Government of Uganda
Ministry of Water and Environment
Directorate of Water Development

Design Guidelines for Water Supply Infrastructure in Uganda

1st Edition
June 2013

FOREWORD

The Ministry of Water and Environment published the First Edition of the Water Supply Design Manual in the year 2000. This Manual has been extremely useful in meeting the needs of those engaged in the planning and design of water supply systems in Uganda. Over time, however, new technologies in the design of water supply systems have evolved; a lot of experience has been gained, and new issues such as climate change and cost effective methods of planning have emerged that have necessitated the revision of this Manual.

In 2011, the Ministry undertook a comprehensive review of the first edition of the Water Supply Design Manual in order to address the gaps identified, and to incorporate the latest appropriate technologies and practices that have shown satisfactory performance in the Ugandan water sector. In updating the Manual, the Ministry has developed two versions; the Second Edition of the **Water Supply Design Manual (2013)**, and the **Design Guidelines for Water Supply Infrastructure in Uganda (2013)**.

While the **Water Supply Design Manual (2013)** is the main reference document, a shorter version of the **Design Guidelines for Water Supply Infrastructure in Uganda (2013)**give a quick reference, guidance and recommendations to the Engineers responsible for planning and design of water supply and sanitation infrastructure in the country. Both documents set uniform standards to be used in planning and designing of infrastructure that meet the needs of the users.

Further, these technical documents require periodic updating from time to time arising from the dynamic technological developments and changes. The Ministry, therefore, welcomes proposals on areas for further developments and revision stemming from the actual field experiences and practice. The comments will contribute to future revisions of the Manual expected to lead to better and more economical designs. Users are therefore invited to send their suggestions for revisions and improvements.

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These guidelines were prepared with the support of hydrophil iC GmbH, Vienna/Austria.

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Abbreviations and Acronyms

BS	British Standards
CAPEX	Capital Expenditure (Investment Cost)
DEA	Directorate of Environmental Affairs
DMA	District Metered Area
DN	Nominal Diameter
DWD	Directorate of Water Development
DWRM	Directorate of Water Resource Management
EN	European Standards
ha	Hectare
IFI	International Financial Institutions
ISO	International Standards Organisation
IWA	International Water Association
km	Kilometre
l	Litre
LGU	Local Government Unit
lpcd	Litre per capita and day
masl	Meter above sea level
MWE	Ministry of Water and Environment
NBI	Nile Basin Initiative
NRW	Non-Revenue Water
NPSH	Net Positive Suction Head
O&M	Operation and Maintenance
OPEX	Operating Expenses
PE	Polyethylene
PN	Nominal Pressure (in bar)
PVC	Polyvinylchloride
UNBS	Uganda National Bureau of Standards
US	Uganda Standards
WSS	Water supply and sanitation

1. INTRODUCTION

The Directorate of Water Development (DWD) herewith presents its Guidelines for the design of water supply infrastructure, at a time when significant investments in piped water are being prepared in order to enhance access to safe water for millions of Ugandans, in particular those living in small towns and rural growth centres.

It is expected that theseGuidelines will contribute to enhance the cost efficiency and sustainability of water supply investments and meet the development partners’ expectations by ensuring that the design of water supply infrastructure is based on high-quality standards that reflect both the international state of the art and the best practices identified for Uganda.

Good design – proposing sound, robust and affordable solutions – is essential for effective and sustainable service delivery. The planning and design phase is critical and is the greatest opportunity for delivering water and sewerage services at the lowest lifecycle cost while also meeting social and environmental requirements.

The Guidelineswill be used in conjunction with the more detailed Technical Design Manual that is currently in the finalisation phase.

The process of formulating the new Guidelineshas been initiated and overseen by DWD’s Design Review Committee. The Guidelines were developed by a team of engineers from hydrophil iC GmbH, Vienna/Austria, in conjunction with senior officers of DWD and support from a national consultant and DWD’s Technical Assistants.

The Design Guidelines shall be updatedat regular intervals in order to make them a living document that reflects the most recent status of sector experience and good practice in Uganda.

1.1 PURPOSE AND SCOPE OF THE GUIDELINES

The intention of the present Design Guidelines is to provide practical guidance to planners and design engineers of water supply infrastructure in Uganda, in order to promote standardization, quality assurance and adherence to national standards and international good practices. It is also intended to facilitate a strategic, integrated planning process and to anchor sector policies in implementation practice.

The focus of the Guidelines is on piped water schemes independently of their size. They can be used by WSDF, Rural Water Supply, Water for Production and District Local Governments, in addition to other private sector practitioners designing water supplies in Uganda. They can be used at different stages of the planning and design process, from developing a strategy for service delivery and investment planning to feasibility studies and detailed design. As any water supply project has an impact on sanitation, this aspect is considered here too.

The format of the Guidelines is deliberately concise. The intention is not to replace more detailed technical manuals or textbooks, but to provide an overview of the aspects and issues to be considered and principles to be followed, along with references for further reading.

Instead, these Guidelines will focus on **rules, criteria, standard methods, procedures and best practices** to be followed when designing water supply infrastructure in Uganda. They define benchmarks and minimum requirements and help to ensure that all important aspects are taken into account by adopting an integrated system planning approach. For engineering details, the user will refer to the more detailed technical manual and textbooks.

The Guidelines provide concrete figures where appropriate, but only general guidance on design processes and procedures or references to other documents and standards in those cases where discussing the details would go beyond the scope of this format. In all cases, the Guidelines cannot replace the professional expertise and sound judgment of an experienced engineer. The Guidelines are to be used together with Uganda’s recognised standards, codes, and acts.

1.2 STRUCTURE OF THE GUIDELINES

TheseGuidelines begin with general chapters introducing the institutional, policy and legal framework, the principles of knowledge management, and general planning and design principles and procedures that are applicable throughout the design process for all components of a water supply scheme. This includes a presentation of the requirements regarding the content of planning and design documents and reports.

- Chapter 2 introduces the regulatory framework
- Chapter 3 deals with knowledge management
- Chapter 4 presents the planning and design principles
- Chapter 5 deals with the planning and design procedures
- Chapter 6 deals with demand projection
- Chapter 7 deals with the required water production
- Chapter 8 deals with water sources
- Chapter 9 speaks about water quality and treatment
- Chapter 10 presents water transmission and storage
- Chapter 11 deals with water distribution
- Chapter 12 introduces customer connections
- Chapter 13 has its focus on costing and cost efficiency
- Chapter 14 deals with wastewater, sanitation and hygiene
- Chapter 15 presents environmental and climate change aspects

Chapter 14 on wastewater, sanitation and hygiene focuses on the links between water supply and sanitation and the need to take sanitation aspects into account at the planning stage of water supply schemes. It does not claim to provide guidance on all aspects of sanitation and wastewater disposal/treatment for which separate design guidelines would be required.

Each chapter has a similar structure that begins with an outline of the purpose and the key principles of design for the topic dealt with in the respective chapter and ends with a checklist – a list of questions to assist the planner and internal reviewer – and a bibliography. Preference has been given to references that can be accessed via the internet.

2. EXISTING REGULATORY FRAMEWORK

Planners and design engineers must be aware of the regulatory framework and its potential impact on options and implementation programs relating to the provision of water supply infrastructure.This chapter provides an overview of the regulatory framework relevant for the planning of water supply infrastructure in Uganda.

It is important that engineers and planners are aware of the legislative and regulatory framework relating to water supply, in particular because:

- Non-compliance may result in prosecution
- Community health and wellbeing may be threatened
- Significant project delays may result from having to rectify failure to comply with standards
- Projects and approval processes may have regulator imposed deadlines

Maintaining and updating knowledge of the regulatory framework, standards and Guidelines is a continuous process for all planners and ignorance of regulatory requirements and standards is not a defence against legal action. Engineers and planners should therefore use the existing regulatory framework to ensure compliance with legal requirements.

2.1 INSTITUTIONAL FRAMEWORK

The institutional framework for the water and sanitation sector, under which water supply infrastructure development lies, comprises a number of organisations and stakeholders at national, district and community levels. They include the following:

Planning and coordinating ministry

- Ministry of Water and Environment (MWE)
    - Directorates
        - Directorate of Water Resources Management (DWRM)
        - Directorate of Water Development (DWD)
        - Directorate of Environmental Affairs (DEA)
    - Authorities and parastatal organisations
        - National Water and Sewerage Corporation (NWSC)
        - National Environment Management Authority (NEMA)
        - National Forestry Authority

Other ministries

- Ministry of Health (MoH)
- Ministry of Education and Sports (MoES)
- Ministry of Local Government (MoLG)
- Ministry of Gender, Labour and Social Development (MGLSD)
- Ministry of Agriculture, Animal Industry and Fisheries (MAAIF)
- Ministry of Trade, Tourism and Industry (MTTI)
- Ministry of Energy and Mineral Development (MEMD);
- Ministry of Works and Transport (MoWT)
- Uganda National Roads Authority (UNRA)
- Ministry of Finance, Planning and Economic Development (MFPED)
- Ministry of Foreign Affairs (MoFA)

Other public and private sector institutions and organisations

- Higher Institutions of Learning
- Local Governments
- Non-Governmental Organisations (NGOs) and Community Based Organisations (CBOs)
- Private Sector
- Development Partners

The Ministry of Water and Environment (MWE) has the overall mission: "*To promote and ensure the rational and sustainable utilisation, development and effective management of water and environment resources for socio-economic development of the country*". The Ministry of Water and Environment, through its three directorates DWD, DWRM and DEA, is responsible for policy and strategy development, regulation, overall national planning and the monitoring of sector performance and capacity development of stakeholders especially at local government level. In urban areas, the urban Water Authority (WA) appoints the Private Operator (PO) through a competitive bidding process to manage the water supply system. In rural areas, the local governments at district and lower levels are responsible for managing the implementation and service provision utilising services from the private sector. The users pay for services through the Water and Sanitation Board (WSSB) and contribute to local level planning and management of service provision

The legal and institutional frameworks provide for organs that coordinate the activities of the sector. These are the Water Policy Committee (WPC), Water and Environment Sector Working Group (WESWG) and Annual GoU/Donor Joint Sector Reviews (JSR). These were established at national level to formulate policies and provide technical guidance to facilitate development of the water and sanitation sector and are central in managing the Sector Wide Approach (SWAP). At district level, coordination takes place through the District Water and Sanitation Coordination Committees (DWSCCs).

2.2 POLICY FRAMEWORK

The policy framework for the management and development of water resources in Uganda is anchoredin two very important documents within the overall framework of the Constitution of Uganda (1995): The Uganda Water Action Plan (1995) and the National Water Policy (1999) which sets out the overall policy framework.

