



Public Water Corporation

MIWR – GONU



MWRI - GOSS

Technical Guidelines For the Construction and Management of Drinking Water Distribution Networks



A Manual for Field Staff and Practitioners

April 2009

DEVELOPED IN PARTNERSHIP WITH



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Ministry of Irrigation and Water Resources – Government of National Unity

Foreword

Significant progress has been achieved in the provision of water and sanitation services in Sudan has 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. 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

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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

CPA	- Comprehensive Peace Agreement
DCI	- Ductile Cast Iron
DPA	- Darfur Peace Agreement
ESPA	- Eastern Sudan Peace Agreement
GLUMRB	- Great Lakes Upper Mississippi River Board of State Sanitary Engineers
GONU	- Government of National Unity
GOSS	- Government of Southern Sudan
GRP	- Glass Reinforced Plastic Pipes
HDPE	- High Density Polyethylene Pipes
KWC	- Khartoum Water Corporation
MCRD	- Ministry of Cooperatives and Rural Development,GOSS
MIWR	- Ministry of Irrigation and Water Resources,GONU
MWRI	- Ministry of Water Resources and Irrigation,GOSS
NTU	- Nephelometric Turbidity Unit
PWC	- Public Water Corporation
RC	- Reinforced Concrete
RCPP	- Reinforced Concrete Pressure Pipe
SSMO	- Sudanese Standards and Measurement Organization
StP	- Steel Pipe
SWC	- State Water Corporation
UNICEF	- United Nation Children's Fund
UPVC	- Unplasticised Polyvinyl Chloride (or Plastic Pipes)
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

- Distribution systems: Gravity, pumping or a combination of gravity and pumping systems
- Layout of distribution networks: Dead end or tree system, gridiron system, circular (ring) system, radial system
- Types of pipes for the distribution networks:
 - Rigid pipes e.g. reinforced concrete pressure pipes
 - Semi-rigid pipes e.g. ductile iron pipes (DCI), or steel pipes
 - Flexible pipes e.g. uPVC, HDPE, or GRP
- Minimum trench depth should be $15 + D + 30 + \geq 145$ cm for heavy and normal traffic and $15 + D + 30 + \geq 115$ cm for other cases, where D is the external diameter of the pipe in cm, 15cm is the bedding thickness, 30cm is the compacted overburden thickness and the remaining is the backfilled compacted thickness.
- Minimum depth of filling on the pipes should not be less than 0.8 m preferably one meter, to protect them from traffic loads and to prevent the effects of climatic changes on the water in the pipe, making it unpalatable.
- For a distribution network size of from 7.5 cm up to 25 cm, the minimum and maximum width of the trench should be 45 cm and 80 cm respectively.
- Distribution network systems are subject to unbalanced thrust forces resulting from static and dynamic fluid action on the pipe especially at the points of change the directions of flow such as elbows, tees, reducers, valves and dead ends. These forces must be balanced in order for the piping system to maintain its integrity.
- Reactive forces must be provided to counter the unbalanced thrust forces in the form of thrust blocks and/or transmitting forces to the pipe wall by restrained, harnessed, flanged or welded joints at these strategic weak points.

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 3.

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.

2. Methods of distribution

The method of drinking water distribution depends upon the topography of the area. Three methods or systems are outlined below:

- Gravity system

This is the most reliable and economical distribution system, where water flows entirely by gravity and is available at sufficient pressure at various points in the distribution network.

- Pumping system

This system is not desirable, as it relies on electricity and in case of a power failure, the entire distribution to the locality could be shut off. Water is pumped directly into the distribution system to achieve the required pressure. Double pumping is required, for raw water as well as for treated water, and the pumps have to be run at varying speeds according to the variations in the consumption. The system also requires constant attendance.

- Combined gravity and pumping system.

This is the most common system in use. Water is supplied by a combination of pumping and gravity system. Depending on the location of distribution area in relation to treatment plants, filtered water may be pumped to clear water reservoir or elevated on a tower.

Adequate pressure should be available in distribution mains at all points located even at the remotest spots for all types of distribution systems. The desired pressure depends upon different factors such as; the height to which water is required to be supplied, fire fighting requirements, whether the supply is metered or not, and availability of funds.

The Manual on Water Supply and Treatment prepared by the Ministry of Urban Development of the Government of India¹ gives the following recommendations for minimum residual pressure at ferrule points:

- Single story building 7m
- Two storey building 12m
- Three story building 17m

Distribution systems should not ordinarily be designed for residual pressures exceeding 22m. Multi-storeyed buildings needing higher pressure should be provided with boosters.

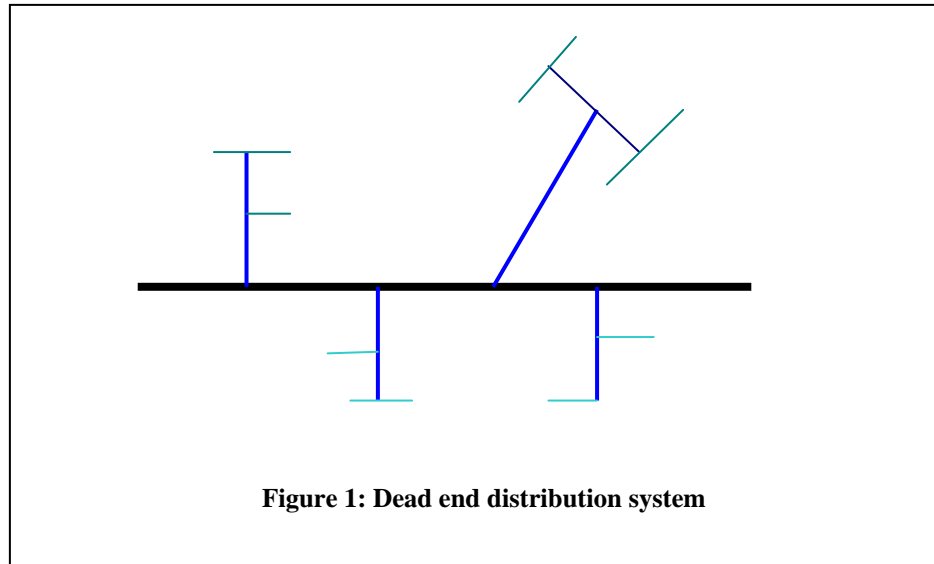
3. Layout of distribution networks

There are four principal methods of layout for distribution systems:

- Dead end or tree system
- Gridiron system
- Circular or ring system
- Radial system

a) **In the dead end system**, one main pipe line runs through the centre of the populated area and sub-mains takeoff from this to both sides (Figure 1). The sub-mains divide into several branch lines from which service connections are provided..

