and Afridev[5]

Criteria	India Mark II	Afridev
International Specification	Specified through Indian Standards. The pump is produced in several countries to these standards. The design is in the public domain and the specifications are available to everybody.	Specified through an International Standard. The pump is produced in several countries to these standards. The specifications are in the public domain and the specifications are available to everybody.
Ease of installation	19 different tools are required for installation. Skilled crew is needed.	8 different tools are needed for installation. Skilled crew is needed.
Ease of repair (routine repairs)	The cylinder components can not be withdrawn without the disassembly of the rising main and pump rods. A trained village mechanic equipped with special tools is required.	All routine repairs can be performed by the community with a single spanner and a fishing tool
Ease of repair (major repairs)	A trained village mechanic equipped with special tools is required. For fishing dropped components special equipment is needed.	A skilled mechanic is required for the replacement of perforated riser pipe and fishing of dropped rods. Retrieval of PVC pipes and rejoining them in the field needs proficiency and special equipment.
Reliability	Reliable in non-corrosive water with few breakdown interventions.	Reliable, but frequency of maintenance interventions will be comparatively higher due to preventive maintenance requirements. Reliability can suffer badly if used in unlined borewells. When breakdowns occur, in most cases, it can be repaired quickly by the village mechanic. However results from the field indicate that the PVC rising main can fail if they are in contact with the rods.
Corrosion resistance	Galvanized rising mains and carbon steel galvanized rods are not corrosion resistant in water with pH values below 6.5. Stainless steel pipes are available but at a very high cost and are not standard to the specification. Corrosion resistant stainless steel rod option available is standard to the specification.	All below ground components including rising main are corrosion resistant with the exception of galvanized pump rods. Corrosion resistant stainless steel rod option available is standard to the specification.
Abrasion resistance	Riser main and rods have shown excellent abrasion resistance in non-corrosive water. The ball bearings generally last for 3-4 years. The introductions of nitrile rubber cup seal in place of leather cup seals reduce the frequency of below ground repairs by over 50%.	The bearings and the seal have a service life of about one year, but they are less expensive and easy to replace. Rubber centralizers prevent the rods coming in contact with the PVC pipes. They need regular replacement. Hook and eye connectors on the rods are subject to wear and frequent replacement of rods may be expected. Riser main perforation can reach unacceptable levels when used in unlined borewells.
Suitability for unlined borewells	Can be installed in unlined borewells.	Should not be installed in unlined borewells.
User preference	Acceptable discharge and ergonomics.	Acceptable discharge and ergonomics. Acceptable discharge and ergonomics.
Cost of pump	For 36m setting ,in 1996, (with galvanized pump rods): USD 200 FOB Bombay, plus packing and freight	For 36m setting (with galvanized pump rods): USD 250, FOB Bombay, plus packing and freight.
Cost of spares	Spare parts are affordable.	Spare parts are affordable.
Suitability for local manufacture	It is manufactured in several countries in Africa and Asia. Can be produced in a country where industrial infrastructure for steel fabrication, hot dip galvanizing, electro-galvanizing, ferrous and non-	It is manufactured in Africa and Asia. Can be produced in a country where industrial infrastructure for steel fabrication, hot dip galvanizing, electro-galvanizing, extrusion of uPVC pipes and moulding of nylon/polyacetal components and familiarity with quality control

[5] Sudan Hand pump Mission Report (January 1996)

	ferrous foundry and galvanized steel pipes and familiarity with quality control practices and mass production techniques exist. A substantial investment has to be made in tooling.	practices and mass production techniques exist. A substantial investment has to be made in tooling. The production of the plastic components requires special skills and extensive tooling.
Pumping lift	Can be used up to 45m, extra deep well version for over 45m available.	Can be used up to 45m.

6.2 National standard hand pumps for Sudan

The nationally accepted standard hand pumps for North Sudan are Indian Mark II standard and extra deep well hand pumps. India Mark II has been used in Sudan since the mid seventies. Its technical standard specifications have been improved from time to time and the latest version conforms to Indian Standard (IS) 15500, 2004.

Pump details of Indian mark II, including the head, handle, cylinder and valve assemblies are shown in Figures 14, 15, 16, 17, 18, 19, 20, 21, 22 and 23 in the annex section.

Minimum delivery of a hand pump is estimated to be 20 l/minute (from 15-70m depth) for operational time of about 8-10 hours per day. One hand pump will serve 500 people during emergency and 250 people during normal situation.

In Southern Sudan, the hand pumps of choice are India Mark II standard hand pumps and Afridev hand pumps (Figure 25 in the annex) for depth of wells up to 45m and Dubba deep well hand pumps for depth of wells over 45m. Direct Action Hand Pumps (Figure 24 in the annex) are used for shallow wells of depth less than 15m.

7 Management, operation and maintenance of hand pumps

7.1 Management of the water supply system

The Village Health Committee (VHC) in North Sudan and Water Committee (WC) in Southern Sudan are responsible for the management of their water supply system with the technical support of a village mechanic. The WC in Southern Sudan states, counties and payams is guided by the recently developed operation and maintenance guideline, which was developed to address problems related to operation and maintenance of the water supply system.

Figure 11: Water Committee members in Bor, Jonglei, Southern Sudan

VHCs and WCs are elected by community members through the facilitation of WES Rural Council Unit in North Sudan and DRWSS at county/payam level in Southern Sudan. VHCs comprise equal representation by men and women from the village. Community leaders and representative from local administration could be included in the committee. VHCs comprise 10 members while WCs have at least 5. The committees' roles include: operation and maintenance of the water supply system at village level, mobilizing the community at village level and raising awareness of important issues, encouraging positive participation and effective contribution, managing the caretaker (guard) and purchasing all necessary spare parts. In cases where a fee is charged for the water the committee is responsible for collecting revenues and managing the accounting, salary/ incentive payments etc. They also report back to the WES Rural Council Unit or Payam Water Supply and Sanitation Committee for follow-up and to the community as well on all aspects of the water supply system.

A caretaker/guard should be employed to overlook the system, carry out routine maintenance and report the need of major works to the VHC or WC, and secure the safety of the system during day time.

7.2 Operation and maintenance

An India Mark II hand pump is easy to operate and can even be done by children. It involves raising and lowering the handle attached to the pump.

The pump and the site around it must always be kept clean. This is part of preventive maintenance which also involves a daily function check. The pump should be greased weekly and all parts of the pump stand must be checked monthly. Pump rods that have corroded must be replaced; under normal conditions, a galvanized steel pump rod needs to be replaced every five to six years. Rising mains consisting of galvanized iron should be dismantled and checked, and pipes with badly corroded threads must be replaced. Small repairs include replacement of bearings, cup seals and washers, straightening bent pumping rod etc. Major repairs may involve the replacement of the plunger, foot valve, cylinder, pump rods, rising main, pump handle, fulcrum etc.

Hand pumps should generally be maintained according to the factory's operation and maintenance manual. Trained village mechanics should be responsible for routine and regular maintenance of the hand pumps and need should have the necessary standard and special tools for maintenance. External support should be sought for any major repairs.

Borehole hand pumps need to be protected from flooding the entry of pollutants. The well site should be protected by a flood diversion ditch from the surface runoff. In case the well is flooded, the first step is to halt the water supply, clean and disinfect the well, check for the presence of pathogens and restart the supply if no substances harmful to public health are found.

Continuous turbidity of the water from a borehole, after some years of service, indicates that the well needs to be cleaned. To do this, one needs to dismantle the pump and the riser pipes from the well and follow the procedure outlined for the development of the well in section 5 until the emerging water is clear. The pump and the riser pipes can then e reinstalled into the well.

7.3 Capacity building

For proper operation, maintenance and sustainability of any water supply system, capacity building of the village mechanics and the communities (through their VHC or WC) and is vital. Periodic refresher training for community based hand pump mechanics is important to ensure the availability of hand pump mechanics at the community level.

The VHC or WC members need to be trained in basic management of the water and sanitation facilities and hygiene promotion activities so that they can operate and maintain the pump in good working condition. Based on community needs, training may include: pump care taker on basic maintenance, village mechanics on operation and maintenance and the supporting agency like WES or Department of Rural Water Supply and Sanitation (DRWSS) on microbial analysis and extension work. Availability of spare parts is one of the determining factors for the sustainability of the water supply system. The spare part supply chain that includes the responsibility, location and current price also needs to be worked out. A list of hand pump spare parts should be made available in Arabic to hand pump mechanics to ensure that standard and recognizable names are used. Once these factors are in place, the hand pump can be handed over to the community.

8. Recommendations

- Site selection is important. Figure 12 demonstrates how the wrong site can be detrimental. The pump site being on the seasonal surface drainage route, the surrounding was eroded and washed away.

Figure 12: Inappropriate site selection

- Addition of protective devices: Figure 13 demonstrates a protection mechanism against injury (e.g a child's finger could get caught in the pump head assembly without the protective shield)

Figure 13: Child finger protection mechanism adapted by North Darfur

- It has been demonstrated that the spout of the hand pump is not compatible with the containers used by the community to collect water, resulting in the unnecessary wastage of water. UNICEF is in discussion with the manufacturers to get the spout modified..

Annexes

1. Sudanese/WHO guidelines for drinking water
2. Borehole Completion Report Format
3. Detail diagrams of hand pumps
4. Technical specifications of hand pumps
5. Standard tools required for installation and or maintenance
6. Recommended spare parts for a hand pump
7. The processes of the development and finalization of technical guidelines and manuals
8. List of contacted persons
9. Technical working group members
10. Some bibliography and references
11. Unit conversion tables

Annex 1: Drinking Water Standards

No	Dissolved substances in water	Sudanese maximum permissible (mg/l) by SSMO, 2008	WHO guideline value (mg/l), 2006
1	Antimony	**0.013**	0.02
2	Arsenic	**0.007**	0.01 (P)
3	Barium	**0.5**	0.7
4	Boron	**0.33**	0.5 (T)
5	Cadmium	0.002	0.003
6	Chromium (total)	**0.033**	0.05 (P)
7	Copper	**1.5**	2
8	Cyanide	**0.05**	0.07
9	Fluoride	1.5	1.5
10	Lead	**0.007**	0.01
11	Manganese	0.27	0.4 (C)
12	Mercury (for inorganic Mercury)	**0.004**	0.006
13	Molybdenum	**0.05**	0.07
14	Nickel	**0.05**	0.07 (P)
15	Nitrate as NO3	50	50 Short term exposure
16	Nitrite as NO2	**2**	3 Short term exposure
17	Selenium	**0.007**	0.01
18	Uranium	0.01	0.015 (P,T)