The National Water Policy promotes an integrated approach to the management of water resources in ways that are sustainable and most beneficial to the country. The approach is based on the continuing recognition of the social value of water, while at the same time giving much more attention to its economic value.

The other policy documents which complement the above policies are the: National Environment Management Policy (1994); Wetlands Policy (1995); Uganda National Land Policy (2011); National Health Policy and Health Sector Strategic Plan (1999); National Environmental Health Policy (2005); School Health Policy (2006); National Gender Policy (1997); MWE Gender Strategy 2010 to 2015; National Water Quality Management Strategy (2006); policy on tariffs for small towns, rural growth centres and large gravity flow schemes in accordance with the Water Act Cap.152; and Section 94 of the National Development Plan (NDP) 2010/11 – 2014/15.

A study commissioned under the NBI-SVP Water Resources Planning and Management Project: Water Policy Component reiterated the need for updating the National Water Policy. The required updates included outlining the emerging issues and dimensions of the sector at the local, regional and international level whichjustify the revision and identified the need for amending the various laws and regulations guiding the water sector in order to take into account the changes and challenges that have emerged since these laws were put in place.

2.3 LEGAL BASIS AND STANDARDS

2.3.1 Legal Framework

The key legal frameworks that guide the management of the water and sanitation sector are:

- Constitution of the Republic of Uganda (1995)
- The Water Act, Cap 152
- The Environment Act, Cap 153
- The National Water and Sewerage Corporation Act, Cap 317
- The Local Governments Act, Cap 243
- The Land Act, Cap 227
- The Public Health Act (1964)
- The Children Statute (1996)

The following regulations and standards are also in place for sector guidance:

- The Water Resources Regulations (1998)
- The Water Supply Regulations (1998)
- The Water (Waste Discharge) Regulations (1998)
- The Sewerage Regulations (1999)
- The Waste Management Regulations (1999)
- Environmental Impact Assessment Regulations (1998)
- National Environment (Standards for Discharge of Effluent into Water or on Land) Regulations(1999)
- National Environment (Waste Management) Regulations (1999)
- The Tariff Policy for Small Towns, Rural Growth Centres and Large Gravity Flow Schemes

There are also a number of Guidelines and strategies for the water and sanitation sector including:

- The Water Sector Pro-poor Strategy, 2006, DWD
- District Water and Sanitation Conditional Grant Guidelines, December 2001
- Rural Water Supply and Sanitation Handbook for Extension Workers, 2002
- Framework for Technical Support Units, November 2001
- Community Based Maintenance System, DWD
- National Water Quality Management Strategy, 2006
- The Plan for Modernisation of Agriculture, 2000
- The Country’s Strategic Interventions Programme for Export Promotion
- The School Health Minimum Requirements, 2000
- The Infant and Maternal Mortality strategy
- The Water and Sanitation Gender strategy, 2003
- The Strategy for ‘Water and Sanitation for Emergency Response’
- The Community Empowerment Strategy, MGLSD
- The National Sanitation Guidelines, 2001, MoH
- The Kampala Declaration on Sanitation (KDS), 1997
- The Sanitation Memorandum of Understanding, 2001 between MWLE, MoH and MoES
- Long-term Strategy for WSS Services in Small Towns, 2003
- Long term Strategy for WSS in Rural Growth Centres, 2003
- The Water Source Protection Guidelines (under preparation)

2.3.2 Uganda Standards

A Uganda Standard is a document declared as such by the National Standards Council.It either may be a specification, a code of practice or may specify other aspects such as terms and definitions, symbols, sampling and test methods or quality systems.Locally manufactured items should meet the requirements of the Uganda National Bureau of Standards (UNBS); a statutory organization established by an Act of Parliament in 1983. In cases where there are no UNBS standards, the items must meet the ISO specifications; otherwise European standard (EN) specifications apply. The water supplied for potable uses should meet the WHO water quality standards for parameters that are not included in the national drinking water quality standards.

Imported items should meet the relevant ISO specifications and where these are non-existent, the items must meet the national standards of the country in which they are manufactured subject to the provision that the official English version of the national standards of the country of origin shall not be lower than the corresponding EN specifications. Updates to existing UNBS, EN, ISO standards and alsoto new standards issued by the same institutions should be taken into account in water supply infrastructure development.

The Civil Engineering standard method of measurement issued by the Institution of Civil Engineers, London, CESMM3, 1995 or an updated version CESMM4, 2012 shall be used as the standard for the preparation of bills of quantities in civil engineering work in Uganda unless a different method is stated and modified to suit local conditions.

The following national standards shall apply to water supply infrastructure provision:

- Specification for Pipes and Fittings made of Unplasticized Poly Vinyl Chloride (uPVC) for water supply - Part 1: General RequirementsUS: 264-1:2000/EAS 182-1
- Specification for Pipes and Fittings made of Unplasticized Poly Vinyl Chloride (uPVC) for water supply - Part 2: Nominal diameters, wall thicknesses and nominal pressures (metric series): US 264-2:2000/EAS 182-1
- Pipes - High Density Polyethylene (HDPE) pipes Part 1. General Quality Requirements: US 482-1:2003
- Pipes - High Density Polyethylene (HDPE pipes Part 2. Dimensions: US 482-2:2003
- Steel pipes, joints and specials for water and sewerage: US 276:2000
- Drinking water (potable) Quality Standards: US 201: 1994
- Deep well hand pump: US 471:2002
- Deep well CBMS hand pump-model U3: US 403:2002
- Shallow well CBMS hand pump-model U2/U3: US 405:2002
- Water meters: US 1021: 2006
- Fixed storage tanks: US 1027: 2006
- Stabilised materials for civil engineering purposes Part 1. General requirements, sampling, sample preparation and tests on materials before stabilisation: US 465-1:2003
- Cement- Part 1: Composition, Specification and Conformity Criteria: US 310:2002
- Aggregates from natural sources for concrete: US 101:2002
- Sand: US 306:2003
- Steel bars for reinforcement of concrete: US 155:1995
- Standards for different hot-rolled steel sections: US 159:2000; US 657-5: 1976; US 657-1 1989; US 657-2: 1989
- Steel plates- hot-dip aluminium zinc plain and corrugated: US 540:2006
- Zinc coated steel sheets and coils: US 618:2006
- Pre-painted Metal coated steel sheets and coils: US 663:2006

2.4 CHECKLIST

1. Have all compliance issues been considered in the planning studies?
2. Have all relevant regulatory bodies been consulted?
3. Have all relevant approvals required for the initiative been obtained?
4. Is there a need for specific legal advice?

2.5 BIBLIOGRAPHY AND RECOMMENDED READING

[1] Strategic Sector Investment Plan for the Water and Sanitation Sector in Uganda. Ministry of Water and Environment, Uganda, 2009

[2] Uganda National Bureau of Standards.http://www.unbs.go.ug

[3] Water Supply Design Manual. Ministry of Water and Environment, Uganda, 2000

[4] National Environmental/Water Laws and Regulations, Uganda.http://www.nemaug.org

3. KNOWLEDGE MANAGEMENT

Knowledge management (KM) comprises a range of strategies and practices used in an organization to identify, create, represent, distribute, and enable the adoption of insights and experiences. Such insights and experiences comprise knowledge, either embodied in individuals or embedded in organizations as processes or practices [1].

Two kinds of "knowledge" are to be addressed in this respect:

1. **Explicit knowledge** – knowledge that has been recorded as information in a document or some other medium;
2. **Tacit knowledge** – information that resides in a person's mind and may include aspects of culture or "ways of doing things".

Quality management (QM) not only aimsat assuring 'good quality' products or service, but rather at ensuring that a product or service is consistent [1] and that certain standard procedures are being followed. Quality management can thus be an important tool for effective knowledge management. It can be considered to have four main components: quality planning, quality control, quality assurance and quality improvement. Quality management is focused not only on product/service quality, but also looks at the means of achieving this. Quality management therefore uses quality assurance and control of processes as well as products to achieve more consistent quality.

Quality assurance (QA)is a set of activities intended to establishconfidence that quality requirements will be met [1]. QA is one part of quality management.

3.1 PURPOSE

Effective knowledge management is a critical foundation for quality infrastructure planning. This chapter provides an overview of knowledge management as it applies to the planning process. Knowledge management in the context of infrastructure planning typically focusses on organizational objectives such as improved performance, innovation, the sharing of lessons learned, integration and continuous improvement of the organization. KM efforts overlap with organizational learning, and may be distinguished from this by a greater focus on the management of knowledge as a strategic asset and a focus on encouraging the sharing of knowledge.

3.2 KEY PRINCIPLES

Knowledge management initiatives related to water and sewerage planning should align as far as is practicable with the overall organisational knowledge management strategies, particularly with regard to:

- technology and systems
- document and records management

The management of knowledge facilitates effective and efficient planning. Effective knowledge management exists when there is:

- A culture of knowledge sharing within an organisation and with key stakeholders
- A process in place for:
    - Capture of knowledge
    - Sharing of knowledge
    - Continual learning and improving
- Appropriate (quality) management systems in place to collect, analyse, store and transfer knowledge
- An understanding of what knowledge is required and where it can be accessed

3.3 WHY IS KNOWLEDGE AND QUALITY MANAGEMENT IMPORTANT?

Knowledge management and quality management can provide important support to the planning process. In particular, because [2]:

- Planning requires access to a wide range of complex and inter-related information.
- It minimises the loss of critical knowledge when key personnel depart from the organisation.
- The move from hardcopy to electronic data storage requires rigorous management to ensure data integrity.
- Water and sewerage provision requires the input of a range of specialists and disciplines.
- It contributes to continuous improvement through the feedback of experiences and knowledge into the planning process.
- Itfacilitatescooperativesharingofknowledgeand information withinanorganisationandwithexternal stakeholders.
- It ensures that systems are in place to deliver information that is readily accessible, accurate, consistent and current.

3.4 WHEN SHOULD KNOWLEDGE AND QUALITY MANAGEMENT BE UNDERTAKEN?

Knowledgemanagementand quality management alreadyexisttovaryingdegreesinallorganisations, whichhave developed a continuous process of [2]:

- Creating, discovering and acquiring knowledge
- Capturing and storing knowledge
- Presenting, distributing and sharing knowledge
- Revising and disposing of knowledge

As this applies to all organisations who are concerned with infrastructure planning and design, it is thus not a question when to undertake knowledge and quality management, but rather how. Knowledge management procedures should address the full lifecycle of the planned infrastructure. Explicit and tacit knowledge of the design phase should be (kept) available during the operational phase of the respective facilities, and be traceable and locatable when rehabilitation or extension measures may become necessary.