¹ Water Supply Engineering, B.C. Punmia, Ashok Jain, Arun Jain



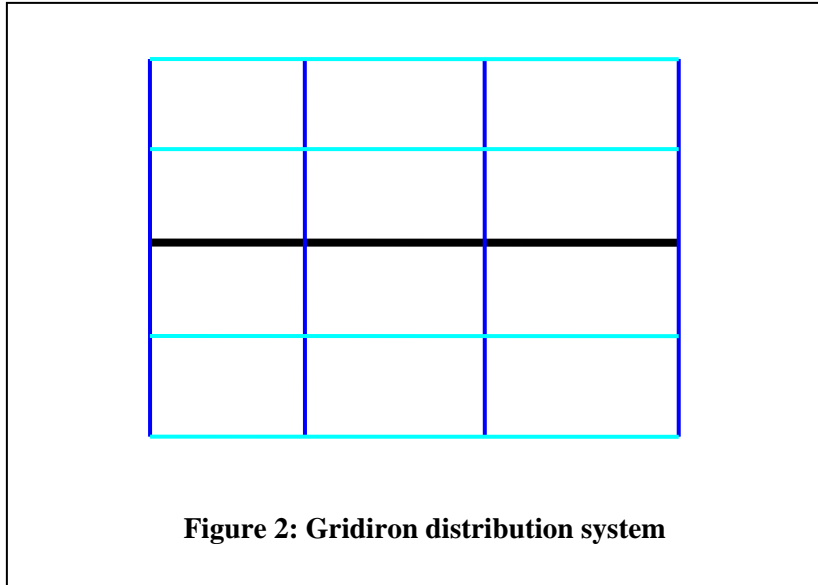
Advantages of the system:

- The design calculation is simple and easy.
- A smaller number of cut-off valves are required and the operation and maintenance cost is low.
- Pipe-laying is simple.

Disadvantages:

- The system is less successful in maintaining satisfactory pressure in the remote areas and is therefore not favoured in modern waterworks practice.
- One main pipeline provides the entire city, which is quite risky. Any defect, damage or breakage at one point of this line will disrupt the supply of water beyond that point, cutting off service to the whole area. This could be dangerous, especially if there is a fire.
- The head loss is relatively high, requiring larger pipe diameter, and/or larger capacities for pumping units.
- Dead ends at line terminals might affect the quality of water by allowing sedimentation and encouraging bacterial growth due to stagnation. Water hammer could also cause burst of lines. A large number of scour valves are required at the dead ends, which need to be opened periodically for the removal of stale water and sediment.
- The discharge available for fire fighting in the streets will be limited due to high head loss in areas with weak pressure.

b) **In Gridiron system** the main supply line runs through the center of the area and sub-mains takeoff from this in perpendicular directions (Figure 2). The branch lines interconnect the sub-mains. This system is ideal for cities laid out in a rectangular plan resembling a grid iron. The distinguishing feature of this system is that all of the pipes are interconnected and there are no dead ends. Water can reach a given point of withdrawal from several directions, which permits more flexible operation, particularly when repairs are required.



Advantages of the system:

- The free circulation of water, without any stagnation or sediment deposit, minimizes the chances of pollution due to stagnation.
- Water is available at every point, with minimum loss of head, because of the interconnections.
- Enough water is available at streets fire hydrants, as the hydrant will draw water from the various branches lines..
- During repairs, only a small area of distribution is affected.

Disadvantages:

- A large number of cut-off valves are required
- The system requires longer pipe lengths with larger diameters.
- The analysis of discharge, pressure and velocities in the pipes is difficult and cumbersome.
- The cost of pipe-laying is higher.

c) **In circular or ring system**, the supply main forms a ring around the distribution area. The branches are connected cross-wise to the mains and also to each other (Figure 3).



This system is most reliable for a town with well planned streets and roads. The advantages and disadvantages of this system are the same as those of the grid iron system. However, in case of fire, a larger quantity of water is available, and the length of the distribution main is much larger.

d) In a **radial system**, the whole area is divided into a number of distribution districts. Each district has a centrally located distribution reservoir (elevated) from where distribution pipes run radially towards the periphery of the distribution district (Figure 4). This system provides swift service, without much loss of head. The design calculations are much simpler.

4. Materials of pipes for distribution networks

In a water distribution network, pipes represent a large proportion of the capital invested by water authorities and the selection of the right type of pipe is of great importance.

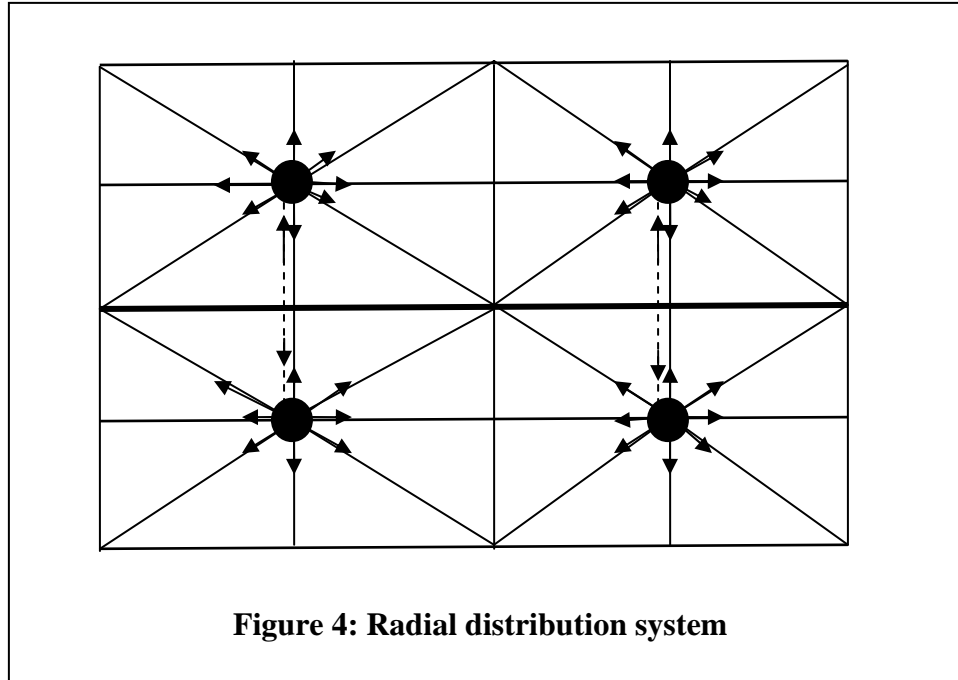


Figure 4: Radial distribution system

The choice of the most suitable pipe material for a distribution system is governed by many factors. It is difficult to find a material that will cover all requirements, but one should select a material that fulfils the majority of the required criteria, which are:

- Able to bear high internal pressures. The pipe materials may be subjected to various pressures from the pumping station during their lifetime, and they vary in the amount of pressure they can bear. The pressure which may exceed double the working pressure is necessary to overcome: a) static pressures resulting from difference of levels of the network, b) friction losses of the pipes, valves, special pieces, etc of the network, and also pressures resulting from changes of direction. c) additional pressure waves (surges) resulting from water hammer caused by sudden start or stopping of pumps, rapid opening and closing of valves.
- Able to resist aggressive soils, groundwater surrounding the pipe, and the liquid within, which necessitates the use of special measures or materials to ensure external and internal protection of pipes.
- Smooth inner surface to ensure maximum flow capacity of water. The ease with which water passes through the pipe is measured by a factor called the flow coefficient, the smoothness coefficient, or the roughness coefficient. The pipe is rated by this coefficient which is usually referred to as the “C” value. The higher the “C” value of the pipe, the smoother it is.
- Able to withstand shock as a result of transportation, storing and construction. This may cause hair cracks in some kinds of pipes. Often these are only detected upon testing after the pipe is erected, causing delays as the pipe has to be replaced.
- Able to bear external loads exerted on it due to the weight of soil above (backfill) plus any live load including the impact of heavy traffic and during construction. It should also be rigid enough to resist deformation due to these superimposed loads, especially when water pipes are laid at shallow depths.