Microbiological contents			
No	Organisms	Sudanese guideline value by SSMO	WHO guideline value
1	All water intended for drinking a) E-coli or thermotolerant coliform bacteria b) Pathogenic intestinal protozoa	Must not be detectable in any 100ml sample	Must not be detectable in 100ml sample
2	Treated water entering the distribution system a) E-coli or thermotolerant coliform bacteria b) Total coliform bacteria c) Pathogenic intestinal protozoa	Must not be detectable in any 100ml sample	Must not be detectable in 100ml sample
3	Treated water in the distribution system a) E-coli or thermotolerant coliform bacteria b) Total coliform bacteria c) Pathogenic intestinal protozoa	Must not be detectable in any 100ml sample Must not be detectable in any 100ml sample. In the case of large supplies where sufficient samples are examined, must not be detectable in 95% of samples examined through out any consecutive 12 months period. Must not be detectable in any 100ml sample.	Must not be detectable in 100ml sample

Maximum permissible limit for other parameters which affect the acceptability of water			
	Parameter	Levels likely to give rise to consumer complaints by SSMO, 2008	
1	Physical parameters Colour Taste & odour Temperature Turbidity pH	 15 TCU Acceptable Acceptable 5 NTU 6.5 – 8.5	
2	Inorganic constituents Aluminum Ammonia Chloride Hydrogen sulfide Iron (total) Manganese Sodium Sulfate Total dissolved solids (TDS) Zinc	 0.13 mg/l 1.5 mg/l 250 mg/l 0.05 mg/l 0.3 mg/l 0.27 mg/l 250 mg/l 250 mg/l 1000 mg/l 3 mg/l	 0.4 mg/l
3	Organic constituents 2-Chlorophenol 2,4-Dichlorophenol	 5 µg/l 2 µg/l	

Parameter	Permissible level in µg/l by SSMO, 2008	WHO guideline value in mg/l, 2006
Carbontetrachloride Dichloromethane 1,2-Dichloroethane	2.7 14 20	0.004 0.02 0.03
1,2-Dichloroethene Trichloroethene Tetrachloroethene	33 13 27	0.05 0.02 (P) 0.04
Benzene Toluene Xylenes Ethylbenzene Styrene	7 470 330 200 13	0.01 0.7(C) 0.5 (C) 0.3 (C) 0.02 (C)
1,2-Dichlorobenzene 1,4-Dichlorobenzene	700 200	1 (C) 0.3 (C)
Di(2-ehylhexyl) phthalate Acrylamide Epichlorohydrin Edetic acid (EDTA) Nitrilotriacetic acid (NTA) Hexachlorobutadiene Dioxane Pentachlorophenol	5.4 0.3 0.3 400 130 0.4 33 7	0.008 0.0005 0.004 (P) 0.6 Applies to the free acid 0.2 0.0006 0.05 0.009 (P)

Parameter	**Maximum Permissible level in µg/l**	WHO guideline value in mg/l, 2006
Pesticides		
Alachlor	15	0.02
Aldrin/Dieldrin	0.02	0.00003 For combined Aldrin and Dieldrin
Aldicarb	7.5	0.01 Applies to Aldicarb Sulfonide and Aldicard Sulfone
Atrazine	1.5	0.002
Carbofuran	4.5	0.007
Chlordane	0.15	0.0002
Chlorotoluron	20	0.03
1,2-Dibromo-3-Chloropane	0.7	0.001
DDT	0.7	0.001
2,4-Dichlorophenoxy acitic acid	20	0.03
1,2-Dichloropropane (1,2 DCP)	26	0.04 (C)
1,3-Dichloropropene	13	0.02
Isoproturon	6	0.009
Lindane	1.3	0.002
MCPA	1.3	0.002
Methoxychlor	13.5	0.02
Metholachlor	7	0.01
Molinate	4	0.006
Pendimethalin	13.5	0.02
Pentachlorophenol	7	0.009 (P)
Permethrin	200	0.3
Simazine	1.3	0.002
Trifluralin	13.5	0.02
2,4-DB	60	0.09
Dichlorprop	66	0.1
Fenoprop	6	0.009
Mecoprop	7	0.01
2,4,5-T	6	0.009
Cyanazine	0.4	0.0006
1,2 Dibromoethane	0.27	0.0004 (P)
Dimethoate	4	0.006
Edin	0.4	0.0006
Terbuthylazine	5	0.007
Chlorpyrifos	20	0.03
Pyriproxyfer	200	0.3
Disinfectants and disinfectants' byproducts		
Chlorine	3	5
Monochloroacetate	13	0.02

Bromate	6.6	0.01 (A,T)
Chlorate	470	0.7 (D)
2,4,6-Trichlorophenol	135	0.2 (C)
Bromoform	70	0.1
Dibromochloromethane	70	0.1
Bromodichloromethane	66	0.06
Chloroform	200	0.3
Dichloroacetate	33	0.05 (T,D)
Trichloroacetate	133	0.2
Dichloroacetonitrile	13	0.02 (P)
Dibromacetonitrile	50	0.07
Cyanogen Chlorides (CN)	50	0.07
Chlorote	470	0.7 (D)
Disinfectants byproducts		
Gross alpha activity	0.07	
Gross beta activity	0.7	

P= Provisional guideline value as there is evidence of a hazard, but the available information on health effects is limited.
T= Provisional guideline value because calculated guideline value is below the level that can be achieved through practical treatment methods, source protection etc.
C= Concentration of the substance at or below the health-based guideline value may affect the appearance taste or odor of the water, leading to consumer complaints.
A= Provisional guideline value because calculated guideline value is below the achievable quantification level.
D= Provisional value because disinfection is likely to result in the guideline value being exceeded.
TCU = True Colour Unit
NTU = Nephlometric Turbidity Unit

Annex 2: Borehole Completion Report Format adapted from Southern Sudan

PROJECT ....

<table>
<tr><td rowspan="1">Borehole ID</td><td>Location
State .... Borehole N° ....
County ....
Payam .... Long. E ....
Boma .... Latit. N ....
Village .... Elevation ....
Site ....

Use
☐ Community water supply ☐ Health facility
☐ Domestic water supply ☐ Education facility
☐ Community center ☐ Test well
☐ Private compound ☐ ....
Property or handed over to ....
Sitting
☐ Geophysics...
☐ Other : ....</td><td>Sketch map

Approximate scale :</td></tr>
</table>

<table>
<tr><td>Drilling operation</td><td>Drilling data
Start date .... End date ....
Total depth ....[m] SWL ....
Main water strike .[m] Yield .... [.....
Dynamic water level …….[m]

Drilling diameter ☐ inch ☐ mm
∅.......... From ..... [m] To ...... [m] Method ....
∅.......... From ..... [m] To ...... [m] Method ....
∅.......... From ..... [m] To ...... [m] Method ....
∅.......... From ..... [m] To ...... [m] Method ....
Method of drilling
☐ Percussion ☐ Hand-drilled
☐ Air rotary ☐ Mud rotary
☐ DTH ☐ Rig make……………..</td><td>Drilling consumption
Diesel……………………[Lt]
Engine Oil……………….[Lt]
Hydraulic Oil…………….[Lt]
Hammer Oil……………..[Lt]
Foam/polymer…………..[Lt]</td></tr>
</table>

<table>
<tr><td>cons</td><td>Casing type
☐ uPVC
☐ Threaded</td><td>Filter pack (gravel pack)
Composition .... Source .....
Units ☐ bags [. kg] ☐ kg ☐ ...</td></tr>
</table>

☐ Bottom plug Height above/below ground level [m]

Plain casing & Screen installation ☐ inch ☐ mm

∅ .... Type From .... [m] To............. [m]
∅ .... Type....... From .... [m] To............. [m] Slot ....
∅ .... Type....... From .... [m] To............. [m] Slot ....
∅ .... Type....... From .... [m] To............. [m] Slot ....
∅ .... Type....... From .... [m] To............. [m] Slot ....

Amount used .... Depth to top..................... [m]

Grouting

☐ yes ☐ no ☐ Cement [

Type... From .... [m] To...... [m] Amount.
Type... From .... [m] To...... [m] Amount.
Type... From .... [m] To...... [m] Amount.
Backfilling ....

Development

☐ Air-lift ☐ Over-pumping ☐ Surging ☐ Backwashing ☐ Jetting
Duration........[hr] Water: ☐ Limpid ☐ Turbid ☐ Other ....
Comment ....
....

Water level ** H.a.g.l. = height above ground level*

Measurement from .... H.a.g.l*........ = ... [m] Static water level (SWL) ... [m] Date .

Test pumping

☐ Air-lift cap. Evaluation ☐ Step Drawdown Test ☐ Constant RateTest-CRT ☐ Short CRT
Duration............. [hr] Discharge ..... [...........] Dynamic water level (final drawdown) ....[m]

Pump & platform

Pump

☐ IM2 ☐ Afridev ☐ Submersible
☐ IM2 x-deep ☐ Mono
☐ Duba
Make..
....
Comment

Date installed
Depth of pump intake [m]
Type of pipes
∅ of pipes

Well head and platform completion

Pump stand ☐ Welded on casing ☐ Fitted around casing ☐
Apron ☐ Concrete slab ☐ Drainage ☐ Soak-away pit ☐ Fence
Comment ....
....

Water quality

Physical quality

Color .... Taste .... Turbidity ..[MTU]

Bacteriological quality

Faecal coliform
…………………….cfu per 100 ml

T° .... [°C] TDS .... [mg/lt] CE .... [µS/cm]	E. coli total .... cfu per 100
Sample taken.......... ☐ Yes ☐ No .... Date	Lab ....
Comment	
Disinfection	
Chemical used	Volume ....
Nearest sources of possible contamination	
Type..	
....	Distance..
Remarks	

Borehole completion date	

Comments ....

....

....

....

PROJECT ....