3.5 IDENTIFICATION OF THE REQUIRED KNOWLEDGE

This involves identifying and prioritising which knowledge is required in order to provide effective and efficient planning.This includes knowing about [2]:

- The regulatory framework including compliance and approvals
- Local, regional and national planning initiatives
- The strategic direction of the service provider
- Trends in the water industry both in Uganda and abroad
- The actual needs of the customers and other stakeholders
- How the particular planned measures relate to other planning and existing measures in the same region
- What (master-)planning has previously been undertaken
- Factors that affect critical planning data (e.g. what is the basis of unit demands?What is the basis of cost estimates?) and design criteria to be applied
- Which information / data is already available and which has to be generated
- Conflicting water uses in the same area / region
- Regionalissuesthatwillimpactonwaterandseweragesserviceprovisionorwhich will beimpactedby these services
- Experiences of the organisation or other organisations with similar projects in the past
- Issues that may have potentially serious impacts on the service provider in the future (e.g. climate change)
- Planning and design standards to be applied

3.6 KNOWLEDGE AND QUALITY MANAGEMENT TOOLS

The Quality Management System (QMS) by the International Organization for Standardization (ISO) was created in 1987. Right from the beginning, these ISO standards were intendedto be applicable in different types of industries, based on the type of activity or process: design, production or service delivery.

Apart from standardized organizational tools however, it is important to select a strategy suitable to the respective organization and personnel structure.

Some basic tools which can help to improve and standardize the planning process within an organisation are listed in the following table [2]:

Table 1: Selected Basic Tools for Improving and Standardising Planning Processes

Tool	Aim	Processing
Meetings	To foster innovation and to share "lessons learned"	Regular and structured meetings betweenplanning and operations staff and where appropriate, relevant stakeholders.
Mentoring and Coaching	Transfer of expertise and tacit knowledge from experts to less experienced or knowledgeable staff	o Mentoring and skills transfer from senior planners to more junior staff. o Transfer of external consultants' knowledge to service provider staff. o Apply approaches that keep knowledge with the service provider staff rather than developing knowledge externally
Organisational Learning	Learning from situations and using this experience to continuously improve	Post completion audits/reviews in relation to project outputs (costs, benefits, timeliness, quality). Learning from the experiences of others through: o Meeting with similar organisations o Conferences/seminars, trainings o Technical literature o Benchmarking
Organisational Memory	A means by which past knowledge is brought to bear on present activities	o Post completion audits o Documenting information before departure of key staff o Documented procedures for the planning process o Documented Operations Management Plan which is kept up to date
Information Management	Collection, storage, analysis and presentation of outputs	Typical planning related information is listed in Section 4.2
Document Records Management	Collection and storage of documents and results	Registration, storage and retrieval of planning related documents (hardcopy and digital) including: o Planning reports o Models, calculations, spreadsheets and databases o Supporting studies o GIS files, maps, drawings
Innovation	State-of-the-art application and improvement	Workshops to include planning and operational staff plus external experts and other stakeholders as appropriate.Life-long learning for key staff to maintain and improve organisational skills and competence.
Market Research		Customer and other stakeholder surveys.

3.7 CHECKLIST

1. How confident are you that the data being used in the planning process is reliable? What has been done to ensure this level of confidence?
2. Has the tacit knowledge of (senior) operational staff been effectively utilised?
3. Have you learnt from the experiences of others? How?
4. Has the knowledge gained by the external consultant been transferred to the service provider?
5. Has the service provider been included in the collection and processing of information so that they have ownership of the knowledge?
6. Are the outputs of the planning process registered in a corporate library (hardcopy and digital)?
7. How have you been able to minimise the impact of losing key planning staff?
8. Have outcomes of the planning process been clearly communicated to stakeholders?

3.8 BIBLIOGRAPHY AND RECOMMENDED READING

[1] Wikipedia (cited November 2012):

- http://en.wikipedia.org/wiki/Quality_management
- http://en.wikipedia.org/wiki/Knowledge_management
- http://en.wikipedia.org/wiki/Quality_assurance

[2] Queensland Department of Environment and Resource Management (formerly Natural Resources & Mines), 2001, Guidelines for Implementing Total Management Planning – Information Management(http://www.derm.qld.gov.au/compliance/wic/pdf/Guidelines/tmp/2001_Guidelines/implementation/performance_2.pdf)

[3] Queensland Department of Environment and Resource Management (formerly Natural Resources & Mines): Planning Guidelines for Water Supply and Sewerage. ISBN 1 921062 13 4 (CD-ROM) ISBN 1 921062 14 2 (Electronic data). April 2010. Web site: www.derm.qld.gov.au

[4] ISO 9001:2008 Quality management systems — Requirements

4. PLANNING AND DESIGN PRINCIPLES

4.1 PURPOSE

The general purpose of the planning and design process is to achieve the following:

- Identification of the short, medium and long-term service requirements based on clearly defined technical and non-technical criteria with stakeholder involvement.
- Determination of a strategy for delivering service levels at the lowest financial (investments, operation and maintenance cost), social and environmental cost for the most feasible option.
- To minimise the risks and also to influence these.
- Evaluation of the options using multi-criteria analysis and selection of the feasible options.
- Communication of the outcomes of the planning and design processes to decision makers through reports.

4.2 KEY PLANNING PRINCIPLES

The key planning principles to be applied during the planning process for water supply infrastructure can be summarized as follows:

- Planning should include a comprehensive and rigorous identification of all options to meet the defined service levels, including options based on non-asset solutions.
- Planning should be an iterative process, which attempts to balance service needs with infrastructure, operation and maintenance, financial and environmental options.
- Key stakeholders should be identified and involved up-front in the planning stage in a partnership approach.
- Non-asset solutions, full lifecycle costs, risks and maximising existing infrastructure capability should be considered before deciding to either construct new assets or to replace existing assets.
- Application of strategic thinking, rigorous analysis and an integrated approach for water supply infrastructure development contributes to effective planning.
- Operational issues have to be tackled and solutions incorporated into the planning process in order to ease future operation and maintenance.
- Good quality data is critical for water supply infrastructure planning.
- Water infrastructure planning should be based on the best information available at the time and an investment should be made in acquiring information on an on-going basis to continually improve the knowledge base.
- Water supply infrastructure should be developed within sustainable limits especially with regard to the available water source.

4.3 STAKEHOLDER INVOLVEMENT

4.3.1 Identification of the Stakeholders

Stakeholders,and their desires and concerns,must be identified at the very start of a water supply project or infrastructure initiative. This should be done after the project idea has in principle been approved by the authoritiesand hence a set of objectives can be defined to facilitate stakeholder identification. The stakeholders will vary depending on the type of planning initiative and the phase of the project and can be individuals or organisations affected by or concerned with the initiative or the project. They may include public, private statutory, local and national interest groups, local communities and NGOs. A number of tools can be used in identifying stakeholder groups. These include relationship diagrams between the providers and the customers, project process diagrams and infrastructure life-cycle diagrams.

4.3.2 Stakeholder Involvement and Analysis

Stakeholder involvement promotes a sense of ownership through influencing planning and project outcomes. In addition, it contributes to sustainability through motivation, maintenance, cost recovery and continuing support (Carter et al., 1999). Stakeholder involvement needs to be interactive for successful planning. Different participatory approaches and techniques are needed to engage stakeholders depending on the purpose of the engagement, the audience and the desired outcomes. They include the production of quality information through newsletters and reports, active involvement in workshops and consultations using well-designed questionnaires and other documents. The best practice is to use a combination of these techniques to meet the widest range of needs and expectations of the stakeholders.

Stakeholder analysis should take into account the importance, involvement and requirements of stakeholders,depending on the time and phase of the project. The stakeholder analysis outcome should include individuals and organizations who:

- Depend on the project
- Will be affected by the project
- Influence the project
- Are interested in the foreseen project outcome
- Are against the foreseen project outcome

4.3.3 Incorporation of Stakeholder Views in the Project

An analysis of the stakeholders' needs and appreciation of their objectives helps to identify potential impacts (both positive and negative) and remedial measures. It is also essential to demonstrate to stakeholders that their views have been taken into account. Changes in decisions and mitigation of problems as a result of issues and concerns which stakeholders have raised should be documented and explained for transparency reasons.

4.4 AFFORDABILITY CONSIDERATIONS

The "ability to pay” and “willingness to pay” by the users of the water supply facilities depend on the tariff structures and the related service levels. A detailed socio-economic study is required to determine the appropriate service levels based on the income levels of the beneficiary community. The financial implications of operating, maintaining, managing, rehabilitating and replacing a given technology should be considered. The emphasis should not always be on minimising investment costs, but also on analysing the O&M costs that the users can afford and are willing to pay. A realistic tariff should be based on the assessment of affordability at household level and on the feasible sources of household income,as user affordability can be a constraint to project sustainability.

Affordability considerations can strongly influence the choice of the technology to be provided as well as determine the design process:

- The poorer the population, the lower the water price should be (if no subsidisation is introduced).
- The poorer the population, the more subsidisation is required for paying the connection fee (yard taps), during and after construction.

- The lower the water price, the lower the costs for operation and maintenance (O&M), incl. management must be.
- The lower the available budget for O&M, the more gravity systems are necessary, the less water treatment can be included (but water quality standardsmust still be met).

The overall result might be that an option will be selected which is not the best option when making the overall financial calculations, but which is affordable for the population in terms of covering O&M cost.

For existing systems, the tariff shall be based on actual O&M costs of the water supply infrastructure rather than an assessment of affordability. In case the tariff exceeds affordability, compensation measures have to be foreseen, after clarification whether any possibility of reducing O&M costs has been implemented (detailed analysis of current O&M conditions).

4.5 PRINCIPLES FOR THE CHOICE OF TECHNOLOGY

The following principles shall apply to the choice of technology in general and to the specific components of the selected option:

- Stakeholders need to be involved in technology selection from the start of the process in order to understand the technical, financial and other implications of their choice.
- The technology must be understandable and physically within the capability of the people responsible for operation and maintenance.
- Choice of spare parts and equipment should be based on availability of credible and reliable supply in Uganda
- The technology must be affordable by the users.
- The technology should be environmentally friendly.
- The technology should be robust and reliable.
- The technology or level of service provided must be attractive and culturally acceptable to the users.