- Pipes in the specified sizes and pressure ratings, should be locally available and be compatible with available fittings.
- Pipes should have relatively low installation costs including freight to job site, a longer lifetime, a long trial period (to allow the possibility of returning damaged or defective pieces),and should be easy to install. This will affect the overall cost and the construction time for the project.
- Pipes should be durable to provide the maximum degree of satisfactory and economical service under the conditions of use. It also implies long life, toughness, and the ability to maintain tight joints with little or no maintenance.
- Necessary connections, for example tees, elbows, couplings and other fittings.
- should be resistant to internal water pressure,

Pipe Types

Types of pipes used for distribution systems include: ductile cast iron pipes (DCI), steel pipes (StP), plastic pipes (UPVC), high density polyethylene pipes (HDPE), glass reinforced plastic pipes (GRP) and reinforced concrete pipes (RCRP).

The pipes fall broadly into three categories; rigid, semi-rigid, and flexible, and each has its advantages and disadvantages.

Rigid Pipes

Reinforced Concrete Pressure Pipes (RCPP), include steel cylinder, pre-stressed, and non-cylinder. (Pre-stressed concrete may be classified as rigid conduits that fail by rupture of the pipe walls from relatively small deflections of the pipe section)

Advantages:

- High strength supporting earth loads.
- Extremely smooth bore has excellent flow characteristics.
- Wide variety of sizes - from 300-3600 mm
- The steel cylinder of the pipe is the basis of its reliability, providing a continuous water tight membrane through out its length.
- The weight of the pipe limits risk of flotation before backfilling.

Disadvantages:

- Attacked by soft water, acids, sulfides, sulfates, and chloride.
- Requires protective lining and coating.
- Poor against water hammering.
- Needs special construction equipment due to its heavy weight.
- High transportation costs.
- Repair time can be long, serious, when it is used as a major feeder to a large area.

Semi-rigid pipe

Ductile iron and steel pipes may be classified as semi-rigid conduits and have the ability to deform under the effect of external loading. In consequence the pipe is better able to absorb the load from backfill. It has a greater resistance to shock loads from traffic and pressure surges than a rigid pipe

Ductile Cast Iron Pipe (DCI)

Advantages:

- It has the mechanical advantages of steel while retaining the cast iron advantages of resisting corrosion.
- Relatively high tensile strength, increasing its capability of bearing high pressures resulting from water hammer and external loads.
- Capable of bearing shocks and has a long lifetime.
- Simplicity of assembly of special pieces, fittings, joints, and valves.

Disadvantages and limitations:

- Relatively more expensive in comparison to other kinds of pipes.
- Relative long procurement and delivery time.
- Available only in sizes up to 1000 – 1350mm (54 inches) diameter.
- Difficult to weld.

Steel pipe (StP)

Advantages:

- Highest tensile strength of all kinds of pipes. Resistant to high pressures and shocks and has the ability to withstand sudden changes in pressure resulting from water hammer.
- Available in longer lengths than other pipes and, hence, fewer joints are required.
- Relative light weight with respect to cast iron pipes.
- Great strength and elasticity, which enables the pipe to be located in difficult ground conditions, where ground movement is likely and where there are significant traffic loading and pressure surges.
- Simplicity of assembling of special pieces and valves.
- Suitable for self-supporting spans.
- Fabricated special pipes and fittings can be incorporated into a pipeline when space is limited (inside pipe stations).
- Does not need costly bedding.
- Available in sizes up to 3600 mm.

Disadvantages:

- Very prone to corrosion, and soil aggressiveness, requiring extra external protection like epoxy coating.
- The presence of electrolytic corrosion or stray currents in urban areas necessitates special costly cathodic protection.

- Ovality occurs under heavy backfill loads. This can result in leakage from flexible joints and must be taken into account.
- Short lifetime.

Flexible pipes

UPVC (Unplasticised Polyvinyl Chloride). PE (Polyethylene) and GRP (Glass Reinforced Plastic) may be classified as flexible pipes, tending to have low inherent strength and deflecting under loads. They derive a large part of their load bearing strength from the ability to transfer top loads to the side fill, and it is therefore essential that the trench should be carefully prepared and the backfill well consolidated round the pipe.

UPVC

Advantages:

- Smoothness of internal surfaces, reducing friction losses.
- Not affected by the soil, so no need for external, internal or cathodic protection.
- Light weight with respect to other types, reducing costs of transportation and construction.
- Suitable in circumstances where ground movement and corrosive soils limit the use of pipes of other materials.
- Resistance to corrosion.
- Ease of installation.
- Rigid without being brittle.

Disadvantages:

- Needs special accuracy or assembling, requiring special precautions for bedding, and compaction of filling, which noticeably increases the cost of construction.
- Weak shock-bearing capacity, requiring certain precautions for transportation, storing and construction.
- Easily deformed under external loads.
- Tensile strength decreases with increasing temperatures.
- If UPVC is selected for a pumping main, its limitations in respect of pressure surges, must be taken into account.
- Affected by direct sunlight when left uncovered for long periods.
- Available in sizes up to 900 mm only.
- Higher unit costs for smaller diameters.

HDPE

Advantages:

- High resistance to corrosion, very durable.
- Light weight.
- Resistant to cracking.
- Smoother interior wall surface.

- Resistant to damage during seismic events.
- Can use ductile iron fittings.
- Suitable where ground movement is experienced and where flexibility is required.
- Good thermal insulation properties.

Disadvantages:

- Available in sizes up to 750mm only.
- Precautions required when using conventional mechanical fittings.

GRP

Advantages:

- Smoothness of internal surfaces, reducing friction losses, providing good flow characteristics.
- Corrosion resistance, so no need for external, internal or cathodic protection.
- Fiberglass piping systems have excellent strength to weight ratio, surpassing iron and stainless steel.
- Fiberglass pipes are non conductive in terms of electricity.
- Light in weight in comparison to other types, reducing costs of transportation and construction (1/6 the weight of similar steel pipes and 10% the weight of similar concrete pipes).
- Supplied in nominal diameters 200 through 4000mm.
- Resistance to biological attack.