Borehole log and construction details					*Construction*	**scale**
From	**To**	Litho logy	**Thickness**	Log [3]		

Log = Lithology drawing

TEST PUMPIMG

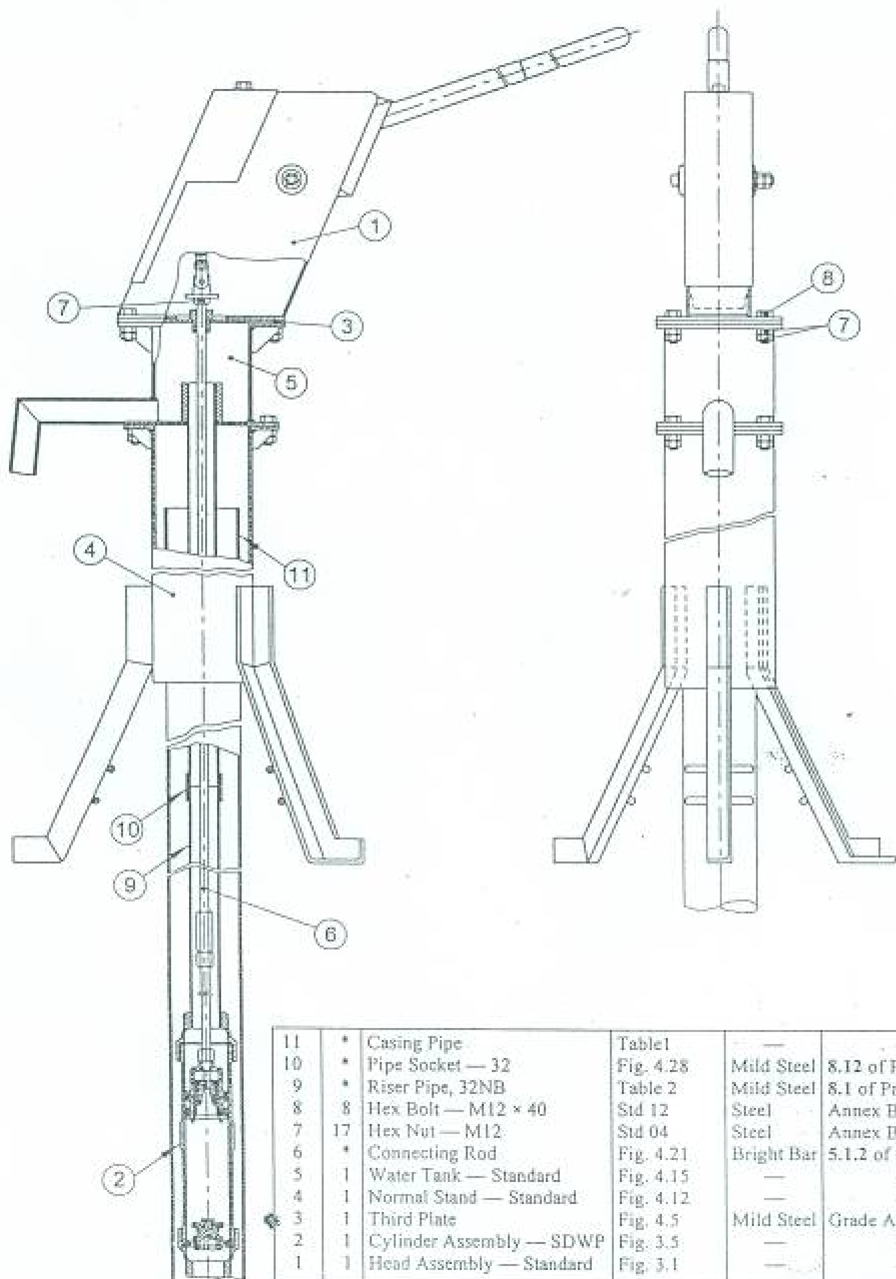
Time	Drawdown(m)	Yield(l/m)	Recovery(m)
0:00			
0:01			
0:02			
0:03			
0:04			
0:05			
0:06			
0:07			
0:08			
0:09			
0:10			
0:15			
0:20			
0:25			
0:30			
0:35			
0:40			
0:45			
0:50			
0:55			
1:00			
1:10			
1:20			
1:30			
1:40			
1:50			
2:00			
2:15			
2:30			
2:45			
3:00			
3:15			
3:30			
3:45			
4:00			

BOREHOLE COMPLETION CERTIFICATE BE SIGNED BY:

FOR THE CONTRACTORS	FOR THE EMPLOYER	LOCAL
Company name:	Organization name:	Authorities:
Signatory:	Signatory:	Signatory:
Date:	Date	Date:
Signature:	Signature:	Signature

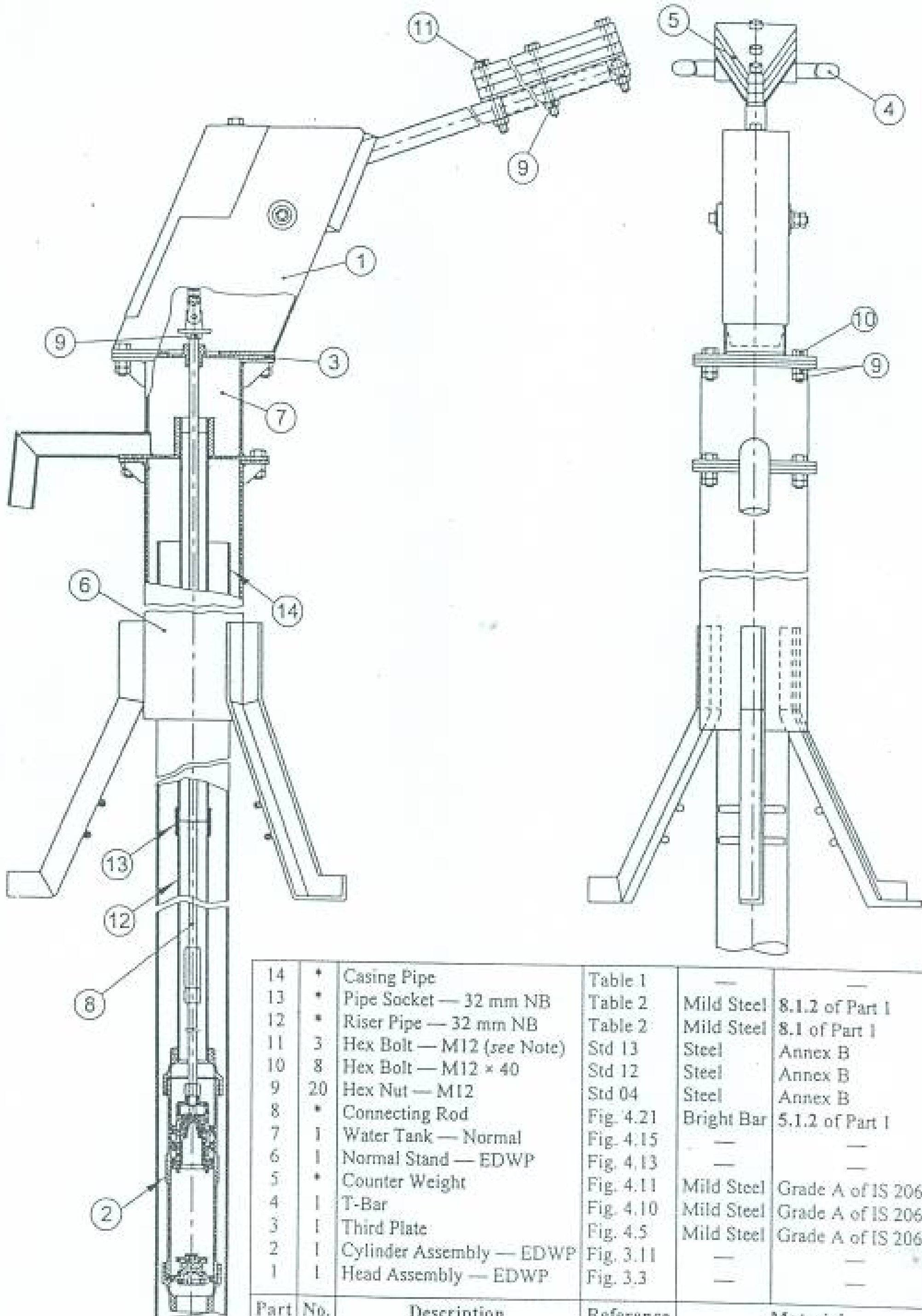
Annex 3: Detail diagrams of India Mark II Hand Pumps

IS 15500 (Part 2) : 2004



Part No.	No. Off	Description	Reference	Material	
11	*	Casing Pipe	Table1	—	—
10	*	Pipe Socket — 32	Fig. 4.28	Mild Steel	8.12 of Part 1
9	*	Riser Pipe, 32NB	Table 2	Mild Steel	8.1 of Part 1
8	8	Hex Bolt — M12 × 40	Std 12	Steel	Annex B
7	17	Hex Nut — M12	Std 04	Steel	Annex B
6	*	Connecting Rod	Fig. 4.21	Bright Bar	5.1.2 of Part 1
5	1	Water Tank — Standard	Fig. 4.15	—	—
4	1	Normal Stand — Standard	Fig. 4.12	—	—
3	1	Third Plate	Fig. 4.5	Mild Steel	Grade A of IS 2062
2	1	Cylinder Assembly — SDWP	Fig. 3.5	—	—
1	1	Head Assembly — Standard	Fig. 3.1	—	—