4.6 CONSIDERATION OF LIFE CYCLE COSTS, O&M IMPLICATIONS, AVAILABILITY OF SPARE PARTS

4.6.1 Lifecycle Costs

Cost information is essential for proper planning, budgeting and implementation of sustainable water supply infrastructure. From a life-cycle perspective, the different components of the costs include:

- **Capital cost:**This is the capital invested in constructing or rehabilitating water facilities such as water intakes, pumps, reservoirs and pipes. It includes expenditure on a new system, extension of the system, enhancement and augmentation of the existing infrastructure.
- **Financial cost:**This isthe cost of borrowing or otherwise acquiring the resources to provide the assets needed for a service, and which is made up of interest payments on debt and dividend payments to equity providers.
- **Operational and maintenance cost:**This refers to expenditure on repairs, electricity, fuel, chemicals, materials, labour and other administrative activities.
- **Asset replacement cost:**This is related to expenditure on asset renewal, replacement and rehabilitation (depending on asset lifetime; please refer to Chapter 13).
- **Direct and indirect support cost.** Direct support cost involves support to improvethe capacity of the local government staff to carry out planning and monitoring, and support to community management structures and awareness campaigns. Indirect support cost involves formal training for professionals and technicians, developing and maintaining frameworks and institutional

arrangements. Direct and indirect support costsare usually considered a sub-item of investment cost, as being not recurrent.

4.6.2 O&M Implications

Operation and maintenance (O&M) functions relate to daily running and upkeep of assets and are particularly important for assets such as pumps and other electro-mechanicals whose deterioration through lack of regular maintenance may result in failure. The operation and maintenance costs have an impact on the tariff and sustainability of the water supply infrastructure. Costs of operation and maintenance will usually increase as the assets age.

Establishing standardized O&M procedures achieves maximum asset life, provided periodic maintenance is performed as required,and also reduces O&M costs. Standardizing O&M procedures helps personnel to operate all assets within acceptable operational levels and ensures that each person is following the same routines. O&M procedures may be developed by the manufacturer or supplier of the equipment for new facilities or by the technical staff for existing facilities or assets. Before handover of the facilities to the operator, the Contractor or Supplier shall bring together all relevant information into a single document, i.e. an O&M Manual. In case of existing infrastructure, it is highly recommended that such an O&M Manual shall be prepared by the operator. O&M procedures to be included in the O&M Manual involve operational, maintenance and laboratory procedures as shown below:

Operational procedures include:

- Standard operating procedure that is typically used during normal daily operations.
- Alternate operating procedure used when operational conditions require that an asset or process be modified or taken off line.

Maintenance procedures include:

- Corrective maintenance procedures used by field technicians for the repair of broken down assets.
- Preventive maintenance procedures to prevent breakdown and prolong asset life such as lubrication or overhaul.
- Reliability centred maintenance procedures for predicting asset failures and minimising the effects of asset failure.

Laboratory procedures include:

- Equipment-related procedures for operating and maintaining the equipment and calibration requirements.
- Sampling-related proceduresfor laboratory technicians that specify when, where, and how samples should be taken, and which, how and how often parameters should be analysed.

The appropriate operation and maintenance strategy for a water supply system depends on a range offactors that include:

- Technology: complexity, familiarity, standardization, availability of spares and skills required.
- Demography: number of people served depending on scattered or dense population.
- Environment: effect on the water source and on materials and equipment.
- Accessibility to the facilities or system components.
- Total cost of O&M and the users' willingness and ability to pay.
- Level of community organization and cohesion; existing management structures and skills.
- Efficiency of support agency management.
- Government policy and legal framework.

4.7 CHECKLIST

1. Is there adequate evidence to support the need for the initiative?
2. How reliable isthe information provided for the planning study? Has the validity of this information been confirmed?
3. Have all the stakeholders and their needs been identified? Have their needs been addressed?
4. Has the outcome of stakeholder analysis been documented and has it been explained to stakeholders how this affected the initiative or project?
5. Have the resources/skills allocated to the planning been appropriate to the scope of the study?
6. Is the level of strategic thinking sufficiently robust? How has this been facilitated?
7. Have a sufficiently wide range of options for water supply infrastructure provision been considered? How were the options identified?
8. Has there been an adequate analysis of lifecycle revenues and costs, social and environmentalimpacts?
9. Have non-asset parameters (socio-economy, sustainability) been adequately identified and assessed?
10. Have the risks been rigorously evaluated?

4.8 BIBLIOGRAPHY AND RECOMMENDED READING

[1] Asset Management: A Guide for Water and Wastewater Systems.Prepared by Environmental Finance Centre New Mexico Tech. 2006 Edition.

[2] Department of Environment and Resource Management, Australia. Planning GuidelinesFor Water Supply & Sewerage. 2010.

[3] Linking technology choice with operation and maintenance in the context of community water supply and sanitation.World Health Organization and IRC Water and Sanitation Centre Geneva, Switzerland, 2003.

[4] Strategic Financial Planning for water supply and sanitation in Africa. Rationale, methodology, experience, lessons learned. EUWI-FWG, 2010.
Source (cited November 2012): http://www.euwi.net/files/EUWI_Strategic_Financial_Planning.pdf

5. PLANNING AND DESIGN PROCEDURES

5.1 PURPOSE

The purpose of well-structured planning and design procedures is to determine and set objectives, identify the required activities at planning and design stages and develop a strategy for producing designs of facilities that can be operated on a sustainable basis during their entire technical lifespan.

5.2 KEY PRINCIPLES

The following key principles shall apply in the planning and design of water supply infrastructure:

- Sustainability of the water supply system to ensure that the benefits of the investment will continue throughout its technical and economic life.
- Affordability of the technology and service by all the beneficiaries including the poor.
- The water source for the water supply system or the point water source shall be exploited on a sustainable basis and its catchment area shall be protected.
- Effectiveness to ensure that the provision of a water supply system will attain its outcomes and purpose shall be emphasised.
- The water supply system shall be designed to operate efficiently to attain optimum outputs qualitatively and quantitatively in relation to project inputs.
- The relevance and appropriateness of the project with respect to government priorities and policies, and the stakeholders' needs.

5.3 PREPARATORY WORKS

5.3.1 Preparatory Data Collection

Data is useful during the planning and design stage and it is important to prepare adequately to ensure that the information obtained is accurate and reliable. At this stage, tools and techniques for data collection shall be prepared and pre-tested before the actual data collection exercise starts. A checklist is usually prepared before data collection to prevent the omission of information or activity important for the process. It is also important to ensure that data collectors are competent and well versed with the data collection tools. Data collection has different forms in relation to water supply infrastructure provision and includes the following:

- Collection of socio-economic data during baseline surveys required for determining the service levels and water demand projection.
- Hydro-geological and hydrological investigations to obtain data on water quantity and quality.
- Topographical surveys to accurately establish significant local variations in the topography and obtain data about altitudes and distances to aid in hydraulic design. In addition, key features such as existing infrastructure and administrative centres, potential sites for key installations like storage tanks are included.
- Soil investigations are especially applicable with respect to foundations for water treatment facilities and elevated storage tanks.

The socio-economic survey shall include a combination of household survey interviews, key informant interviews and focus group discussions. The following process shall be followed in preparing for the collection of socio-economic data:

i) Preparation of a questionnaire complete with relevant questions for obtaining baseline data. Different questions for households, institutions and key informants shall be prepared.

ii) Determination of the sample size, depending on the project area population characteristics.
iii) Training of enumerators.
iv) Pre-testing the questionnaires.

5.3.2 Preparatory Stakeholder Consultations

The preparation of stakeholder consultations for effective involvement is important atdifferent planning stages and can be achievedin the following ways:

- Providing reliable information to the stakeholders in a form whichthey can understand.
- Ensuring that there is time to participate, to build trust, to learn, to resolve disputes, to create solutions.
- Obtaining the commitment of stakeholders through preliminary interactions during the identification process.
- The willingness to learn amongst stakeholders.
- Sharing authority and responsibility to affect and implement decisions.

Stakeholder mapping is important in order to know the relationship and relative importance of each stakeholder group before the consultations are made. A number of tools that may be used to assist in the identification of stakeholder groups include:

- Evaluation of current accountability and reporting frameworks
- Relationship diagrams illustrating the relationships between the service providers and various stakeholders (elected members, owners/shareholders, customers, suppliers).
- Process diagramswhich outline the stakeholders involved in processes such as the project approval process; from need identification, project planning and prioritisation through to financing and budget approval.
- Infrastructure lifecycle diagramswhich indicate the stakeholder groups impacted or which have an interest in various stages of the asset lifecycle

5.4 CONTENTS

Based on project cycle management, the starting point is the identification of needs and the formulation of a related project concept.For water supply systems in small towns and rural growth centres, the beneficiaries prepare a brief report of their needs to the district water office. The proposals from different communities are then ranked for prioritisation and inclusion in the district development plans depending on the need and the available funds. Water supply projects for urban areas are usually initiated from the centre in consultation with the Water and Sanitation Development Facility (WSDF) for inclusion in the budget and development plans.

The design stage, which follows the project formulation stage, is carried outin two steps: feasibility study and detailed design. Both are presented hereunder.

5.4.1 Feasibility Study Reports

In Uganda, feasibility studies are to be carried out for major water supply projects including piped water supply systems, bulk water transfer systems and dams.No such studies are required for point water sources such as spring sources, shallow wells and boreholes fitted with hand pumps.

The feasibility study shall include baseline surveys and preliminary designs for the identified alternatives and culminate in the feasibility study report. The following content shall apply for the feasibility study report:

1) Cover page with the project title, the Client's name and logo and the submission date

2) Table of contents

3) Executive summary with main findings from the feasibility study

4) Introduction

- Background information highlighting the project identification outcomes
- Study objectives
- Scope of the feasibility study
- Project area location and boundaries, topography
- Climate
- Land use

5) Findings from the baseline survey; socio-economic report

- Administrative status of the study area
- Educational institutions in place
- Health facilities
- Income levels, ability and willingness to pay for water supply services
- Commercial and industrial establishments
- Means of transport and communications

6) Water resources investigations (hydrological and hydro geological)

7) Detailed appraisal of the water supply system options

- Basis for assessment
- Design criteria
- Preliminary design options
- Environmental impact assessment considerations for the alternatives. This should be part of the criteria for the selection of the best option. The outcome of the screening process depends on the nature of the project and may necessitate carrying out an Environmental Impact Study.
- Management options
- Estimates for investment costs, O&M costs for the alternatives
- Cost-benefit analysis for the options
- Phasing strategy for the feasible options based on the resource envelop

8) Conclusion and recommendations

5.4.2 Detailed Design

After completion of the feasibility study, a detailed engineering design is to be prepared for the preferred alternative agreed upon by the Client (district, MWE/DWD) and other stakeholders. The following content for the detailed design report shall apply:

1) Cover page with the project title, the Client's name and logo and the submission date

2) Table of contents

3) Executive summary

4) Introduction

- Background
- Project objectives
- Scope of the study

5) Previous studies (summary of Feasibility Study)

6) Situation assessment and analysis (in case previous studies are missing or need updating)

- Project area location and boundaries, topography
- Population
- Climate
- Land use
- Economic activities
- Settlement pattern
- Existing water supply situation
- Existing sanitation situation

7) Design criteria

8) Population projection and water demand estimation

9) Water supply system variants (a summary can be presented if a detailed feasibility report exists)

- Water source investigations: Water quantity and quality for both ground and surface water sources including sustainability considerations
- Appraisal of the technically feasible variants
- Financial analysis of the variants taking into account investment costs, O&M costs, residual values etc.