Disadvantages:

- Needs special accuracy for design and construction, requiring special precautions for bedding, and compaction of filling, which noticeably increases cost of construction.
- Weak shock-bearing capacity, requiring certain precautions for transportation, storing and construction.
- Easily deformed under external loads, requiring careful selection of minimum pipe stiffness $< 10,000 \text{ N/m}^2$.
- Easily affected by sudden changes of pressures (water hammer), this limits its use for high pressure distribution systems (least tensile strength).
- Precaution against excavation around the pipe is essential after construction.

5. Steps in designing water distribution networks

- Conducting topographic surveys and preparation of maps.
- Preparation of tentative layout.
- Computation of discharges in pipelines.
- Calculation of pipe diameters.
- Computation of pressures in the pipelines.
- Determination and positioning of appurtenances.

- a) **Surveys and maps:** The strip of land lying between the source of water supply and the distribution area is surveyed to obtain the levels for fixing up the alignment of the rising main. This main will carry treated water to the distribution reservoir(s) located in the distribution area. The distribution area is also surveyed and detailed maps of are prepared showing the positions of roads, streets, lanes, residential areas, commercial locality, industrial areas, gardens etc. A topographical map of the area is prepared to locate the high and low areas. The cross section of streets, roads, lanes, etc. are prepared, showing the position of existing underground service lines like electric and telephone lines, sewer lines, existing water supply lines (if any), etc.
- b) **Tentative layout:** A tentative layout of the distribution line is then marked, showing the location of the treatment plant(s), distribution mains, distribution and balancing reservoirs, valves, hydrants, etc. The whole area is divided into various distribution districts. The density of population (average number of people per hectare area) is also marked. The length of pipelines should be kept as short as possible.
- c) **Discharge in pipelines:** Based on the density of the population, type of distribution district (residential, commercial etc) and fire fighting and other requirements, the discharge required from each pipeline is calculated. The fire hydrants are placed at 50 to 100m intervals on straight runs, and on street junctions. The size of the distribution pipes are fixed such that a minimum necessary pressure head is maintained at all points, carrying peak hourly flow through them. The pipes should be designed for a discharge ranging from 2.25 to 3 times the average rate of supply. For populations over 50,000, the distribution mains should have a capacity of 225% of average rate of supply, while for population below 5000; the distribution pipes should have a capacity of 300% for the average rate of supply. The flow required for fire fighting should be added to this maximum flow, to get the total flow. The pipes should be able to carry this total flow without excessive pressure drops.
- d) **Calculation of pipe diameters:** Once the design discharge is known, pipe diameters are assumed in a way that the velocities of flow in pipes remain between 0.6 to 3 m/s. Smaller velocity is assumed for pipes of smaller diameter and larger velocity for pipes of larger diameter. The loss of head in the pipes is then calculated using Hazen-Williams formula (or nomogram) as:

$$V = 0.849 CR^{0.63}S^{0.54}$$

Where:

V = mean velocity of flow in pipe (m/s)

R = hydraulic radius (mean depth) in m

S = hydraulic gradient

C = coefficient of roughness of pipe

In terms of diameter D of the pipe, the above formula reduces to:

$$V = 0.354 CD^{0.63}S^{0.54}$$

Where, D is the diameter of the pipe in meters.

Expressed in terms of head loss h_f and the length L of the pipe, the Hazen Williams formula takes the following form:

$$h_f = (6.843L / (D^{1.167})) \times (V / C)^{1.852} = 10.7 \times (Q/C)^{1.852} \times (L/D^{4.87})$$

The discharge Q (m^3/s) is given by:

$$Q = 0.278CD^{2.63}S^{0.54}$$

If, however, D is expressed in mm, we have:

$$V = 4.56 \times 10^{-3} CD^{0.63}S^{0.54} \quad \text{m/s and}$$

$$Q = 3.581 \times 10^{-9} CD^{2.63}S^{0.54} \quad \text{m}^3/\text{s}$$

- e) **Computation of pressures:** Various methods used for the analysis of pressure in the distribution system, include: equivalent pipe method, Hardy Cross method, method of sections and circle method etc. The first two methods are discussed below:

Table 1: Values of coefficient C for Hazen Williams Formula

Pipe Material	C
Asbestos cement	140
Ductile iron	
Cement lined	130 -150
New, unlined	130
5 year old unlined	120
20 year old unlined	100
Concrete	130
Copper	130 – 140
Plastic	140 – 150
New welded steel	120
New riveted steel	110

Equivalent pipe method: In this method, a complex system of pipes is replaced by a single hydraulically equivalent pipe. The equivalent pipe is one which will replace a given system of pipes with equal head loss for a given flow.

$$h_r = KLQ^n / Dx \quad \text{or} \quad Q = KD^aS^b$$

For Hazen Williams formula: $x = 4.87$, $a = 2.63$ and $b = 0.54$

Hardy Cross method: Hardy Cross method is essentially a relaxation technique involving controlled trial and error. In any system of pipes, connected together and conveying water under pressure, the following three laws are applicable. 1) In each separate pipe or element comprising the system, there will be a relation between the head loss in the element and the quantity of water flowing through it. 2) At each junction, the algebraic sum of the quantities of water entering and leaving the junction is zero i.e. $\Sigma Q =$

0. 3) In any closed path or circuit, the algebraic sum of the head loss in the individual elements is zero, i.e. $\sum h = 0$. In this method modification can be done either to balance heads by correcting flows or to balance flows by correcting heads.

As traditional calculations of the parameters of distribution networks are time consuming, various computer software programmes have been developed by different companies to deal with this, for example, a complicated network can be designed in a noticeably short time, with the help of water computer application utilities such as WESNET.²

6. Appurtenances

Listed below are accessories that may be fitted to the distribution systems for various purposes.

- Sluice valves or gate valves
- Air valves
- Reflux valves
- Relief valves
- Altitude valves, and scour valves

Air valves, pressure relief valves, and scour valves are fixed at allocated locations along the alignment of a water distribution line. These valves are necessary to isolate and drain pipeline sections for test, inspection, cleaning and repairs.

Sluice valves or gate valves: These are also known as shut off valves or stop valves. They are extensively used in the distribution system to shut off the supply where desired. They are also used to divide the water mains into suitable sections, of between 150 to 300m. They can also be used at street corners or where two pipe lines intersect. They have the advantage over most other types of valves in that they are relatively less expensive, and they offer almost no resistance to the flow when the valve is wide open.

Air relief valves: The water flowing through the pipe lines always contain some air. When this air accumulates at high points, it may interfere with the flow. Air relief valves are provided at the summits along the water pipe, to provide an exit for the accumulated air. Air valves are also required to discharge air when a main is being filled and to admit air when it is being emptied, the latter especially important in large steel mains which may flatten if the pressure falls below that of the atmosphere.

Reflux valves: These are also known as check valves or non-return valves. They are placed in water pipes which receive water directly from the pump. When the pump is stopped, these automatic devices only allow water to flow in one direction, preventing it from rush back and damaging the pump.