14

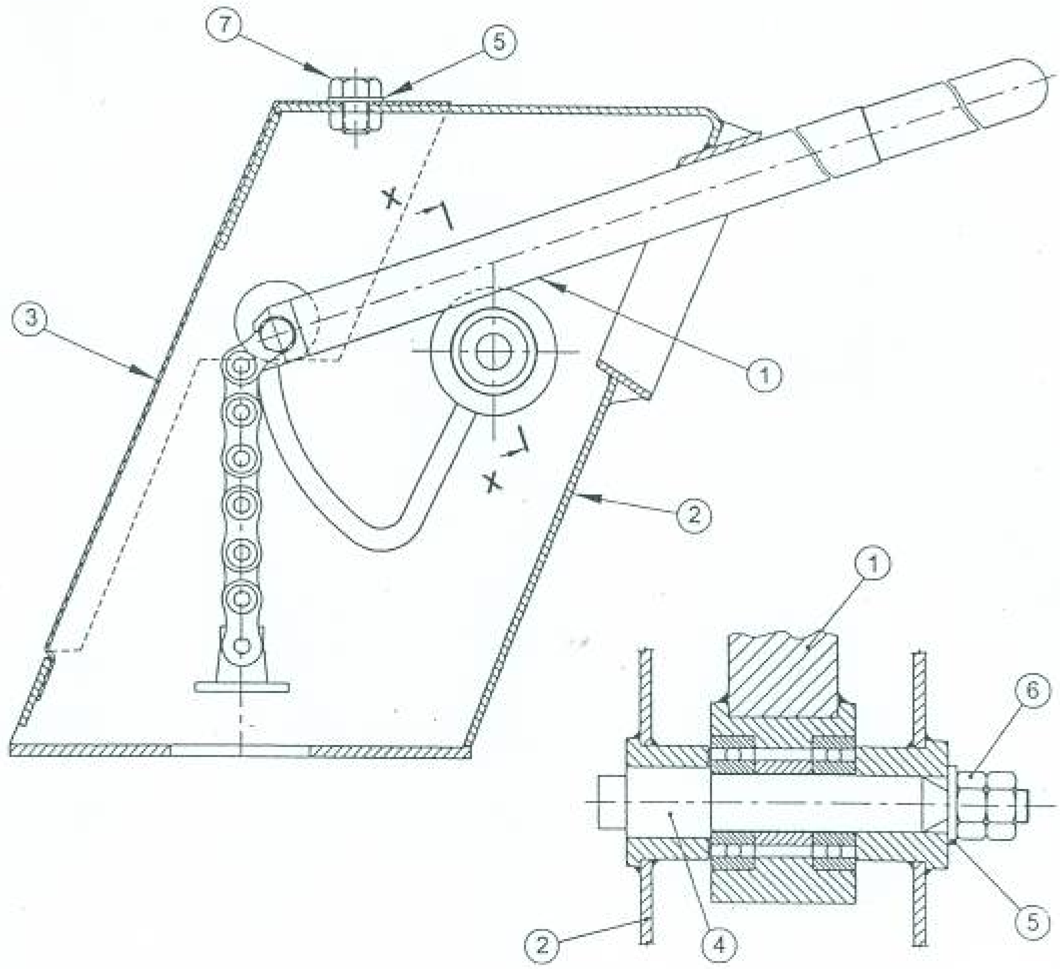


Part No.	No. Off	Description	Reference	Material	
14	*	Casing Pipe	Table 1	—	—
13	*	Pipe Socket — 32 mm NB	Table 2	Mild Steel	8.1.2 of Part 1
12	*	Riser Pipe — 32 mm NB	Table 2	Mild Steel	8.1 of Part 1
11	3	Hex Bolt — M12 (*see* Note)	Std 13	Steel	Annex B
10	8	Hex Bolt — M12 × 40	Std 12	Steel	Annex B
9	20	Hex Nut — M12	Std 04	Steel	Annex B
8	*	Connecting Rod	Fig. 4.21	Bright Bar	5.1.2 of Part 1
7	1	Water Tank — Normal	Fig. 4.15	—	—
6	1	Normal Stand — EDWP	Fig. 4.13	—	—
5	*	Counter Weight	Fig. 4.11	Mild Steel	Grade A of IS 2062
4	1	T-Bar	Fig. 4.10	Mild Steel	Grade A of IS 2062
3	1	Third Plate	Fig. 4.5	Mild Steel	Grade A of IS 2062
2	1	Cylinder Assembly — EDWP	Fig. 3.11	—	—
1	1	Head Assembly — EDWP	Fig. 3.3	—	—

* Depending on field conditions/pump settings.

NOTE — In case of item 11, the bolt length will depend upon the number of counter weight.

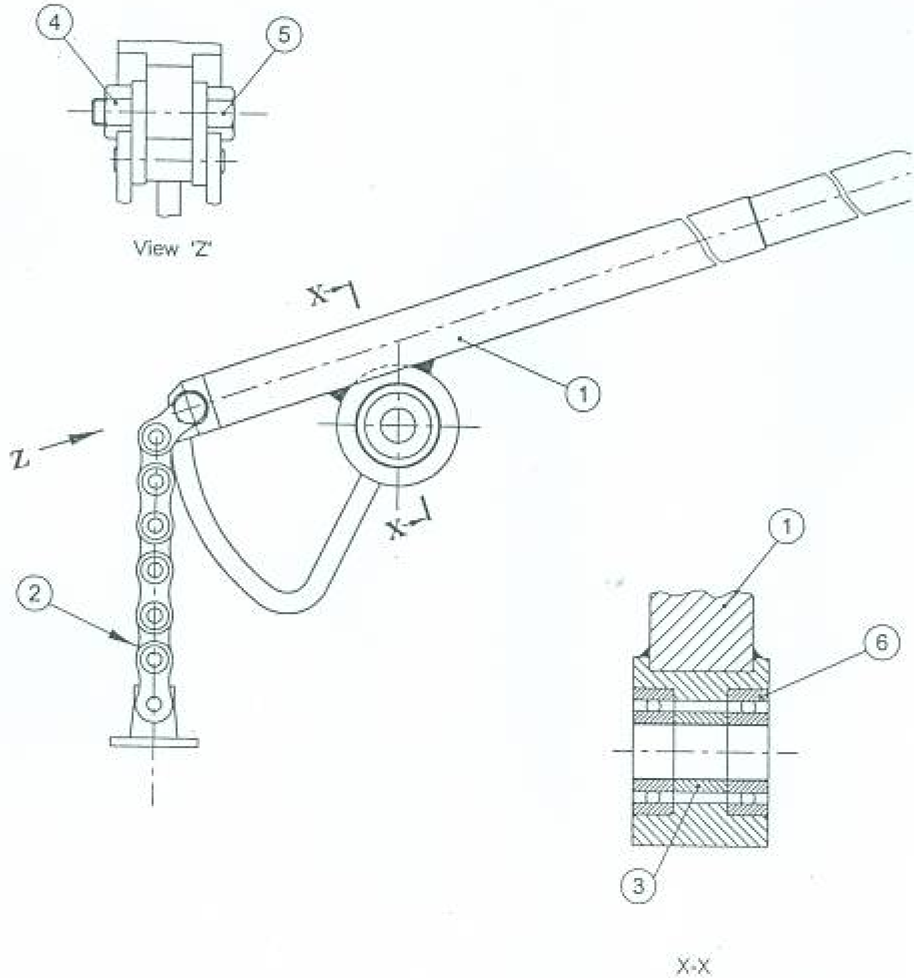
Figure 15 EPWELL HANDPUMP — EXTRA DEEP (EDWP)



X-X

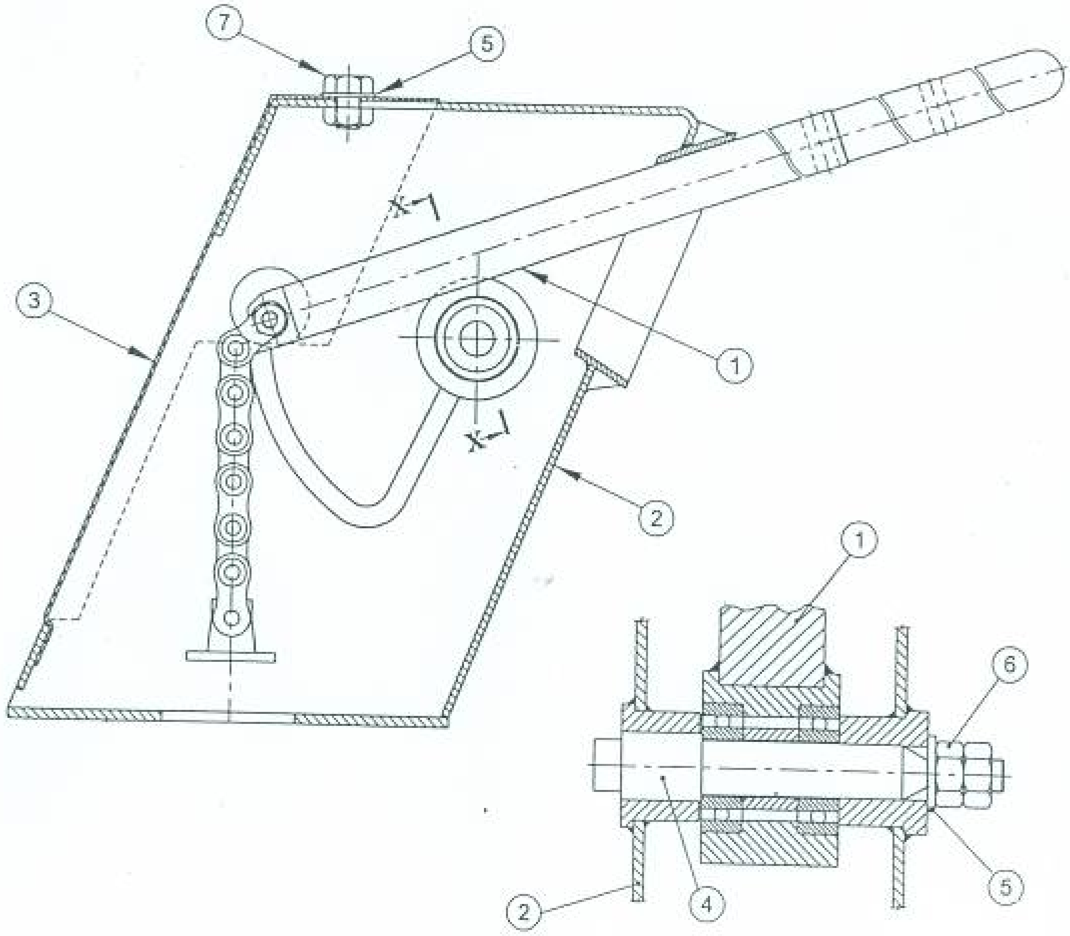
Part No.	No. Off	Description	Reference	Material	
7	1	Hexagonal Bolt — M12 × 20	Std 10	Steel	Annex B
6	1	Hexagonal Nut — M12	Std 04	Steel	Annex B
5	1	Washer	Fig. 4.27	Mild Steel	Grade A of IS 2062
4	1	Handle Axle	Fig. 4.24	Stainless Steel	5.2 of Part 1
3	1	Front Cover	Fig. 4.4	CRS Sheet	Ord. Grade of IS 513
2	1	Head — Standard	Fig. 4.1	—	—
1	1	Handle Assembly — Standard	Fig. 3.2	—	—