10) Detailed design drawingsincluding all variants of the following water supply system components for the selected option

- Raw water intake or production well
- Raw water transmission
- Water treatment unit operations and processes (major or minor treatment depending on the raw water quality)
- Treated water transmission
- Water storage tanks or reservoirs
- Pumping stations and booster stations
- Distribution system (pipelines, connections)

The network design shall be based on the design criteria in the report using stateoftheart software for network modelling(the use of widely used software such asWaterCAD, and EPAnet is recommended). All structural drawings with all the required details shall be prepared for all major works including reinforced concreted structures, concrete structures, steel structures and stone masonry structures. Structural drawings for all reinforced concrete works must have a bar bending schedule

11) Environmental Impact Assessment

12) Cost estimates and financial analysis

- Capital investment cost
- Investment per capita
- O&M costs
- Financial analysis and tariff determination

The cost estimates in the design report shall be based on the BoQprepared using plausible unit prices in Uganda.

13) Development and management strategy for the water supply system

- Proposed development strategy depending on the resource envelop and water supply infrastructure components
- Proposed management for the water supply option

14) Appendices (minimum requirement)

- General layout, layout of the transmission and distribution network
- Detailed hydraulic calculations for both peak hourly and static conditions
- Detailed structural calculations
- Detailed financial analysis calculations

5.4.3 Tender Documents

The format of the tender documents should enable the contractors to understand the scope of work. They should include all sensitive contractual areas of the project and ways to minimise contractual problems from arising during the construction phase. The typical tender documents used in Uganda include the following:

- Invitation for Tenders
- Conditions of Tender and instructions to bidders
- Forms of Tender as an appendix to Tender and Tender Security
- Form of Agreement
- Forms of Securities for performance and advance payments
- General Conditions of Contract
- Special Conditions of Contract
- Technical specifications
- Bills of Quantities (uncosted)
- Drawings (optional)

The Bills of Quantities shall be prepared for all civil works and preliminaries and general items using Civil Engineering standard methods of measurement CESMM3 1995 or CESMM4, 2012. The Bills of Quantities shall include the following:

1) Cover page with the project title, the Client's name and logo and the submission date.
2) A preamble with a summary of the requirements and special conditions to be met, civil works to be undertaken, any issues concerning variations.
3) The estimated quantities shall be based on detailed engineering drawings approved by a registered engineer of the Consultant or from the Ministry of Water and Environment/DWD.
4) A summary page of the total cost of the main system components subdivided into the major cost items such aswater source, water treatment unit(s), treated water transmission, storage tanks, electro-mechanicals. Costs for general items, method related charges and software activities should also be included.
5) The main purpose of a Bill of Quantities (BoQ) is to define and itemize a project in a way that all tenderers prepare their price and submission on the same information.
6) All services should be described clearly and unambiguously.

Only the Client (in case of internationally funded projects also the Donor Organisation/IFI) will receive the costed Bills of Quantities in hard and soft copy. Costing needs to be done based on the following approaches:

- The costs shall be estimated in an understandable and reproducible manner
- The cost estimates shall be based on plausible unit prices

5.5 FORMATS TO BE USED

The feasibility study and detailed engineering reports shall be prepared using appropriate office software such as Microsoft Word and Microsoft Excel in A4 format. The reports should be concise and complete content wise and all detailed information shall be included as an Appendix. Appendices to the reports in the form of drawings, tablesor figures,may be printedin A3 format. All pages in the reports shall be numbered and the table of contents shall include three section levels and the page numbers. Tables and figures within the reports shall be named and a separate table of contents prepared for each of these. A table presenting the abbreviations and acronyms used shall also be included. The main maps and drawings have to be presented in a scale and size allowing for a decent analysis.

The following formats shall apply to drawings:

1) All detailed engineering drawings shall be prepared in AutoCAD oranother equivalent software.
2) Topographical profiles shall be drawn and printed to scale on A3. Typical scales used are 1:200 for the vertical scale and 1:2000 for the horizontal scale.
3) SI units shall be used for dimensions.
4) Longitudinal sections (hydraulic profiles) shall include chainage (m), ground level (masl), invert levels (m), section slopes (%), hydraulic static and dynamic pressures (verification of gravityconditions by sufficient dynamic pressure; sufficient pumping head), locations of air valves and washouts, locations of connections and other important elements.
5) Plan views and details for valve chambers, reservoirs, pumping stations, treatment plants.
6) Node details for each single node.
7) Sectional views of different elements of the structural drawings shall be drawn and printed to suitable scales for legibility and with details of schedules.
8) The general layout of the transmission mains and distribution network may be printed to scale on A2, A1 or A0 depending on the size of the scheme.
9) All drawings shall be provided with a title block completed with the project title, scale and scale band, north arrow (where applicable), and place for the initials of the designer and person who checks and approves the drawings and the corresponding dates.
10) Titles and drawing numbers of profiles, structural drawings and standard drawings shall be included in the table of contents.

The number of hard copies of the reports and drawings to be submitted with the soft copy will be as specified in the Terms of Reference. A soft copy of the hydraulic modelling has to be providedin order to enable the reviewer to assess input data and to check the quality of optimisation.

5.6 CHECKLIST

1. Do the outputs and outcomes of the projects meet the needs of beneficiaries?
2. Is the investment relevant to sector strategic objectives and policies?
3. Will the outputs achieved continue to promote their effects?
4. Is there any replication possibility of the technology or initiative from one place to others?
5. Have the planned objectives been achieved?
6. Are the objectives expected to be achieved over the design horizon?
7. Could outputs be reduced without impacting the achievement of the objectives?
8. Are there sufficient financial and human resources to implement activities at once or in phases?
9. Are there plans in place for initial evaluation, mid-term evaluation, completion evaluation and impact evaluation?
10. Are the different alternatives for the water supply adequately explained and are any comparisons made based on clearly defined criteria?
11. Have soil investigations been carried out for sites where foundations for all load-bearing structures such as reinforced and non-reinforced concrete works, elevated storage tanks, office blocks etc. are to be constructed?
12. Are the engineering drawings drawn and printed to scale, with a complete legend and sufficient details?
13. Have all the necessary drawings for different sections and views been provided?
14. Have the drawings and design reports been reviewed by a registered engineer or equivalent competent authority?
15. Are all documents of the tender consistent and without contradictions?
16. Have the relevant standards been respected in defining the Technical Specifications?
17. Have the BoQs been produced based on the drawings?
18. Are the cost estimates in the BoQs based on plausible unit process?
19. Is the costed BoQbased on current market prices?

5.7 BIBLIOGRAPHY AND RECOMMENDED READING

[1] Water supply design manual 2012, Final Draft, prepared by AIM Engineering by order of the Republic of Uganda, Ministry of Water and Environment.

[2] IRC International Water And Sanitation Centre**.** Making your water supply work. Operation and Maintenance of small water supply systems. Occasional Paper Series.

[3] Design reports for recently implemented water supply systems for small towns in Uganda**.**

6. DEMAND PROJECTION

6.1 PURPOSE

The accurate assessment of current and future water demand is the starting point for the design work. The main purpose of demand projection is thus to ensure that not only the current demand, but also the future demand up to the design horizon can be covered by all infrastructure elements of the water supply system to be designed.

Water demand is thus to be understood as the amount of water that will be used by all groups of consumers, assuming that no limiting factor such as lack of resource, lack of pressure, negatively perceived water quality, inaccurate distribution etc. will interfere. In well-functioning systems, water demand and water consumption match each other.

6.2 KEY PRINCIPLES

It is preferable to present the calculation of water demand for each single year up to the given design horizon.

The following key principles rule:

- Water demand has to be calculated based on available data and projections, accuracy of provided data has to be assessed.
- Population projections have to take into account that creating a new system in an area lacking sufficient systems will attract more people to move to this new system (internal migration as well as rural depopulation); historical growth rates from the past will be exceeded (in addition, child mortality is expected to decrease, having a further positive influence on growth rates).
- Water demand has to introduce projections based on these data.
- Water demand has to be expressed as the sum of the specific water demands multiplied by their respective numbers of units; if not applicable as a percentage of eitherthe total consumption or of household consumption.
- Water demand has to be calculated for each consumer group separately.
- The total water demand is the sum of the water demands of all consumer groups.
- For systems supplying more than one settlement, demand calculations have to be done separately for each settlement.

6.3 SERVICE AREA

The water demand calculation has to be performed for the area that will be serviced by the infrastructure to be designed. This might be a complete settlement where no system exists, or a part of a settlement requiring an extension from an existing water supply system. The decision on the service area subject to planning is usually decided prior to the project. Adaptations may occur depending on planning results.

6.4 HOUSEHOLD DEMAND

Household (domestic) demand usually accounts for the majority of the demand. Therefore, it is of utmost importance to assess it as realistically as possible, even if the future is hard to predict.

6.4.1 Demographic Growth

One key element in assessing household demand is knowledge of current and predicted future population figures. The better the quality of the data and the projections are, the better the result. Population data are usually available at local government units and at central levels too. Projection of population growth is usually the business of UBOS.The data provided shall be cross-checked by on-site verifications.

It might be that for different time horizons different growth rates have to be applied (depending on the statistical projections made by UBOS).

6.4.2 Specific Consumption

The specific consumption, calculated as lpcd, depends on the level of service. The level of service is usually defined by the capacity of each consumer to pay for an individual connection. Usually, the selected specific consumptions are invariant to change over time. This is one basic assumption for design.

6.4.2.1 House Connection

A house connection delivers the best service for people. As a result, the specific consumption is the highest amongst all premises. The range may vary according to the living standard. A usual range is between 50 to 200 lpcd, with most consumers being between 80 to 100 lpcd.

House connections can be further broken down into income categories:

- High level income
- Medium level income
- Low level income

Each category has different consumption patterns and thus different specific consumptions to be applied to.