² WESNET: An Important Utility in Water Distribution Network Design; Eng. N.B. Abdeljabar, Prof. I.M. Abdelmagid, Eng. A.S. Altahir, Dr. A.H. Hassan, Eng. O.B. Ibrahim, Eng. F.G. Faris, and Eng. M. A. Saad, Scientific Paper Series, SPS, No 1: Sudan Academy of Sciences Publishing & Distribution Home

Pressure relief valves: These are also known as automatic cut-off valves or safety valves. They are located at points where pressure is likely to be maximum. When the line pressure increases above the preset value, the valve operates automatically, and the pressure is reduced.

Altitude valves: These are mainly used in lines which supply water to elevated tanks. They close automatically when the tank is full and open when the pressure on the pump side is less than that on the tank side of the valve.

Scour valves: Scour valves or blow-off valves or washout valves are ordinary sluice valves that are located either at dead ends or at the lowest points in the mains. They blow-off or remove sand and silt deposits in the pipe line. They are operated manually.

Fire hydrants: Hydrants provide access to groundwater mains for the purpose of extinguishing fires, washing down streets, and flushing out water mains. The typical parts of a hydrant are the cast iron barrel and the shutoff valve. The cast iron barrel is fitted with an outlet on top and the shutoff valve at the base is operated by a long valve stem that terminates above the barrel. A typical unit has two 2 ½ inch diameter hose nozzles and one 4 ½ inch pumper outlet for a suction line. Hydrants are installed along streets behind the curb line

7. Laying of distribution networks

- Minimum trench depth should be $15 + D + 30 + \geq 145$ cm for heavy and normal traffic and $15 + D + 30 + \geq 115$ cm for other cases, where D is the external diameter of the pipe in cm, 15cm is the bedding thickness, 30cm is the compacted overburden thickness and the remaining is the backfilled compacted thickness.
 - Minimum depth of filling on the pipes should not be less than 0.8 m, and preferably one meter, to protect them from traffic loads to prevent the effects of climatic changes on water, in the pipe, making it unpalatable.
 - For distribution network sizes ranging from 7.5 cm up to 25 cm, the minimum and maximum width of the trench should be 45 cm and 80 cm respectively.
 - Sluice valves should be fitted in suitable places with relevant signs marked for easy location for operation and maintenance.
 - Air valves should be fitted at the top of the pipelines, also marked for easy location.
 - Outlets for fire hydrants must be located at street crossings and 100 to 180m in front of buildings depending on the building density, its importance, and particularly in industrial areas. Signs indicating the location of the outlets must be clearly placed.
- Distribution network systems are subject to unbalanced thrust forces resulting from static and dynamic fluid action on the pipe. These forces must be balanced if the piping system is to maintain its integrity. Unbalanced thrust forces occur at change in directions of flow such as elbows, tees, reducers, valves and dead ends. At these places, reactive forces must be provided in the form of thrust blocks, or transmitting forces to the pipe wall by restrained, harnessed, flanged or welded joints (forces from the pipe shell transferred to the soil). Annex 2 outlines the procedure for designing thrust blocks.

8. Operation and maintenance

8.1 Distribution system chlorination

Upon installation, the new main should be pressure tested, flushed to remove all dirt and foreign matter and disinfected prior to being placed in service.

The continuous method is one of the various methods that are used for chlorination of a distribution system. This method involves supplying water to the new main with a chlorine concentration of at least 50 mg/l, injected into the water either through a solution-feed chlorinator or a hypochlorite feeder. The chlorinated water should remain in the pipe for a minimum of 24 hours with all valves and hydrants along the main operating to ensure their disinfection. At the end of 24 hours, no less than 25 mg/l chlorine residual should be remaining.

In the slug method of chlorination, a continuous flow of water is fed to the main with a chlorine concentration of at least 300 mg/l. The rate of flow is set so that a column of chlorinated water is in contact with the interior surfaces of the main for 3 hours. As the slug passes through the connections, the valves are operated to ensure disinfection of appurtenances. This method is used principally for large-diameter mains where the continuous feed technique is impractical.

Following disinfection the chlorinated water should be flushed to waste with potable water. Microbiological test are required before the main is placed in service.

To disinfect a broken main, isolate it by closing the nearest valves. The first step in repair involves flushing the broken section to remove contamination while pumping the discharge out of the trench. Minimum disinfection includes swabbing the new pipe sections and fittings with a 5% hypochlorite solution before installation and flushing the main from both directions before returning the system to service. Where conditions permit, the repaired section should be isolated and disinfected by one of the procedures described above.

8.2 Preventive maintenance of appurtenances

Preventive maintenance of valves involves location, inspection and operation. Location of the valve box is confirmed by checking the measurements given on the map. Next, the valve box cover is removed and the interior inspected with a flashlight. Finally, the valve is fully closed, and the number of turns required to close it is recorded. The tightness of closure is checked through listening with a leak detector. To avoid damage/failure of the stem, the applied torque using a power turning should not exceed the recommended limit specified by the manufacturer.

Common defects requiring repair are broken stems, need for packing, and internal incrustation. Repair of a valve is a difficult task requiring isolation of that section of the

pipe network, excavation, and removal of the valve. Either the damaged valve can be repaired and replaced or, if the overall conditions is good, new parts that need to be changed can be installed on site.

8. 3 Leakage and leak detection

Pipe leakages occurring as a result of aging of pipe material, poor quality of workmanship, poor quality of material, high pressures, water hammers etc., contribute to loss of water, i.e. loss of precious resource. The points of leakage not only allow water to be lost, but may also allow contaminants to enter.

Leak detection aims to locate and repair small defects in a pipe network before failures occur and huge amounts of water are lost from the system. As water under pressure exits a crack or small hole, sound waves in the audible range are emitted by the pipe wall and surrounding wall. Electronic detectors, capable of amplifying sound waves and filtering out unwanted background noise, can locate and isolate leaks. An experienced person can also estimate the rate of leakage from the detector. The sound transmitted by the pipe wall can be heard by listening at the hydrants, main valves, and curb valves. In conducting a survey, areas of water loss are identified by listening at these direct contact points. An approximate location is established by evaluating the intensity from different locations. Water impacting the soil and circulating in a cavity creates lower frequency waves that have limited transmission through the ground. Through the use of a surface microphone, the leak can be located with greater precision. The nature of the sound emitted by escaping water depends on water pressure in the main, pipe material and size, soil conditions, and configuration of the opening. Consequently, locating and estimating the severity requires operator training and experience.

Pipes and joints are commonly repaired by placing an external cover over the leak. Repair sleeves are cylindrical halves that are fitted around the pipe or joint and bolted together. At a joint, a solid insert may be placed inside with half of the length in each pipe and a split-coupling clamped around the outside.