Figur 16 HEAD ASSEMBLY STANDARD
For ...,



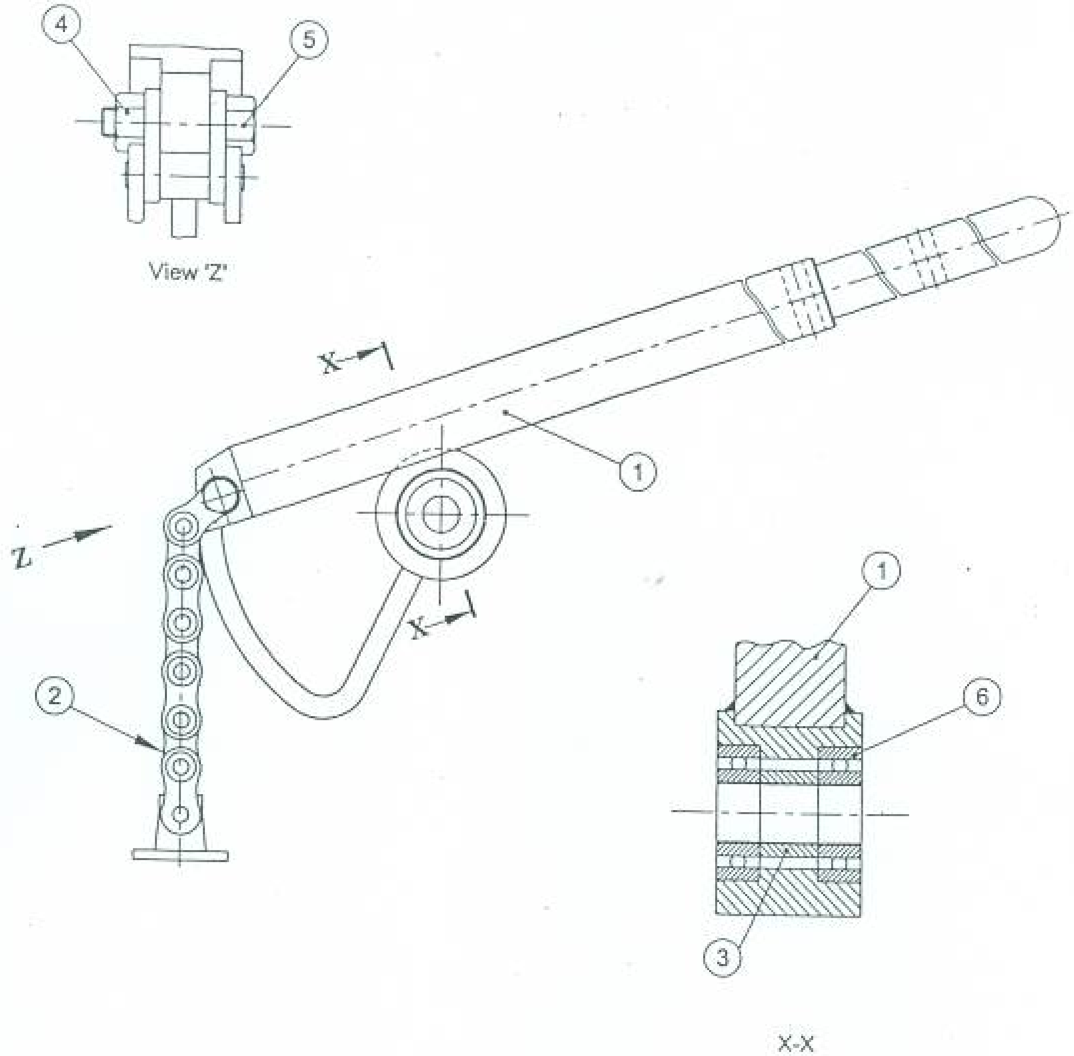
6	2	Bearing, Single Side Shielded	Std 15	Designation 20 BC 02 PP of IS 6455	
5	1	Hex. Bolt — M10 × 40 (Gr 8.8)	Std 09	HT Bold	Annex B
4	1	Prevailing Torque Type Hex. Nut, M10	Std 03	Steel	Annex B
3	1	Bearing Spacer	Fig. 4.26	Mild Steel	Grade A of IS 2062
2	1	Chain with Coupling	Fig. 4.9	—	—
1	1	Handle — Standard	Fig. 4.6	—	—
Part No.	No. Off	Description	Reference	Material	

Figure 17 ANDLE ASSEMBLY — STANDARD For SDWP



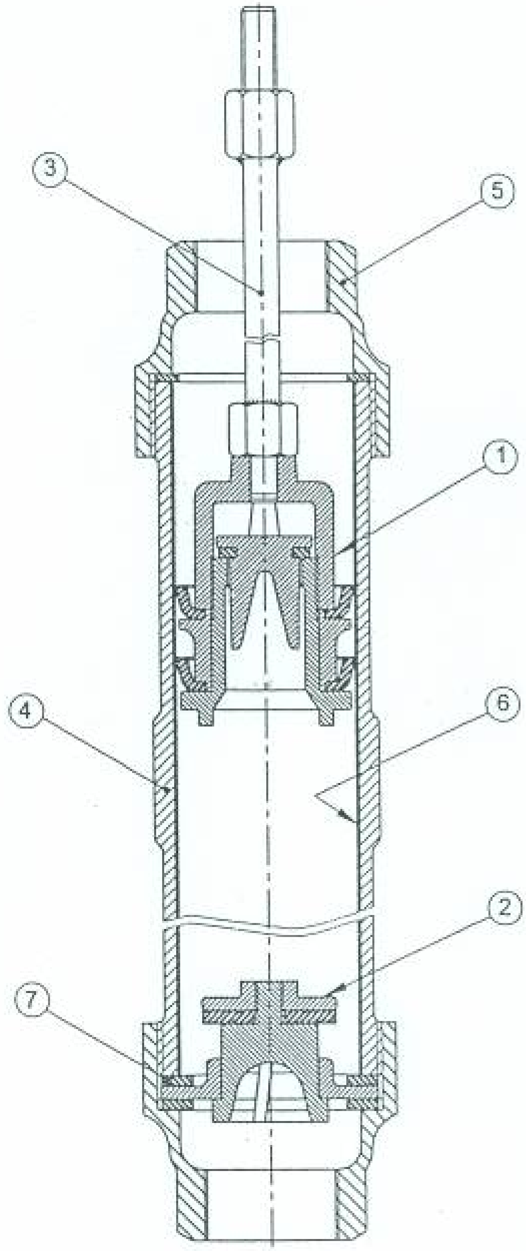
7	1	Hexagonal Bolt — M12 × 20	Std 10	Steel	Annex B
6	1	Hexagonal Nut — M12	Std 04	Steel	Annex B
5	1	Washer	Fig. 4.27	Mild Steel	Grade A of IS 2062
4	1	Handle Axle	Fig. 4.24	Stainless Steel	5.2 of Part 1
3	1	Front Cover	Fig. 4.4	CRS Sheet	Ord. Grade of IS 513
2	1	Head — EDWP	Fig. 4.2	—	—
1	1	Handle Assembly — EDWP	Fig. 3.4	—	—
Part No.	No. Off	Description	Reference	Material	

Figur 18 HEAD ASSEMBLY — EDWP



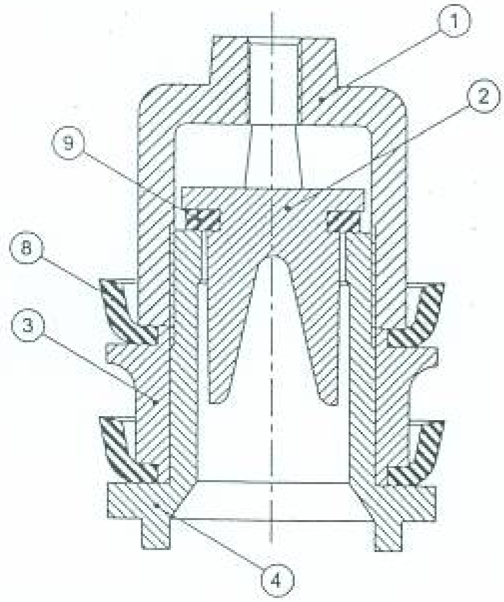
6	2	Bearing, Single Side Shielded	Std 15	Designation 20 BC 02 PP of IS 6455	
5	1	Hex. Bolt — M10 × 40 (8.8)	Std 09	HT Bolt	Annex B
4	1	Prevailing Torque Type Hex. Nut, M10	Std 03	Steel	Annex B
3	1	Bearing Spacer	Fig. 4.26	Mild Steel	Grade A of IS 2062
2	1	Chain with Coupling	Fig. 4.9	—	—
1	1	Handle — EDWP	Fig. 4.7	—	—
Part No.	No. Off	Description	Reference	Material	

Figt 19 : HANDLE ASSEMBLY — EDWP

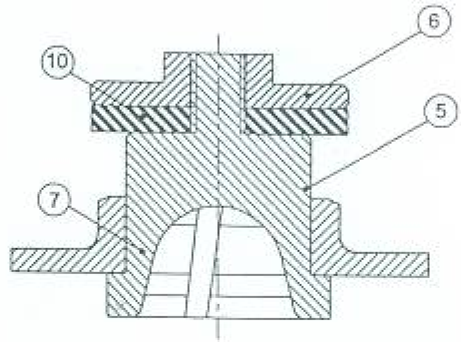


Part No.	No. Off	Description	Reference	Material	
7	3	Sealing Ring — Standard	Fig. 7.3	Nitrile Rubber	5.6 of Part 1
6	1	Brass Line — Standard	Fig. 6.1A	Brass Tube	CuZn30 As of IS 407
5	2	Reducer Cap	Fig. 5.4	Cast Iron	FG 200 of IS 210
4	1	Cylinder Body — Standard	Fig. 5.1	Cast Iron	FG 200 of IS 210
3	1	Plunger Rod — Standard	Fig. 4.22	Stainless Steel	04Cr18Ni10 of IS 6603
2	1	Check Valve Assembly — Standard	Fig. 3.6B	—	—
1	1	Plunger Valve Assembly — Standard	Fig. 3.6A	—	—

Figu 20 Cylinder Assembly — SDWP



3.6A Plunger Valve Assembly — SWDP

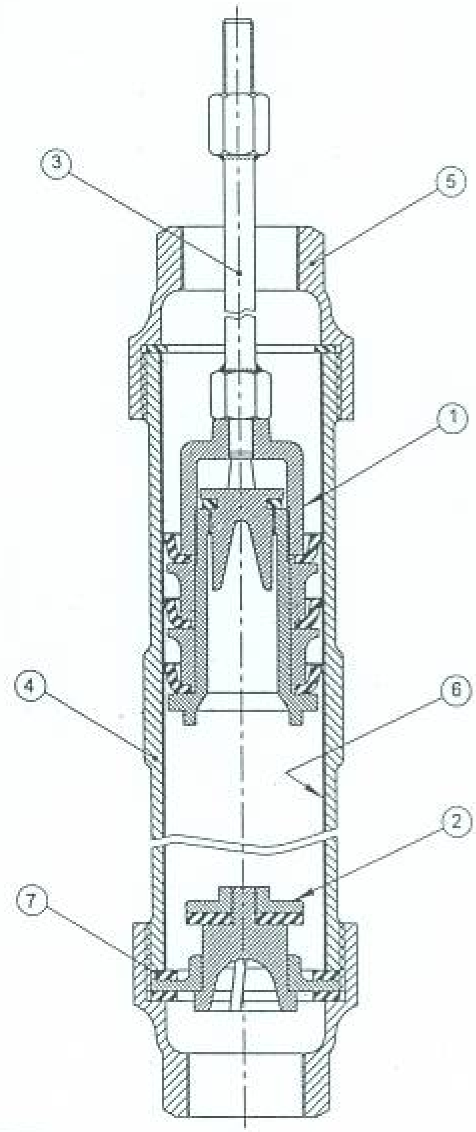


3.6B Check Valve Assembly — SDWP

Part No.	No. Off	Description	Reference	Material	
10	1	Check Valve Seating — Standard	Fig. 7.7	Nitrile Rubber	5.6 of Part 1
9	1	Upper Valve Seating	Fig. 7.6	Nitrile Rubber	5.6 of Part 1
8	2	Pump Bucket — Standard	Fig. 7.1	Nitrile Rubber	5.6 of Part 1
7	1	Check Valve Seat — Standard	Fig. 6.12	Bronze	Grade LTB2 of IS 318
6	1	Rubber Seat Retainer	Fig. 6.11	Bronze	Grade LTB2 of IS 318
5	1	Check Valve — Standard	Fig. 6.9	Bronze	Grade LTB2 of IS 318
4	1	Follower — SDWP	Fig. 6.6	Bronze	Grade LTB2 of IS 318
3	1	Bucket Spacer — Standard	Fig. 6.4	Bronze	Grade LTB2 of IS 318
2	1	Upper Valve	Fig. 6.3	Bronze	Grade LTB2 of IS 318
1	1	Plunger Yoke Body	Fig. 6.2	Bronze	Grade LTB2 of IS 318