6.4.2.2 Yard Tap

Yard taps are taps installed as a unique water source in the yard of a premise. A usual range of specific consumption is 20 to 40 lpcd. The actual specific consumption is to be based on reasoned assumptions by the designer based on all available information. The respective assumptions as made by the designer must be documented accordingly in the Feasibility Study and the Design Report.

6.4.2.3 Public Standpost

Public standposts consist of a tap or a number of taps installed on one connection line. People are supplied by means of buckets or similar recipients. The usual range of specific consumption is between 5 to 20 lpcd.The actual specific consumption is to be based on reasoned assumptions by the designer based on all available information. The respective assumptions as made by the designer must be documented accordingly in the Feasibility Study and the Design Report.

6.4.3 Development of Service Levels

Service levels (house connection; yard tap; public standpost) are derived based on the end consumers' ability to pay – which is established from the results of the socio-economy survey. It is based on the assumption that 5% of household revenue can be dedicated to water related expenses (water supply and sanitation/sewerage). A graph of expenditures and cumulative percentages of ability to pay proportions is used to derive service levels at selected tariff levels.

The connection rate during a certain time horizon is thus the percentage of people that will be supplied with a specific service level compared to the total population over the same time horizon. The sum of all service levels must always come to 100%.

Designers have to be aware that with economic development the ratio between house connections, yard taps and public standposts will change. In time, the number of house connections will usually increase. Prediction of the development of the figures of the different possibilities for people to have access to water is a key element of good planning.

6.4.4 Overall Household Demand

The overall household demand is the sum of the specific demand multiplied with the relevant figure for the connection rate multiplied by the served population for each single time horizon:

(6.1) $Q_{HH,i} = Q_{HC,i} + Q_{YT,i} + Q_{PS,i}$

With:
$Q_{HH,i}$: Overall household demand at time horizon i
$Q_{HC,i}$: Demand by household connections at time horizon i
$Q_{YT,i}$: Demand by yard taps at time horizon i
$Q_{PS,i}$: Demand by public standposts at time horizon i
i: The difference between the year the calculation is for and the year serving as a starting base

The consequences of being partly supplied by rainwater are depicted in Section 6.10.1. The calculation of the different sub factors of household demand is presented hereunder:

(6.2) $Q_{HC,i} = q_{HC} * Pop_i * CR_{HC,i}$

With:
QHC,i : Water demand of people with house connections at time horizon i
q_{HC} : Specific consumption for house connections (lpcd)
P_{opi} : Population at time horizon i
$C_{Rhc,i}$: The connection rate of house connections at time horizon i
i: The difference between the year the calculation is for and the year serving as a starting base

For the water demand for people supplied by yard taps or standposts, the basic formula is the same, but the right factors have to be used (specific consumption of yard taps and connection rate for yard taps; specific consumption of public standposts and connection rate for standposts; all for the time horizon under consideration).

The relevant population is calculatedaccording to the following formula:

(6.3) $Pop_i = Pop * (1 + gr_{pop})^i$

With:
Popi : Population at time horizon i
Pop: Population in the year of calculation
gr_{pop} : Yearly growth rate of the population as an absolute figure (if used as a percentage, then divide by100 before performing the sum inside the brackets)
i : The difference between the year the calculation is for and the year serving as a starting base

6.5 SPECIAL CASE: TRANSIENT POPULATION

Transient population (commuters) are people working in one place but living in another. During working hours, they will consume potable water, but not at the same level as resident people living and working within the same area (and supplied by the same system).

In an existing metered water supply system, ifreliable consumption data are available allowing the deductionof specific consumption figures, transient people do not need to be taken into account, as the specific figures will already include their consumption (in institutional, industrial and commercial demands).

For new systems, assessing the number of transient people is a challenge in itself. Sometimes, local government units have some figures, sometimes sector ministries. A second element is the size of the town; the bigger the town, usually the higher the number of transient people (not only in absolute figures, but also expressed as a percentage of the resident population). The main reason for this is that prices for plots, apartments and houses are higher than in smaller cities or rural areas, making it unaffordable for some people to settle in the town. Usually, there is a positive correlation between water consumption of non-domestic consumers (institutions, industry and commerce), expressed as a percentage of total consumption, and the number of transient people.

Where facilities with flushing toilets exist, the specific consumption of transient people is usually set at around 50% of the specific consumption of the household demand generated by house connections. For other cases, the percentage has to be decided accordingly depending on the available infrastructure.

The number of commuters may also vary over time. A usual approach is to take a certain percentage of the population to calculate the numbers of commuters for each time horizon:

(6.4) $CO_i = Pop_i * RC$

With:
CO_i : Number of commuters at time horizon i
Pop_i : Population at time horizon i
RC: Ratio of commuters (% of population)
i : The difference between the year the calculation is for and the year serving asa starting base

The additional water demand generated by commuters is thus:

(6.5) $Q_{CO,i} = q_{CO} * CO_i$

With:
$Q_{CO,i}$: Water demand of commuters at time horizon i
q_{CO} : Specific consumption for commuters (lpcd)
C_{Oi} : Number of commuters at time horizon i
i: The difference between the year the calculation is for and the year serving asa starting base

6.6 INSTITUTIONAL DEMAND

Institutional demand is generated by people working in institutions, or by institutions requiring water for their activities (such as watering public green areas). In case no specific data are available, the institutional demand can be expressed as a percentage of household demand. Settlements already equipped with a reliable water supply system in terms of 24/7 supply, fully metered, with a low amount of NRW (reliable metering in place) and of comparable size to the one subject to design may be used as a reference to assess a range of percentages for the institutional demand. Usually, it is in the threshold of 2%-10%, depending on the importance of the place.

6.6.1 Specific Institutional Demand

Usually, the institutional demand generated by small institutions is considered as a block demand, without taking a closer look at the different institutions.It is then expressed as volume per time unit (m^3/d; m^3/y).

A special look only has to be taken at institutions accounting for important water consumption (big consumers)such as hospitals, prisons, military camps etc.i.e. institutions with an important number of people working/staying there.

Prisons and military camps can be considered as occupied by resident people and the respective specific consumption applied.

For hospitals, the assessment of specific water consumption expressed in l/bed/day is more difficult, as different services generate different demands. It is likely that data on water consumption for hospitals of different sizes are available at the Ministry of Health. By knowing consumption data and the number of beds, it is easy to calculate the specific demand.

6.6.2 Overall Institutional Demand

The overall institutional demand is the sum of the specific demands multiplied with the relevant figures.

For assessing the future institutional demand, it is recommended to use a growth rate that is not higher than the one applied for population development. Only if special circumstances are obvious for the future, this approach may be obsolete.

The growth rate may be calculated for each big institutional consumer separately. Military camps for instance have in most cases no growth rate, whereas hospitals might have, especially if new services are offered.

$$Q_{inst,i} = q_{inst} * (1 + gr_{inst})^{i} + \sum q_{BGinst,j} * (1+gr_{inst,j})^{i} \quad (6.6)$$

With:
$Q_{inst,i}$: Water demand of institutions at time horizon i
q_{inst} : Specific consumption ofinstitutions not considered as big consumers
gr_{inst} : Growth rate of institutions not considered as big consumersat time horizon i
$\sum q_{BGinst,j}$: Sum of the water demand of all big institutional consumers
$q_{BGinst,j}$: Specific consumption of each big institutional consumer (from 1 to j)
$gr_{inst,j}$: Growth rate for each big institutional consumer (from 1 to j)
i: The difference between the year the calculation is for and the year serving as a starting base

6.7 INDUSTRIAL DEMAND

For small-scale industries such as grain milling, ginneries etc. the industrial demand can often be expressed as a percentage of household consumption (please refer to Chapter 6.7.3, formula 6.8). Large-scale industries are often big consumers and are to be treatedindividually.

Assessing the industrial demand requires visiting the industries and talking to the officer in charge of infrastructure. Industrial demand varies widely from one place to another, depending on the number and size of the industrial complexes, their type and on the number of shifts. Industrial demand has to be assessed on a yearly, monthly, daily and even hourly basis. The best solution is to prepare one template for questioning and another one for analysingthe replies for an easy calculation of current and future demands.

Industrial demand usually covers two elements:

- Water for human needs such as washing, flushing, cooking (where applicable) etc.
- Water for industrial processes

Assessing the industrial demand requires visitingindustries and speaking to the officer in charge for infrastructure to get information on:

- Currentlyused sources and sources to be used in the future
- Current consumption figures, if possible separated into human needs and process water, including daily averages and daily peak consumption
- Seasonal variations in demand (monthly consumption figures for at least one year)
- Future expansion
- Plans for raw material substitution as this may affect process water usage

In case consumption figures are not known, refer to the specific professional literature to make an informed decision on the data to use.

In addition, perspectives on the development of each single industry complex are required:

- Current and future staff figures (divided into workers and administrative staff)
- Current and future number of shifts
- Current and future working days per week
- Current and future seasonal peaks

- Foreseen changes in technology that might influence water consumption (changes in machinery, in processes, in products, recycling of water etc.)

For future industries, please refer to the urban development planning. In case this hasnot yet been developed, take other settlements of similar size and similar conditions into account to calculate a percentage for industrial water demand.

Total industrial demand is the sum of already settled industries plus the future ones.

6.7.1 Industrial Water Sources

Industrial complexes basicallyhave three possibilities to cover their water demand:

- Connection to the public water supply system
- Self-supply by tapping own resources (wells, spring catchments)
- A mixture of both

6.7.1.1 Connection to the Public Water Supply System

The connection of the industrial complex to the public water supply system is the usual case. Out of this source, both human related and process needs are covered. It is generally beneficial to the supply system operator too, as industries generate an important amount of revenues for the operator.

6.7.1.2 Tapping own Resources

In some cases, especially when the water tariff for industrial customers becomes an economic issue for the industry, the industrial complex might install a self-supply system. Only in rare cases, is self-supplied water treated to a level that covers human related needs as well. Usually, it is treatedat a level to fit with process quality requirements only.

If theindustrial complex is connected to a public sewer, this fact must be duly consideredas additional wastewater will be generated which does not correspond to the water consumption figures provided by (and known to) the water operator only.

6.7.1.3 Mixture of Public and Self-Supply

Depending on the raw water quality used by the industrial complex, it is often the case that the water for human related needs is delivered by a connection to the public water supply system, whereas process water is covered by self-supply.

In this case too, if the complex is connected to a public sewer,it is necessary to assess the additional amount of wastewater coming from the residual process waters.