Annexes

1. Drinking Water Standards
2. Design and installation of thrust blocks
3. The development of these Guidelines
4. People contacted
5. Technical working group members
6. Some bibliography and references

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 NO ₃	50	50 Short term exposure
16	Nitrite as NO ₂	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	2.7	0.004
Dichloromethane	14	0.02
1,2-Dichloroethane	20	0.03
1,2-Dichloroethene	33	0.05
Trichloroethene	13	0.02 (P)
Tetrachloroethene	27	0.04
Benzene	7	0.01
Toluene	470	0.7(C)
Xylenes	330	0.5 (C)
Ethylbenzene	200	0.3 (C)
Styrene	13	0.02 (C)
1,2-Dichlorobenzene	700	1 (C)
1,4-Dichlorobenzene	200	0.3 (C)
Di(2-ethylhexyl) phthalate	5.4	0.008
Acrylamide	0.3	0.0005
Epichlorohydrin	0.3	0.004 (P)
Edetic acid (EDTA)	400	0.6 Applies to the free acid
Nitrilotriacetic acid (NTA)	130	0.2
Hexachlorobutadiene	0.4	0.0006
Dioxane	33	0.05
Pentachlorophenol	7	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 Aldicarb Sulfone
Atrazine	1.5	0.002
Carbofuran	4.5	0.007
Chlordane	0.15	0.0002
Chlorotoluron	20	0.03
1,2-Dibromo-3-Chloropropane	0.7	0.001
DDT	0.7	0.001
2,4-Dichlorophenoxy acetic 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
Chlorate	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 = Nephelometric Turbidity Unit

Annex 2: Design and installation of thrust blocks³

Piping systems are subject to unbalanced thrust forces resulting from static and dynamic fluid action on the pipe. These forces must be balanced if the piping system is to maintain its integrity. Unbalanced thrust forces occur at change in directions of flow such as elbows, tees, reducers, valves and dead ends. Reactive forces can be provided in the form of thrust blocks, or transmitting forces to the pipe wall by restrained, harnessed, flanged or welded joints (forces from the pipe shell transferred to the soil).

Three fundamental equations of fluid dynamics have to be used in order to calculate the thrust forces that are acting on the piping systems. These are:

a) Conservation of matter (mass): Mass flow entering (Q_e) is equal to mass flow leaving (Q_l)

b) Conservation of energy:

$$p_1 / (\rho g) + (v_1^2 / 2g) + z_1 = p_2 / (\rho g) + (v_2^2 / 2g) + z_2 + h_f + h_l$$

c) Conservation of momentum:

$$F = (mdv / dt) \rightarrow \delta F = \rho Q(v_2 - v_1)$$

Where:

p_1, p_2 = pressure of the liquid at point 1 and 2 respectively and expressed in meters

ρ = density of the liquid in kg/m^3

g = gravitational acceleration in m/s^2

v_1, v_2 = velocities of the liquid at point 1 and 2 in m/s

z_1, z_2 = reference heights of point 1 and 2 in m

h_f = loss of pressure due to friction in m

h_l = local loss of pressure in m

$F, \delta F$ = resultant forces due to change of velocity in N

m = mass of the liquid in kg

dv = change of velocity in m/s

dt = change in time in s

Q = amount of flow in m^3/s

Based on above fundamental equations, it is possible to calculate the forces as indicated below.

Pressure forces (F_{Px}) = $p_x A$

Momentum force (F_{Mx}) = $\rho Q(v_2 - v_1)$

³ Adapted from SHC 310 – Hydraulics Thrust Block Design, by Marco van Dijk, Department of Civil Engineering, University of Pretoria

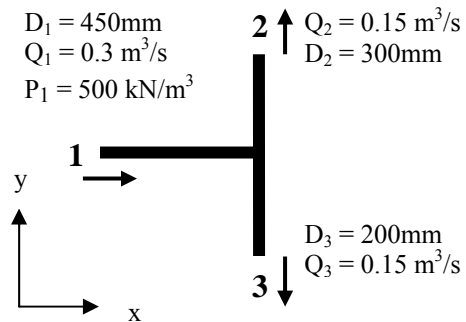
Reaction forces: $F_{Mx} = \Sigma (F_{Px} + F_{Rx})$

The calculation procedures need to follow the following steps.

- Choose the axis either x, y or z.
- Determine the pressures, velocities and flow rates at the specific point.
- Determine the forces using the fundamental equations of fluid dynamics.
- Determine the soil conditions.
- Calculate thrust block dimensions/weight.

Example:

Calculate the magnitude and direction of the force exerted by the following T – junction



Three velocities by continuity will be:

$$v_1 = Q_1 / A_1 = 1.886 \text{ m/s}$$

$$v_2 = Q_2 / A_2 = 2.122 \text{ m/s}$$

$$v_3 = Q_3 / A_3 = 4.775 \text{ m/s}$$

By applying Bernoulli's equation, the pressures at point 2 and 3 will be:

$$p_1 / (\rho g) + (v_1^2 / 2g) + z_1 = p_2 / (\rho g) + (v_2^2 / 2g) + z_2 + h_f + h_l$$

As the difference of reference heights z_1 and z_2 and the friction and local loss are negligible:

$$p_2 = p_1 + (\rho (v_1^2 - v_2^2)) / 2 = 499.53 \text{ kN/m}^2$$

$$p_3 = p_1 + (\rho (v_1^2 - v_3^2)) / 2 = 490.38 \text{ kN/m}^2$$

Pressure forces:

x – direction;

$$F_{Px} = F_{P1x} + F_{P2x} + F_{P3x} = p_{1x}A_1 + 0 + 0 = 79.95 \text{ kN}$$

y – direction

$$F_{Py} = F_{P1y} + F_{P2y} + F_{P3y} = 0 + (-p_{2y}A_2) + p_{3y}A_3 = -19.96 \text{ kN (the pressure forces acting at point 2 and 3 are assumed to act in the opposite direction of flows).}$$

Momentum forces:

x – direction

$$F_{Mx} = 0 + 0 - (\rho Q_1 v_1)$$

y – direction

$$F_{My} = (\rho Q_2 v_2) - (\rho Q_3 v_3) + 0 = -0.40 \text{ kN}$$

Resultant forces:

Resultant forces = - Reaction forces

Reaction forces:

x – direction

$$F_{Rx} = F_{Mx} - F_{Px} = -80.09 \text{ kN}$$

y – direction

$$F_{Ry} = F_{My} + F_{Py} = 19.50 \text{ kN}$$

$$F_R = \sqrt{(F_{Rx})^2 + (F_{Ry})^2} = 82.43 \text{ kN}$$

Angle of reaction:

$$\theta = \tan^{-1}(F_{Ry} / F_{Rx}) = 13.7^\circ$$

Restraining method:

Bearing area (for thrust block), friction between thrust block and soil (for thrust block), required dimensions of anchor rings/puddle flange, friction between soil and pipe (for

harnessed joints) and combination of all these methods is done using calculation of restraining method.