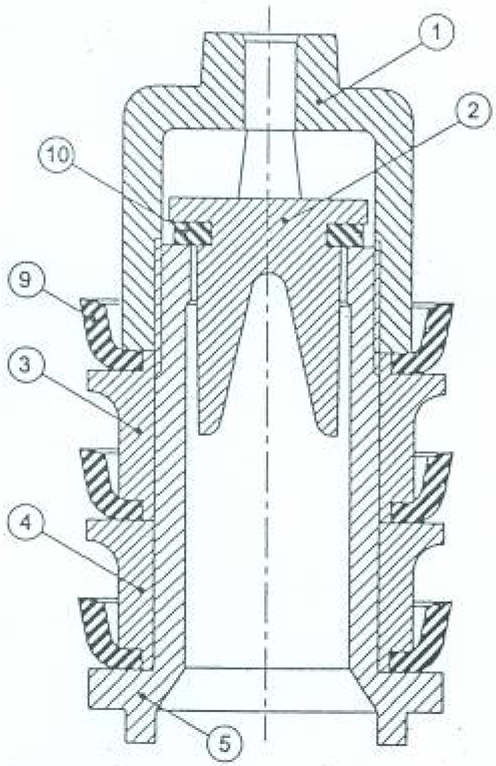
NOTE — Check valve assembly to be punch locked on top at M10 joint at diametrically opposite two points after filing the two surfaces even.

Figu 21 VALVE ASSEMBLIES — SDWP

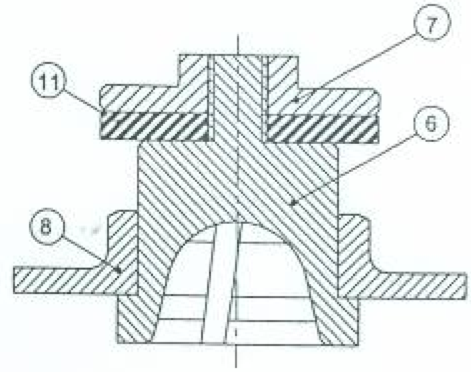


Part No.	No. Off	Description	Reference	Material	
7	3	Sealing Ring — Standard	Fig. 7.3	Nitrile Rubber	5.6 of Part 1
6	1	Brass Liner — Long	Fig. 6.1B	Brass Tube	CuZn30 As of IS 407
5	2	Reducer Cap	Fig. 5.4	Cast Iron	FG 200 of IS 210
4	1	Cylinder Body — Long	Fig. 5.2	Cast Iron	FG 200 of IS 210
3	1	Plunger Rod — Long	Fig. 4.23	Stainless Steel	04Cr18Ni10 of IS 6603
2	1	Check Valve Assembly — EDWP	Fig. 3.12B	—	—
1	1	Plunger Valve Assembly — EDWP	Fig. 3.12A	—	—

Fig 22 CYLINDER ASSEMBLY — EDWP



3.12A Plunger Valve Assembly — EDWP

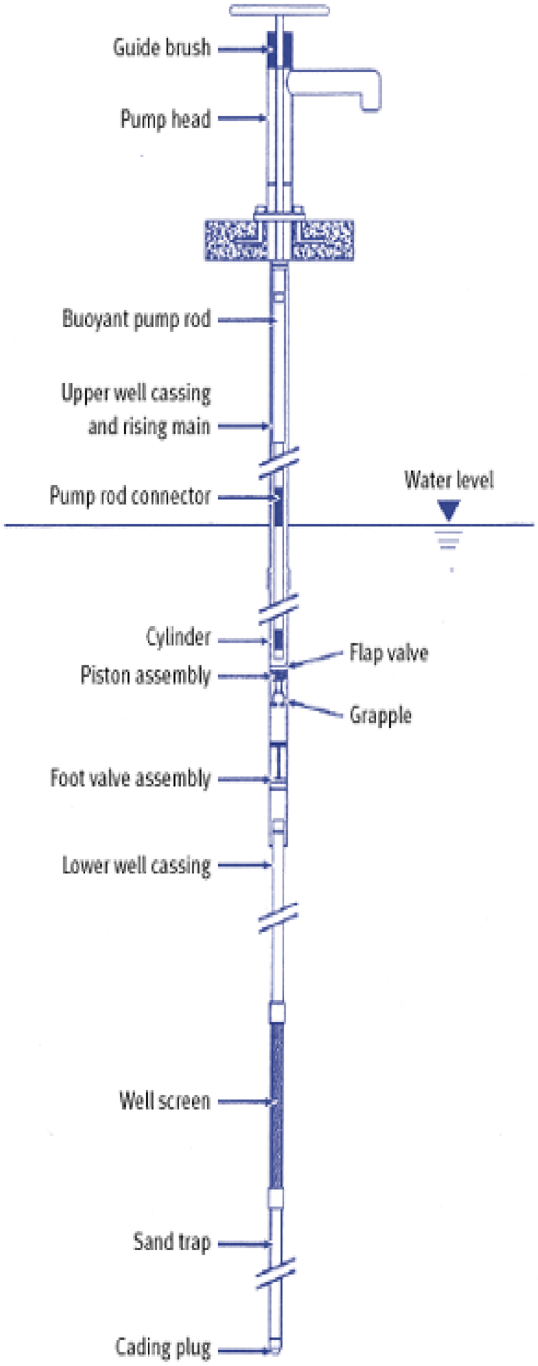


3.12B Check Valve Assembly — EDWP

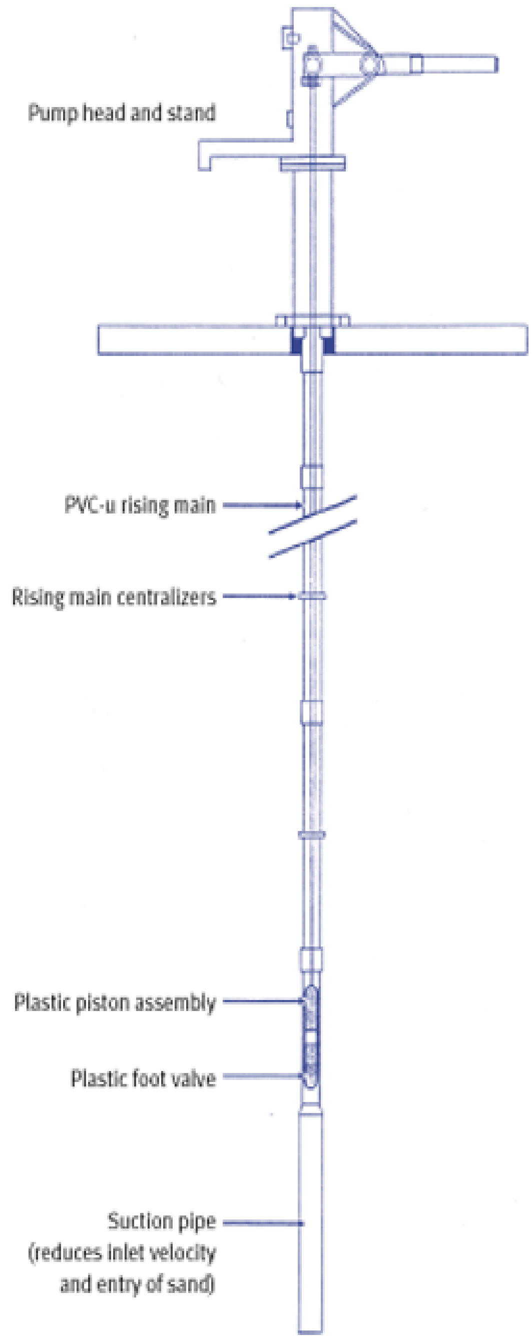
Part No.	No. Off	Description	Reference	Material	
11	1	Lower Valve Seating — Standard	Fig. 7.7	Nitrile Rubber	5.6 of Part 1
10	1	Upper Valve Seating	Fig. 7.6	Nitrile Rubber	5.6 of Part 1
9	3	Pump Bucket — Standard	Fig. 7.1	Nitrile Rubber	5.6 of Part 1
8	1	Check Valve Seat — Standard	Fig. 6.13	Bronze	Grade LTB2 of IS 318
7	1	Rubber Seat Retainer	Fig. 6.11	Bronze	Grade LTB2 of IS 318
6	1	Check Valve — Standard	Fig. 6.9	Bronze	Grade LTB2 of IS 318
5	1	Follower — EDWP	Fig. 6.7	Bronze	Grade LTB2 of IS 318
4	1	Bucket Spacer — Lower	Fig. 6.5	Bronze	Grade LTB2 of IS 318
3	1	Bucket Spacer — Standard	Fig. 6.4	Bronze	Grade LTB2 of IS 318
2	1	Upper Valve	Fig. 6.3	Bronze	Grade LTB2 of IS 318
1	1	Plunger Yoke Body	Fig. 6.2	Bronze	Grade LTB2 of IS 318

NOTE — Lower valve assembly to be punch locked on top at M10 joint at diametrically opposite two points after filing the two surfaces even.

Figure 23 'ALVE ASSEMBLIES — EDWP



24. Direct Action Pump



25. Afridev Hand Pump

Annex 4: Technical Specifications for Hand Pumps

Technical Specifications for India Mark II Standard and Extra Deep Well Hand Pumps conforming to Indian Standard (IS) 15500, 2004 are outlined below. Every India Mark II hand pump imported into Sudan must have an Inspection Seal. It is important to ensure this when purchasing this type of hand pump.

Dimensions and tolerances

- The material, dimensions and tolerances for different components/assemblies must comply with the specifications provided in respective figures given in Parts 2 to 8 of IS 15500, 2004.
- Unless otherwise specified, the tolerance on the un-machined dimensions relating to the following items used in the pump production, should be governed by their respective Indian Standards:
  Hot/cold rolled carbon steel plates, sheets, flat and bars.
  Steel sections
  Brass tube, and
  Cast iron/bronze castings
- For all other linear and angular dimensions where tolerances are not specified, the tolerance as per Class C (coarse) of IS 2102 (Part 1) should be followed for the manufacturing of the components.
- The tolerance of metric thread should conform to IS 14962 (Part 3), Class 6g for bolts and 6H for nuts.
- Standard parts like fasteners, ball bearings, etc used in the hand pump assembly and sub-assemblies should match specifications in Annex B of IS 15500
- All bolts, nuts and washers except high tensile bolts should be electro-galvanized to conform to IS 1367 (Part 11)

Raw materials

- All raw materials for use in the manufacturing of the pump parts like steel, stainless steel, cast iron, brass, rubber should conform to specifications in point 5 of IS 15500 (Part 1).