6.7.2 Specific Industrial Demands

6.7.2.1 Water for Human Needs

Depending on facilities and processes in each industrial complex, the following specific demands can be taken as indicative:

Table 2: Specific Demand for Human Related Needs in Industries, Indicative

Item	Average Daily Demand		Average Hourly Demand
	Specific Demand	Demand (l/d)	Average Demand (l/h)
No daily showering for the workers required (clean production)	40 lpcd	40 * number of workers	Demand / shifts / working hours per shift
Daily showering required (dirty production)	75 lpcd	75 * number of workers	Demand / shifts / working hours per shift
Administrative staff	40 lpcd	40 * number of staff	Demand / working hours per shift (administrative staff isusually present during one shift only)
Kitchen (restaurant for workers)	5 lpcd	5 * total number of persons[1] (workers + administrative staff)	Demand / shifts / working hours per shift

Please be aware that the presented specific consumptions may vary from one place to another: investments in water saving facilities such as toilets with 2 flush buttons might reduce the specific demand by up to 50%, whereas heavily leaking toilets, showers and taps may double it[2].

In case an industrial complex offers regular accommodation to its workers and the accommodationis supplied by the industrial connection, the consumption of these workers shall be considered part of the household consumption, as the workers will have similar consumption patterns to other residents. By doing so, the purely industrial demand will then be reduced.The total daily demand for an individual industrial complex is the sum of its daily demands; its total hourly demand is the sum of the respective hourly demands.

The total industrial daily demand is, therefore, the sum of the daily demands of all industrial complexes together;similarly,the total hourly demand is the sum of all hourly demands of all industrial complexes together.

6.7.2.2 Process Water

Process water is water used in a manufacturing or treatment process or in the actual product manufactured. Examples would include water used for washing, rinsing, direct contact, cooling, solution

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[1] Assumption: the restaurant is open for all shifts. In case this does not happen, multiply the specific consumption with the number of workers and administrative staff that will be present during the opening hours of the restaurant.

[2] Please be aware that these water losses, when metered and thus registered, are not considered part of NRW by water operators, as they will bill for it. It might be that, only when the management of the industry becomes aware of it, will investments to rehabilitate the infrastructure and to reduce water consumptionbe introduced. It is therefore recommended, even if current consumption figures might lead to the conclusion that the specific consumption related to human needs is higher than shown in the table, only to use the higher figures for projections if good reasons speak for it.

make-up, chemical reactions, and gas scrubbing in industrial and food processing applications. In many cases, water is especially treated to produce the quality of water needed for the process.

The demand for process water (as far as this is not provided by private water sources, if so the demand for process water from the public supply system is logically zero) is not easy to assess. It depends on a variety of information required in order to make a sound estimate. For existing industries, consumption data might be available; the big challenge is to assess the water demand of future industries, especially if there is no urban development planning available limiting the type of industries allowed to settle in the urban area.

For existing industries, if data are not made available, either refer to professional literature, or find data for the same type of industries in other settlements connected to a public water supply system. Data might also be available at the sector ministry. You may then use this data by dividing the water consumption of the known industry by its known number of staff to get an overall figure for specific water consumption, and then multiply it by the number of staff in the industry under investigation. This will give you a good estimate. Please be aware that this approach has two assumptions:

- The industrial production lines are comparable (it doesnot make sense to compare a brewery with a milk dairy for instance) and the technology is similar (if one recycles water and the other doesnot, you will not get credible results).
- Similar water sources (both rely on public water supply as an overall source).

Industries do not always meter internal water flows to know the exact volumes used for processing and the exact volumesused for human needs. Therefore, by using the overall consumption of these industries and dividing it by the number of staff (office staff and workers),it is possible to calculate a specific consumption encompassing both; human related needs as well as process water needs. Be aware in this case, when multiplying the specific consumption with the number of people of the considered industry, not to double count the demand for human needs.

6.7.3 Overall Industrial Demand

The overall industrial demand for each industrial complex is thus the sum of the water used for human related needs and process water to be supplied by the public system:

$$Q_{ind,i} = Q_{HRN,i} * (1 + gr_{HRN})^{i} + Q_{PW,i} * (1 + gr_{PW})^{i} \qquad (6.7)$$

With:

$Q_{ind,i}$: Industrial water demand at time horizon i
$Q_{HR,i}$: Water demand for human related needs at time horizon i
gr_{HRN} : Growth rate of human related needs
$Q_{PW,i}$: Water demand for process water at time horizon i
gr_{PW} : Growth rate of process water
i : The difference between the year the calculation is for and the year serving as a starting base

To tackle the future demand, there are different approaches:

Table 3: Approaches for Defining the Future Industrial Demand

Starting point	**Subcategories**	**Specific Industrial Demand**
No current industries at all, but expected to settle after installation of the water supply system	Urban development planning available showing the size of land use allocated for industrial purposes up to the design horizon	Depending on the type of expected industry: 2-5 l/s/ha (rarely up to 10)
	No urban development available, or no land use for industries foreseen yet	% of household demand to be used for industrial purposes
Current industries existing but no consumption data available	Urban development planning available showing the size of land use allocated for industrial purposes up to the design horizon	Assess current specific consumption figures by comparable industries connected to other public supply systems. Compare the figures with relevant professional literature to ensure that the consumption figures are reliable (water metering working properly). Then calculate a specific water demand for each industry type. Multiply it with the growth rate derived from the respective questionnaires. The sum is the total future industrial water demand of existing industries. For future industries: 2-5 l/s/ha
	No urban development available, or no land use for industries foreseen yet	Assess current specific consumption figures by comparable industries connected to other public supply systems. Compare the figures with relevant professional literature to ensure that the consumption figures are reliable (water metering working properly). Then calculate a specific water demand for each industry type. Multiply it with the growth rate derived from the respective questionnaires. The sum is the total future industrial water demand of existing industries. Apply a growth rate for the future industries of half the population growth rate (as part of the growth is already included in the growth of current industries)
Current industries existing and consumption data available	Urban development planning available showing the remaining amount of land allocated for future industrial purposes up to the design horizon	Calculation of the future demand of: • Current industries based on the results of the questionnaires for their assumed development; • New industries based on 2-5 l/s/ha Alternative: the current percentage of industrial water demand to be multiplied by the growth rate applied for population development
	No urban development available, or no land use for industries foreseen yet	Current percentage of industrial water demand to be multiplied by the growth rate applied for population development

The total industrial demand is therefore the sum of the different industrial demands.

Simplified formula based on household demand:

(6.8) $Q_{ind,i} = q_{ind} * Q_{HH,i}$

With:

$Q_{ind,i}$: Overall industrial demand at time horizon i (in l/s)
q_{ind} : Specific industrial demand (as a % of household demand)
$Q_{HH,i}$: Household demand at time horizon i (in l/s)

For each year, the industrial demand is expressed as an invariant percentage of household demand.

Simplified formula based on land use:

(6.9) $Q_{ind,i} = q_{ind} * A_i$

With:

$Q_{ind,i}$: Overall industrial demand at time horizon i (in l/s)
q_{ind} : Specific industrial demand (in l/s/ha)
Ai : Area subject to industrial purposes (in ha) at time horizon i

Mixture of both simple formulas:

(6.10) $Q_{ind,i} = q_{ind,1} * Q_{HH,i} + q_{ind,2} * A_i$

In this formula, two different industrial specific demand values are introduced, $q_{ind,1}$ being a percentage of household demand, whereas$q_{ind,2}$ deals with land use specificities.

6.8 COMMERCIAL DEMAND

Usually, commercial demand will notreach more than a few per cent of household demand; only in centres of touristic relevance, where hotel and restaurant activities are important, can the percentage go up, but usually limited to the tourist season.

6.8.1 Specific Commercial Demands

The overall demand of small scale commerce within any town does not usually consume more water than approximately 2-5% of total household consumption within the same town.

Markets equipped with sanitation facilities using water flushing have to be considered as big consumers. On the specific market day(s), the water consumption forcommercial activities (assumption: the market belongs to the category of commercial customers) might reach an important percentage of the total water consumption. This has to be checked before defining the overall percentage of commercial demand.

Commerce may have some other big consumers, such as hotels, slaughterhouses etc. The specific consumption of hotels expressed as l/bed/dlies in a wide range from around 60 to up to 200, depending on the number of stars and thus the offered services. For restaurants, a usual figure is 20 l/seat/d (if flushing toilets are provided). Assess the rate of occupation during the tourist season and off-season to calculate two different water demands: a daily peak demand during the tourist season and an average daily demand off-season. Assess when the tourist season occurs, and whether its peak consumption will have to be added to the peak consumption of the other consumers, or whether the peak demand will occur during a day of more or less average consumption for the other consumers. For slaughterhouses, the water consumption depends on the number and type of slaughtered animals per day.

In case no data are available, use data from a similar system in a settlement of similar size and conditions.

6.8.2 Overall Commercial Demand

The overall commercial demand is therefore the sum of all specific commercial demands multiplied with the respective figures.

For assessing the future commercial demand, it is recommended to use a growth rate that is not higher than the one applied for population development. Only if special circumstances are obvious for the future (enhanced tourist development for instance), might this approach be obsolete. Often, a growth rate close to 50% of the population growth rate is sufficient.

(6.11) $Q_{com,i} = q_{com} * (1 + gr_{com})^{i} + \sum q_{BGcom,j} * (1+gr_{com,j})^{i}$

With:
$Q_{com,i}$: Water demand of commercial entities at time horizon i
Q_{com}: Specific consumption of commercial entities not considered as big consumers
Gr_{com}: Growth rate of commercial entities not considered as big consumers at time horizon i
$\sum q_{BG,com,j}$: Sum of the water demand of all big commercial consumers
$q_{BG,com,j}$: Specific consumption of each big commercial consumer (from 1 to j)
$g_{rcom,j}$: Growth rate for each big commercial consumer (from 1 to j)
i : The difference between the year the calculation is for and the year serving as a starting base

6.9 OTHER DEMAND

Other demandscan be subsumed by:

- Demand for livestock, if not covered by industrial/commercial demand
- Internal Demand: for special processes for water production

6.9.1 Livestock Demand

Usually, water treated for human needs should not be used for livestock needs. There might be some special circumstances when a designer has to consider this. In this case, the number of current and future animals has to be assessed, as well as their size:

- Big animals such as horses and cows account for around 200 l/d
- Middle sized animals such as sheep and goats count for around 60 l/d
- Small animals such as chickens count for 1 l/d

These amounts include the needs for cleaning the stables.

More detailed figuresmay be obtained at MAAIF.