Bearing area (A) required for thrust block:

A = Thrust force divided by Safe horizontal bearing capacity of soil i.e.

$$A = F_u / P_{\text{bearing}}$$

Where:

A = bearing area of thrust block (m²)

F_u = total thrust block (kN)

P_{bearing} = bearing capacity of soil (kPa or kN)

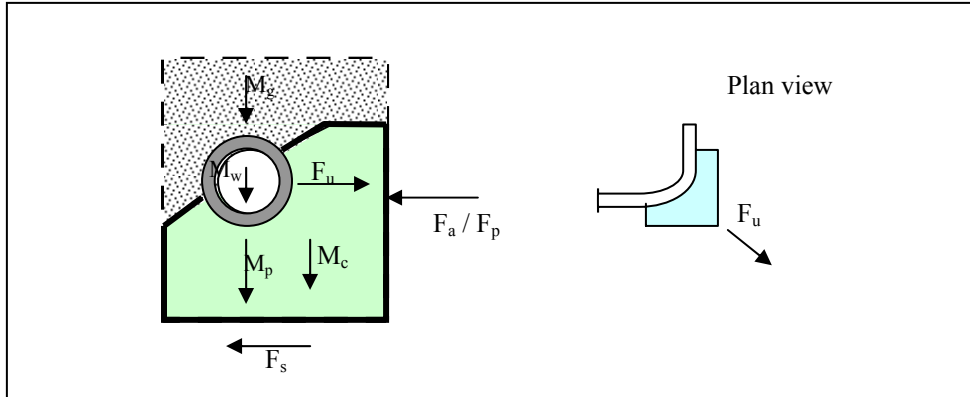
Safety factor = ? (this safety factor should be chosen based on the judgment of the local ground situation)

Guidelines for bearing capacities

Soil type	Bearing capacity (kPa)
Rock	
Hard sound rock – Broken with some difficulty and rig when struck.	10000
Medium hard rock – cannot be scraped or peeled with a knife: hand held specimen breaks with firm blow of the pick.	5000
Soft rock – can just be scrape with a knife: indentation of 2 to 4 mm with firm blow of the pick point	2000
Very soft rock – can be peeled with a knife: material crumbles under firm blows with sharp end of a geological pick	1000
Non-Cohesive Soils	
Dense well-graded sand, gravel and sand-gravel mixture	
Dry	400
Submerged	200
Loose well-graded sand, gravel, sand-gravel mixtures or dense uniform sand	
Dry	200
Submerged	100
Loose uniform sand	
Dry	100
Submerged	40

Calculation of frictional force between thrust block and soil

$$F_s = \mu(M_c + M_w + M_s + M_p)g$$



Where:

F_s = total friction resistance between the thrust block and soil (N)

μ = friction coefficient between soil and thrust block

M_c = mass of concrete thrust block (kg)

M_w = mass of water in pipe resting on thrust block (kg)

M_s = mass of soil on top of thrust block (kg)

M_p = mass of pipe resting on thrust block (kg)

g = gravitational acceleration (m/s^2)

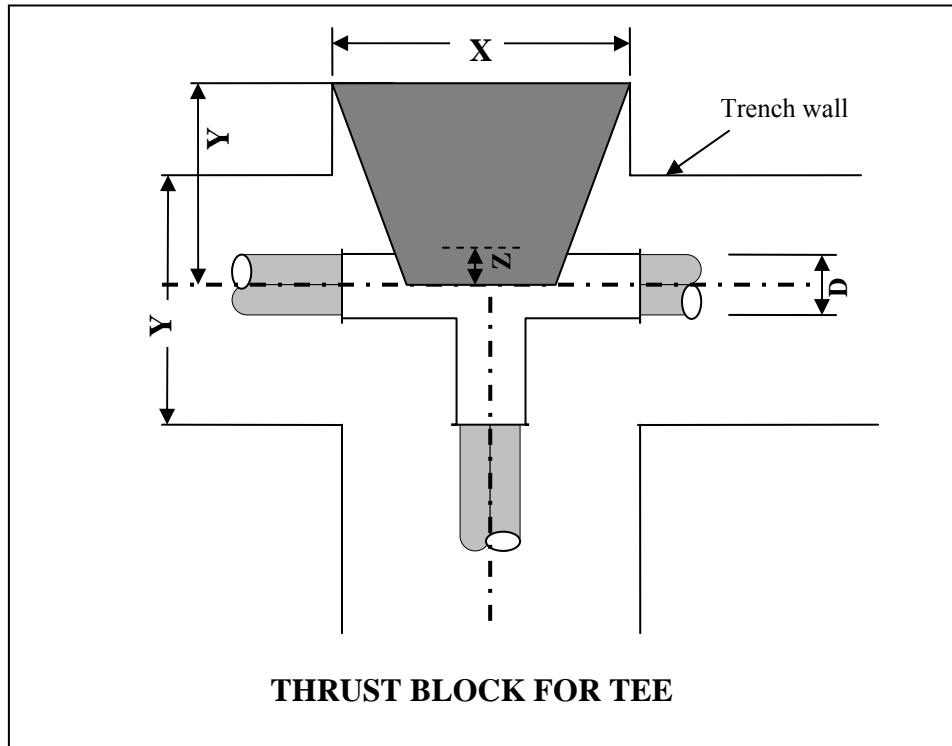
F_a, F_p = Forces from active and passive earth pressures

Friction between thrust block and soil

Soil	Friction coefficient (μ)
Clean hard rock	0.70
Clean gravel to coarse sand	0.55 to 0.60
Clean fine to medium sand, medium to coarse sand with silt, gravel with silt or clay	0.45 to 0.55
Clean fine sand; fine to medium sand with silt or clay	0.35 to 0.45
Fine sand with silt; non-plastic silt	0.30 to 0.35
Very firm and hard clay	0.40 to 0.50
Medium to hard clay and clay with silt	0.30 to 0.35

Friction coefficient (μ) is affected by the degree of compaction and moisture content