Anti-corrosive treatment

- Connecting rod (mild steel), bearing spacer, and washer should be electro-galvanized and passivated conforming to service condition No 4 of IS 1573.
- The stand, water tank, head, cover, handle, third plate, T-bar (for extra deep well), counter weight (for extra deep well), and socket for riser pipe should be hot dip galvanized according to IS 4759.
- Galvanized assemblies should be chromate conversion coated according to point 5.9 of IS 2629.
- Exterior surfaces of cast iron components should treated with
  -One coat of red oxide primer, conforming to IS 2074.
  -Two coats of synthetic enamel paint conforming to IS 2932
- Chain coupling should be coated with epoxy primer and paint.
- Chain assembly should be boiled in graphite grease for better anti-corrosion

Workmanship

- All components should be free from rough edges, burrs and other surface defects. Sharp machined edges should be filed smooth.
- Casting should not be repaired or welded and should conform to Grade PG 200 or higher grade of IS 210.
- Welding of mild steel components should be done in accordance with IS 9595.
- Welding for stainless steel components should conform to IS 2811.
- All welding should be free from blow holes, pin holes, cracks, etc.
- All other workmanship must be carried out in accordance with point 7 of IS 15500 (Part 1)

Riser pipes

- Riser pipes shall be hot dipped galvanized, screwed and socketed conforming to IS 1239 (Part 1) medium class with special emphasis on the instructions in point 6.4. Pipe ends should have a smooth finish and should be free of burrs or sharp machining chip. The internal surface of pipes should not have any lump of zinc. One end of each riser pipe should be fitted with a hot dipped galvanized socket and the other end with a thread protector. The nominal bore and length of each pipe for both Standard and Extra Deep Well Hand pumps should be 32mm and 3000mm. respectively.
- The socket for the riser pipe should be manufactured from a seamless pipe according to IS 1239 (Part 2), or machined from a solid bar conforming to Grade A of IS 2062 and should be hot dipped galvanized. The dimensions of the socket should conform to Fig 4.28 of IS 15500. Sockets should be tightly screwed into the rising main thread to avoid disconnection during transportation.
- Poly-tetra-flouro-ethylene (PTFE) tape or similar shall be used on the riser pipe joints before installation.

Testing

- The procedure given in IS 2500 (Part 1) should be followed for sampling inspection.
- The single sampling plan with general inspection level1 and AQL of one percent as given in Table I and II-A of IS 2500 (Part 1) should be followed for the characteristics given in testing clause 9 of IS 15500 (Part 1) of all the parts.
- Stroke length and discharge of pumps should be as follows:
    - For Standard Deep Well, stroke length :125±4mm and minimum discharge: 15 liters per minute or 40 strokes.
    - For Extra Deep Well, stroke length: 100±4mm and minimum discharge:12 liters per minute or 40 strokes.

Criteria for Conformity

- A lot shall be considered conforming to the requirements of the standard, if the batch selected according to 9.3 of IS 15500 (Part 1) satisfy the criteria for conformity given in the corresponding part (Part 2 to Part 7) of IS 15500 depending on the assembly, sub-assembly or component it is comprised of .

Guarantee

- All pumps and accessories should have a guarantee for 12 months from the date of installation or 18 months from the date of supply whichever is earlier against bad workmanship/material.

Marking

- The pump head assembly should have a name plate incorporating the name and address of the manufacturer, date of manufacturing and a serial number correlating it with the production records.
- A code/serial number should be punched on the raised portion of the cylinder body, correlating it with the production records.
- The connecting rod should have a steel punch impression indicating rhe manufacturer's identification mark, month and year of manufacture on the 50mm long hexagonal coupler.
- For Standard and Extra Deep Well Hand pumps, a number '32' shall be marked on the upper side of bottom flange of the water tank in minimum 10mm size ensuring that it is legible after galvanizing.
- All other markings should be done according to clause of 11 of IS 15500 (Part 1)

Packing

- The packing procedure in Annex C of IS 15500 should be followed.
- External threads of all the threaded components should be fitted with suitable thread protectors to avoid transit damage.
- The riser pipe should be packed as per instructions in IS 4740.
- In addition to the requirements given in 12.1 and 12.2 of IS 15500 (Part 1), the following conditions apply for the head assembly:
    - The handle should be locked in position with some suitable arrangement before packing the head assembly.
    - An extra hexagonal nut (Std 04 in Annex B of IS 15500) should be attached to the chain to lock the last connecting rod with the chain coupling.
    - The chain should be smeared with graphite grease and covered with a polyethylene bag prior to dispatch.

Annex 5: Standard tools required for installation and or maintenance and repair

The various kinds of tools required for maintenance and repair are categorized under standard tools for routine maintenance and special tools for major repair work. Village mechanics should always have a set of standard tools available.

The following table shows the list of items required under the standard tools category for both modified Deep Well and modified Extra Deep Well Hand Pumps.

Table 4: List of standard tools

No	Description of the standard tools	Unit	Quantity
1	Button Die to suit M12x1.75 threads	No	1
2	Die set for 32/40mm NB pipe	set	1
3	600mm pipe wrench (stilson type)	No	2
4	450mm pipe wrench (stilson type)	No	1
5	M 17 x M19 double ended spanners (10mm x 12mm)	No	2
6	Screw Driver 300mm long	No	1
7	1 kg (approx) ball pein hammer with handle	No	1
8	Hacksaw frame with spare blade 300mm	No	1
9	Pressure type oil can with oil	No	1
10	Wire brush	No	1
11	250mm half round file with handle	No	1
12	250mm flat file with handle	No	1
13	Lithium base/multipurpose grease	Kg	1
14	Graphite grease	Kg	1
15	0-9 number punch (6mm)	set	1
16	Nylon rope (3mm thick)	M	75
17	Adjustable spanner	No	1
18	Pipe stands	set	1

The following items, as listed down in Table 5, are required as part of special tools.

Table 5: List of items of special tool kit

No	Description of the special tools	Unit	Quantity
1	Self locking clamp	No	1
2	Water tank (or Tank pipe) lifter	No	1
3	Rod coupler (or Coupling) spanner	No	2
4	Axle (or Handle axle) punch	No	1
5	Connecting rod lifter	No	1
6	Crank spanner	No	2
7	Pipe lifting (or Lifting) spanner	No	3
8	Connecting (or Connections) rod vice	No	1
9	Chain coupling (or coupler) supporting tool	No	1
10	Bearing pressing tool	No	1
11	Tool box	No	1

- Self-locking clamp is required for clamping of the riser pipe. It grips the pipe as soon as the handle is released.
- Water tank lifter handles the water tank during assembly and dismantling of the pump.
- Rod coupler spanner is required for easy fitting of the connecting rods.
- Axle punch helps in driving the handle axle out of the head assembly.
- Connecting rod lifter facilitates in lowering or lifting of the connecting rods.
- Crank spanner is required for fastening of M12 and M10 bolts and nuts specially the chain bolt.
- Pipe lifting spanner helps in lifting or lowering riser pipes.
- Connecting rod vice is required to clamp the connecting rod.
- Chain coupling supporting tool facilitates the disconnection of the chain from the handle.
- Bearing pressing tool is required for pressing the bearings in the bearing housing,
- Tool box to keep all above tools except water tank lifter, pipe lifting spanner and self-locking clamp

Annex 6: Recommended spare parts for a hand pump

The following spare parts are recommended for two years as per the current Indian Mark II Technical Standard (IS 15500) Technical Specification.

Table 6: Recommended spare parts for two years

No	Description of the spare part	Unit	Quantity
	Spares for pump head		
1	Hexagonal bolts M12 x 20mm long	No	8
2	Hexagonal nuts M12	No	18
3	Washers M12	No	10
4	Hexagonal bolt M10 x 40	No	1
5	Prevailing Torque Type Hexagonal nuts M10	No	2
6	Handle axle (stainless steel)	No	1
7	Washer (4mm thick) for handle axle	No	1
8	Bearing single side shielded	No	2
9	Bearing Spacer	No	1
10	Chain with coupling	No	1
	Spare for cylinder		
1	Pump bucket (Nitrile rubber)	No	4
2	sealing ring (Nitrile rubber)	No	6
3	Check valve seating	No	2
4	Upper valve seating	No	2
	Spares for connecting rods and G.I. riser pipe		
1	Hexagonal coupling M12 x 1.75 x 50mm	No	2
2	Pipe sockets (32mm NB medium grade hot dip galvanized	No	4

Annex 7: The Development of these Technical Guidelines

The Technical Guidelines development process was completed in two stages: preparation and finalization.

A. The Preparation Stage

The preparation stage began in April 2006 with the agreement to select eight WASH facilities. At the request of the GONU, 3 additional water supply facilities were added, making the total eleven. The preparation stage that included information collection and analysis was completed in December 2006.

Collection of Information:

Technical and managerial information related to the development of the 14 Technical Guidelines was collected from the following sources:

- PWC/WES, SWCs and GWWD
- UNICEF, WHO, World bank and NGOs
- National institutions like SSMO
- International institutions like IRC and WEDC
- Donors like DFID.
- Different countries' standards like BS, IS, DIN, etc.
- Field trips to 14 states in the northern and southern states of Sudan to visit the different existing facilities and to have live discussion with the sector professionals and community members.

Analysis of collected information:

The Steering Committee, which comprised senior staff from PWC, WES and UNICEF together with the consultant analyzed the collected information, which led to the development of the outlines of the documents in a zero draft. The draft documents were shared with the Steering Committee at Khartoum level. The committee met to discuss the drafts, and provided comments, which were incorporated, resulting in the first draft. .

The first draft was widely circulated to PWC, UNICEF, various SWCs, INGOs and GoSS for information and feedback. All relevant feedback from the sector actors were incorporated into the documents and the second draft prepared and presented to the first national review workshop in December 2006. The relevant recommendations and comments of the national review workshop were incorporated into the documents resulting in a third draft.. The first National Review Workshop recommended that this draft of the Technical Guidelines be shared with a wider range of stakeholders, including specific technical working groups.

B. The Finalization Stage

The finalization of the 14 Technical Guidelines involved wider consultation with WASH sector partners through technical working group discussions, 3 regional review workshops, wider consultation and revision by GoSS and a national review workshop at the final stage.

Technical Working Group Discussions:
Professionals from various ministries participated in these technical working group discussions. MIWR, MOH, University of Khartoum, Sudan Academy of Science, private sector, NGOs, PWC/WES, UNICEF and Khartoum Water Corporation were also represented in these groups. This technical consultation process started in July 2007 and continued up to December 2007 resulting in the fourth draft of Technical Guidelines.

Regional Review Workshops:
Three Regional Review Workshops were conducted in Nyala, Wad Medani and Juba in November-December 2007 for GoSS and state level inputs into the documents. The Juba workshop recommended that the need for wider consultation within Southern Sudan to review the documents and to incorporate Southern Sudan specific contexts into the documents such as information relating to the location and different hydrogeological situations. These 3 workshops, resulted in the fifth draft.

Wider Consultation by GoSS:
Based on the recommendation of the Juba Review Workshop, a wider consultation process was started in July 2008 and completed in October 2008. The process included state level consultation with sector actors, technical working group discussions and a final consultation workshop in Juba. The process was concluded by the finalization and the approval of the final draft documents which were reviewed at a final National Workshop.

Final National Workshop:
The final National Workshop was conducted in April 2009 in Khartoum under the guidance and the presence of H.E. Eng. Kamal Ali Mohamed, Minister of Irrigation and Water Resources of GONU, Eng. Isaac Liabwel, Undersecretary, Ministry of Water Resources and Irrigation of GoSS, Eng. Mohammed Hassan Mahmud Amar, DG of PWC and Eng. Adam Ibrahim, Minister of Physical Planning and Public Utilities of South Darfur State.

The workshop was attended by ninety two participants representing MIWR, MWRI, MOH, PWC, WES, GWWD, Engineering Council, SWCs, SMoH, University of Khartoum, UNICEF, WHO, IOM, ICRC, NGOs, USAID and private sector.

The National Workshop reviewed the 14 WASH Technical Guidelines and approved them as the national WASH Technical Guidelines.

The workshop recommendations included:

- Publication and wide distribution of the Guidelines;
- Translation of the Guidelines into Arabic and other major Sudanese languages;
- Organization of training and advocacy courses/workshops related to the Guidelines;
- Adoption of supportive policies, strategies, laws and regulations to ensure best utilization of the Guidelines;

- Development of a system for feedback from implementing partners for inclusion in future updates of the Guidelines. MIWR/PWC, MWRI and SWCs were selected as focal points for that purpose.

Annex 8: People contacted

At Khartoum level

1. Mr Mohammed Hassan Mahmoud Amar, Director General, PWC
2. Mr Eisa Mohammed, National WES Coordinator, WES/PWC
3. Mr Mohammed Habib, National Project Coordinator, PWC
4. Mr Sampath Kumar, Chief WASH Section, UNICEF
5. Mr Vishwas Joshi, PO, UNICEF
6. Mr Zaid Jurji, PO, UNICEF
7. Mr Stanely Hall, SPO, UNICEF
8. Mr Fouad Yassa, PO, UNICEF
9. Mrs Awatif Khalil, APO, UNICEF
10. Mr Samuel Riak, PO, UNICEF
11. Mr. Mohammed El Hassan Eldori, Director of Department of Groundwater, MOIWR
12. Mr Mohammed Ahmed Bukab, Mechanical Engineering Department, PWC
13. Mr Mohammed Salih Mahmoud, Mechanical Consultant, PWC
14. Mr. Yassir Ismael, WES/PWC
15. Mr Al Amin Ahmed Ibrahim,PWC
16. Mr Mohy El Deen Kabeer, Groundwater and Wadis, MOIWR.

North Darfur, El Fashier

1. Osman Bukhari Ibrahim	SMOH	DG Envoronmental Health
2. Abdul Azim Ahmed	SWC	Mechanical Engineer
3. Abdella M. Adam	WES	Drilling Engineer
4. Mohammed Mohammedein	WES	Mechanical Engineer
5. Omer Abdurahman Adam	GWWD	Hydrogeologist
6.Nour Eldin Adam	WES	Surveying Engineer
7. Abdella Adam Ibrahim	WES	Geologist
8. Tayalla El Medomi	UNICEF	Water Engineer
9. Mohammed Mohammedein Subi	SWC	Acting DG & Manager of RW
10. Salma Hassan	WES	Social Mobilzer
11. Ahmed Abu Elgasim	WES	Acting GM
12. Hassan Sheik Nur	Oxfam GB	Public Health Engineering Coord.
13. Jaka Magoma	IRC	Environmental Health Manager

North Kordofan, El Obeid

1. Hassan Adam Suleiman	ACU WES	Monitoring Officer
2. Ahmed El Abeid	RWD	Surface Water Section
3.Alehmin Ahmed	WES	Mechanical Engineer
4. Saeed Elmahdi	WES	Programme Manager
5. Asia Mahmoud Mohmed	ACU WES	W Coord. Kordofan Section
6. Yassin Abbas	NWC, NK	RWC Manager
7. Mahgoup Dahia	WES, NK	Mini Water Yard Officer
8. Abeer Ali Elnour	WES, NK	Civil Engineer

9. Mutasim Hamad	WES, NK	Monitoring Officer
10. Makin Mohammed Toto	WES, NK	Drilling Engineer
11. Salah Mohammed	GWWD	Director General

South Kordofan

1. Adil Awad Farog	SWC	Geologist
2. Jakob Jebbrel	SWC	Engineer
3. Haidar Ariah Abdel Bari	SWC	Geologist
4. Mohammed Morgan Yhya	SWC	WES PA
5. Gamaa Aziz	UNICEF	APO
6. Fatima Toto	SWC	Urban Water Management
7. Sunaya Zroog	SWC	Urban Water Management
8. Mymona Taha	SWC	Urban Water Management
9. Adam Mohammed Ibrahim	SWC	Urban Water Management
10. Ali Gabaur Ahmad	SWC	Urban Water Management
11. Elzaki Eisa	WES	Drilling Engineer
12. Kamal Bashir	SC/USA	Watsan
13. Osman Elnour	SWC	DG
14. Dr Abdel Rahim Ahmed	UNICEF	APO
15. Hassaballa Hamad	SWC	Rural Water Management
16. Absaida	SWC	Mechanic
17. Awatif Elhag	WFP	Field Monitor
18. Al Amin Shawish	Sudan Aid	Coordination Officer

People Contacted in Southern Sudan, July 2008

1. Juma Chisto, Operator of Kator Emergency Water Supply, Juba
2. Habib Dolas, Member of Watsan committee, Hai Jebel
3. Andew Wan Stephen, Member of Watsan committee, Hai Jebel
4. Francis Yokwe, Member of Watsan committee, Hai Jebel
5. William Ali Jakob, Member of Watsan committee, Hai Jebel
6. William Nadow Simon, Member of Watsan committee, Hai Jebel
7. Ali Sama, Director General, Rural Water Department, Central Equatoria State (CES)
8. Engineer Samuel Toban Longa, Deputy Area Manager, UWC, CES
9. Sabil Sabrino, Director General UWC, WBeG
10. James Morter, Technician, UWC, Wau
11. Carmen Garrigos, RPO, Unicef Wau
12. Sevit Veterino, Director General, RWC, WBeG
13. Stephen Alek, Director General, Ministry of Physical Infrastructure (MPI), Warap
14. John Marie, Director of Finance, MPI, Warap State
15. Angelo Okol, Deputy Director of O&M, Warap State
16. Santino Ohak Yomon, Director, RWSS, Upper Nile State
17. Abdulkadir Musse, RPO, Unicef Malakal
18. Dok Jok Dok, Governor, Upper Nile State

19. Yoanes Agawis, Acting Minister, MPI, Upper Nile State
20. Bruce Pagedud, Watsan Manager, Solidarites, Malakal
21. Garang William Woul, SRCS, Malakal
22. Peter Onak, WVI, Malakal
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33. Emmanuel Parmenas, DG of O&M, MCRD GOSS
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Annex 9. Technical Working Group Members

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2) For Borehole Hand pumps, Hand dug well Hand pumps, Hand dug well Water yards, Mini Water yards and Water yards

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Mr. James Adam, MWRI

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Annex 11: Unit conversion tables

Length

	m	ft	in
1 m	1	3.281	39.37
1 ft	0.3048	1	12
1 in	0.0254	0.0833	1

Area

	m^2	ft^2
1 m^2	1	10.76
1 ft^2	9.29×10^{-2}	1

Volume

	m^3	litre	ft^3
1 m^3	1	1.0×10^{3}	35.32
1 litre	1.0×10^{-3}	1	3.532×10^{-2}
1 ft^3	2.832×10^{-2}	28.32	1

Discharge

	l/s	m^3/s	m^3/d	ft^3/s
1 l/s	1	1.0×10^{-3}	86.40	3.531×10^{-2}
1 m^3/s	1.0×10^{3}	1	8.640×10^{4}	35.313
1 m^3/d	1.157×10^{-2}	1.157×10^{-5}	1	4.087×10^{-4}
1 ft^3/s	28.32	2.832×10^{-2}	2.447×10^{3}	1

Velocity

	m/s	ft/s
1 m/s	1	3.281
1 ft/s	0.3048	1

Mass

	kg	lb	t
1 kg	1	2.205	1×10^{-3}
1 lb	0.454	1	4.536×10^{-4}
1 metric ton (t)	1000	2205	1

Density

	g/m^3	kg/m^3	lb/in^3	lb/ft^3
1 g/cm^3	1	1000	0.0361	62.43
1 kg/m^3	1×10^{-3}	1	3.61×10^{-5}	0.0624

1 lb/in^3	27.68	27.68 x 10^3	1	1728
1 lb/ft^3	0.016	16.02	5.787 x 10^{-4}	1

Pressure

	kgf/cm^2	bar	kN/m^2	lbf/in^2 (psi)
1 kgf/cm^2	1	0.981	98.1	14.223
1 bar	1.02	1	100	14.504
1 kN/m^2	0.01	0.0098	1	0.145
1 lbf/in^2 (psi)	0.07	0.0689	6.89	1

1 Pa (pascal) = 1 N/m^2

1 N/mm^2 = 1 MN/m^2 = 1 MPa

101325 Pa = 1 standard atmosphere (atm) = 1.01325 bar

100 kPa = 1 bar

10.33 m head of water = 1 atm

2989 Pa = 1 ft head of water = 22.42 mm of mercury (mmHg)

1 mmHg = 0.0394 inch of mercury (inHg)

1 MPa = 145 lbf/in^2 (psi)

Force

	N	kgf	lbf	pdl
1 N	1	0.1019	0.2248	7.2330
1 kgf	9.8066	1	2.2046	70.9316
1 lbf	4.4482	0.4536	1	32.1740
1 poundal (pdl)	0.1382	0.0141	0.0311	1

1 N = 1 kg m/s^2

1 pdl = 1 lb ft/s^2

Power

	kW	CV	bhp
1 kilowatt (kW)	1	1.3596	1.3410
1 metric horsepower (CV)	0.7355	1	0.9863
1 brake horsepower (bhp)	0.7457	1.0139	1

The metric horsepower, Chavel Vapeur, is variously denoted as CV, ch and PS.

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