Examples of thrust block for underground T – piece



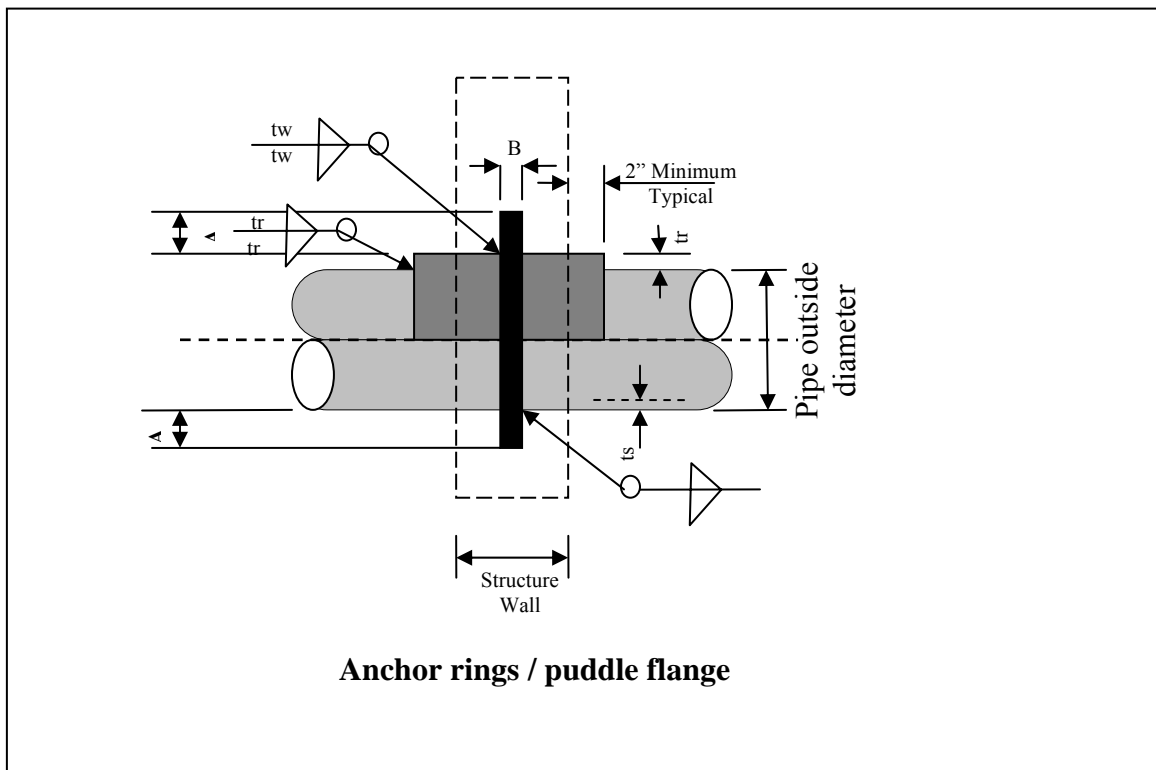
Nominal diameter (mm)	Dimensions				
	D (mm)	Z (mm)	X (mm)	Y (mm)	Volume (m ³)
300	1400	700	2700	1300	2.55
250	1300	650	2150	1100	1.50
200	1200	600	1600	800	0.77
150	1000	500	1300	650	0.42
100	1000	500	500	300	0.075
75	800	400	400	300	0.054

Installation guidelines for thrust blocks:

- The sides and bottoms of excavations against which thrust blocks are cast should be sound and undisturbed and all loose material should be removed.
- Excess excavations should be filled with concrete simultaneously with the thrust block.
- All joints should be left accessible.
- No thrust block is usually required with a steel pipeline which is flanged or welded,
- Valves and plugs at stop-end pipes must be adequately anchored.
- Pressure forces should be compared with momentum forces.
- Balance upward forces through the mass of the thrust block.

Anchor rings / Puddle flange

Pipe OD (mm)	Ring width A (mm)	Ring thickness B (mm)	t_y ($t_y = t_s + t_r$) (mm)	Minimum weld t_w (mm)	Permissible load on ring (kN)
Maximum pipe pressure of 1034 kPa (150 Psi)					
168	25	10	1.9	3.2	23
219	25	10	2.0	3.2	39
273	38	10	2.5	3.2	61
324	38	10	3.0	3.2	85
356	51	10	3.3	3.2	103
406	51	10	3.7	3.2	134
457	51	10	4.2	3.2	170
508	76	13	4.7	3.2	210
610	76	13	5.6	3.2	302
762	102	16	7.0	4.8	472
914	102	16	8.4	4.8	679



Annex 3: 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. 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, and 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 further 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 4: People Contacted

1. Mr Omer ElKhadir, Director of New Soba Water Works Project
2. Mr Gaser Elfarouk, Resident Mech. Engineer, New Soba Water Works Project
3. Mr Khalid M Khier, Resident Civil Engineer, New Soba Water Works Project
4. Mr Khidir Eltom, Director, Mogran Water Treatment Plant
5. Mrs Samia Maki, Lab. Director Mogran Water Treatment Plant
6. Mr Ahmed Gasim Elseed, Director, Khartoum North Water Treatment Plant
7. Mr Ahmed Hassan, Technical Director, Khartoum North Water Treatment Plant
8. Mr Mohammed Abdel Rahman, Eng. Tech. Office, Khartoum Water Corporation
9. Mr Burhan Ahmed Almustafa, Projects/Networks Department, KWC

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. Andrew 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
23. Gailda Kwenda, ACF, Malakal
24. Amardine Atsain, ACF, Malakal
25. Peter Mumo Gathwu, Care, Malakal
26. Engineer John Kangatini, MPI, Upper Nile State
27. Wilson Ajwek Ayik, MoH, Upper Nile State
28. James Deng Akurkuac, Department of RWSS, Upper Nile State
29. Oman Clement Anei, SIM
30. Abuk N. Manyok, Unicef, Malakal
31. Jakob A. Mathiong, Unicef, Malakal
32. Emmanuel Badang, UNMIS/RRR

33. Emmanuel Parmenas, DG of O&M, MCRD GOSS
34. Cosmos Andrugá, APO, Unicef Juba

Annex 5. Technical Working Group Members

A) At Khartoum level

1) For Slow Sand Filters

Dr Mohammed Adam Khadam, University of Khartoum
Dr V. Haraprasad, UNICEF
Mr. Ibrahim Adam, PWC
Mr Eshetu Abate, UNICEF - Consultant

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

Mr. Mohamed Hassan Ibrahim, GWW
Mr. Mohy Al Deen Mohamed Kabeer, GWW
Mr. Abd el Raziq Mukhtar, Private Consultant
Mr. Mohamed Salih Mahmoud, PWC
Mr. Mohamed Ahmed Bukab, PWC
Mr. Mudawi Ibrahim, PWC/WES
Mr. Yasir Ismail, PWC/WES
Mr Eshetu Abate, UNICEF - Consultant

3) For Improved Small Dams

Dr. Mohamed Osman Akoud, University of Khartoum
Professor Saif el Deen Hamad, MIWR
Mr. Mohamed Salih Mohamed Abdulla, PWC
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4) For Improved Haffirs

Mr. Mohamed Hassan Al Tayeb, Private Consultant
Mr. Hisham Al Amir Yousif, PWC
Mr. Hamad Abdulla Zayed, PWC
Mr Eshetu Abate, UNICEF - Consultant

5) For Drinking Water Treatment Plants, Drinking Water Distribution Networks and Protected Springs & Roof Water Harvesting

Dr Mohamed Adam Khadam, University of Khartoum
Mr. Burhan Ahmed Al Mustafa, Khartoum State Water Corporation (KSWC)
Mr Eshetu Abate, UNICEF - Consultant

6) For Household Latrines, School Latrines and Rural Health Institution Latrines

Mr. Sampath Kumar, UNICEF
Mr. Fouad Yassa, UNICEF
Dr. Isam Mohamed Abd Al Magid, Sudan Academy of Science
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B) At Juba level:

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Annex 6: Selected bibliography and references

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