(6.12) $Q_{LS,i} = \sum q_{LS,j} * n_{LS,j} * (1+gr_{LS,j})^{i}$

With:
$Q_{LS,i}$: Water demand of livestock at time horizon i
$\sum q_{LSt,j}$: Sum of the water demand of all livestock elements
$q_{LS,j}$: Specific consumption of each livestock element (from 1 to j)
$n_{LS,j}$: Number of livestock at design start (i = 0) for each livestock element (from 1 to j)
$gr_{LS,j}$: Growth rate for each livestock element (from 1 to j)
i : The difference between the year the calculation is for and the year serving as a starting base

6.9.2 Internal Demand

An important internal demand might occur if a water treatment process encompasses filtering with related filter backwashing. This occurs usually when coagulation/flocculation and filtration processes for treating surface waters are necessary. If backwash water volumes are not reused in the treatment process but rejected into a receiving water body, these volumes have to be assessed and counttoward the total water demand. In worst cases, these might be responsible for up to 15% (rarely above that figure) of the total demand.In case it is not assessed, it will be included in NRW figures.

It often happens, that filter backwash cycles will differ seasonally: in the rainy season, more turbidity may be found in raw water than in the dry season, requiring higher numbers of backwash cycles. If peak consumption occurs in the dry season, the influence of filter backwashing on the peak water demand will be less than in the rainy season. Therefore, a careful analysis has to be carried out to assess the annual amount of backwash water on one side, but also the amount occurring during peak consumption (please refer to Section 7.5). As a result, two different specific consumptions for the internal demand may arise; one to calculate the yearly amount of water for backwashing (for financial purposes, please refer to Chapter 13), and another one to be added to the peak daily demand (for hydraulic sizing reasons, please refer to Chapter 7.3).

This analysis has to be done when designing the water treatment plant.

Caremust be taken to calculate the internal demand for filter backwashing only after having defined the required water production (peak daily demand plus NRW) for each single year within the design horizon:

(6.13) $Q_{ID,i} = q_{ID} * DPD_i$

With:

QID,i :	Internal water demand at time horizon i
qID,j :	Specific consumption for internal demand expressed as percentage of required production
DPDi:	Daily peak demand (refer to Section 7.5.1) at time horizon i
i :	The difference between the year the calculation is for and the year serving as a starting base

6.10 TOTAL DEMAND

The total demand per time period is the sum of the demand of each single category ofcustomer in the same time period:

(6.14) $Q_{tot,i} = Q_{HH,i} + Q_{CO,i} + Q_{inst,i} + Q_{ind,i} + Q_{com,i} + Q_{LS,i} + Q_{ID,i}$

The total demand shall be calculated as yearly water volume (m^3/y), average daily water volume (m^3/d) and average hourly water volume (m^3/h), all three for each single year up to the design horizon.

6.10.1 Yearly Demand

The yearly demand enters into financial calculations (please refer to Chapter 13).

The yearly demand is usually the average daily demand multiplied by 365. Deviations can occur when due to seasonal peaks in industrial production and/or internal use of water for filter backwashing the average daily demand is higher than the yearly demand/365.

Another reason for deviation is rainwater harvesting. As rainwater is not available all year round, calculation of the average daily demand should not take rainwater into account, as this would lead to lower consumption figures and consequently to undersized infrastructures.

For yearly figures however, which are a base for financial calculations (please refer to Section 13), the fact that potable water from the public network is partly substituted by stormwater at zero cost has an important impact on financial figures for the utility.

The design has then to assess the amount of water that might be – based on average rainfall – substituted by rainwater (usually valid for households), and this amount has to be retrieved from the calculated yearly demand. Please note that due to the fact thatrainfall is concentrated in specific months in Uganda, an important percentage of rainwater most likely overflows from private storage facilities.

6.10.2 Average Daily Demand

Based on the facts presented for calculating the industrial demand and the internal demand, dividing the yearly water volume by the average daily water volume may not result in the factor 365.

The average daily demand (ADD) does not take into account any rainwater harvesting.

6.10.3 Average Hourly Demand

Similarly, the division of the average daily water volume by the average hourly water volume may differ from the factor 24, especially if industrial consumption (human related needs with less than 3 shifts) is important. Again, as for the calculation of average daily demand, rainwater harvesting should not enter into the calculations.

6.11 CHECKLIST

1. Are figures for the current population available, and how reliable are they?
2. Does a reliable population growth rate assumption exist up to the design horizon?
3. Is it possible to define the ratio between house connections, yard taps and standposts?
4. Is it possible to define the tendencies for the development of the number of people with the need for supply by house connections, yard taps and standposts?
5. Is it necessary to include commuters? If yes, are figures for their present and future development available?
6. Is it necessary to conduct a survey for future institutional demand (big consumers)?
7. Is it necessary to conduct a survey for future industrial demand?
8. Is it necessary to conduct a survey for future commercial demand (big consumers)?
9. Are reliable figures available for assessing the current and future demand of institutions, industries and commerce?
10. Is it obvious which formula is to be used for future industrial demand, and are the necessary input data available?
11. Is it necessary to include livestock demand and/or internal water use?
12. Are growth rates available for assessing future demands of institutions, industries, commerce and livestock?
13. If there is a need to consider internal use, has the required water production been calculated?
14. Have the water demand calculations been performed for each year up to the planning horizon?
15. Have the calculations been performed for yearly demand, average daily demand and average hourly demand?
16. Is it necessary to deduct rainwater harvesting from yearly demand calculations?

6.12 DESIGN VALUES

The following design criteria and their respective values are proposed:

Table 4: Design Criteria and Values for Demand Calculation

Main Parameter	Sub Parameter	Unit	Minimum	Maximum	Usual
Household Demand (HHD)	House connection	lpcd	60	140	80-100
	Yard tap	lpcd	20	40	35
	Public standpost	lpcd	5	20	20
Transient Population		lpcd	10	60	40
Institutional demand	Small inst. consumers	% HHD	2%	10%	8%
	Big inst. consumers				To be assessed separately
Industrial Demand	Small ind. consumers	% HHD	0%	5%	4%
	Big ind. consumers				To be assessed separately
	Future industrial areas	l/s/ha	2	10	5
Commercial Demand	Small com. consumers	% HHD	2	5	4
	Big com. consumers				To be assessed separately
Livestock Demand	Big animals	lpcd	80	200	140
	Middle sized animals	lpcd	40	70	60
	Small animals	lpcd	1	5	2
Internal Demand	Backwashing	% of Total Production	0%	15%	To be assessed separately

6.13 BIBLIOGRAPHY AND RECOMMENDED READING

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7. REQUIRED WATER PRODUCTION

7.1 PURPOSE

Calculation of the required water production aims to ensure that within the design period no water shortage will occur in covering the demands of the customers under normal operational issues.

7.2 KEY PRINCIPLES

The following key principles will prevail:

- Water production has to cover demand and losses.
- Water production has to cope with the maximum daily peak demand likely to occur during the design period (calculation year by year).
- Water distribution has to cope with the maximum hourly peak demand likely to occur during the design period (calculation year by year).

7.3 REQUIRED PRODUCTION

The calculation of the required production is made for two cases:

- Yearly required water production (for financial reasons, please refer to Chapter 13)
- Daily peak production (for hydraulic sizing reasons)

The yearly required production is basically the yearly demand (please refer to Section 6.10) at the time horizon i plus Non-Revenue Water for the same time horizon.

Calculation of the daily peak demand and therefore the related required maximum production capacityis presented in Section 7.5.1.

7.4 NON-REVENUE WATER

Non-revenue water (NRW)[3] is the amount of water that is produced (and thus generates costs) but is not subject to billing (thus, is not generating revenues). NRW is simply to be calculated as the difference between raw water produced (bulk metering) and treated water billed (sum of all customer metering). It is usually presented on a yearly basis (in absolute figures), and/or as a percentage of water production:

(7.1) $NRW = (YWP - YWC) / YWP$

With:
NRW : Non-revenue water (in % of production)
YWP: Yearly Water Production
YWC: Yearly Water Consumption

Please note: this formula applies for existing systems only; production figures and consumption figures have to be known. If bulk metering and/or customer metering is not reliable, the figures for NRW calculated from this data will be incorrect! It is thus obligatory to have reliable metering devices of good quality and well maintained to assess reliable figures of NRW (operational issue).

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[3] Sometimes, Unaccounted-for Water (UFW) is used as a synonym for NRW

For new systems, as production figures have still to be calculated, NRW cannot be defined as a percentage of production. Calculation has to start from the only figures available, the yearly water consumption:

(7.2) $$NRW_i = \frac{Q_{tot,i}}{1 - f_{NRW,i}} - Q_{tot,}$$

With:
NRW_i : Non-revenue water at time horizon i (in m³/y)
$Q_{tot,i}$: Yearly Water Demand at time horizon i (in m³/y) (please refer to Section 6.10)
$f_{NRW,i}$: Factor for NRW at time horizon i (for new schemes: invariable)
i : The difference between the year the calculation is for and the year serving as a starting base

Please be aware that the factor for NRW is still the one used as a percentage of production, even if NRW is now calculatedfrom consumption figures; the formula has been adapted to it!

In case NRWis not accounted for in production, the production facilities will be undersized, meaning that the water volumes delivered to the customers will be reduced by NRW (occurring on the way from the production facilities to the point of customer metering). The consumption figures based on meter readings will be lower than the real demand, as not enough water is available for consumption. We have then a typical case of a system with suppressed demand. Using systems with suppressed demand for deriving design figures is very dangerous, as they will not reflect reality (the figures would change if sufficient water would be available, which should be the calculation base for any new system).

Based on IWA approaches, the following core elements are part of NRW:

- Authorised unbilled consumption (whether metered or unmetered; examples: water taken out for fire fighting, or for filter backwashing, if not recycled)
- Apparent losses:
  - Unauthorised consumption (illegal connections)
  - Metering inaccuracies
- Real losses:
  - Leakages on mains, distribution pipes, pumps and fittings
  - Leakages and overflows at reservoirs
  - Leakage on service connection up to the point of customer metering

The level of NRW in a system depends on many parameters and the most important are:

- Age of the system
- Quality and type of materials used in the system
- Pressure levels and fluctuations within the system
- Quality of water meters and accuracy of meter readings
- Quality of work implementation
- Aggressiveness of water
- Equipment of storage infrastructure with overflow prevention
- Operational skills
- Level of maintenance (repairs and proactive maintenance)

In general, investments into NRW reduction are five to ten times more efficient than into extended water production.

The best supply systems in the world have NRW of around 5%, amongst the worst was, at a certain point in time, Mexico City with approx. 95% NRW.

For design purposes, a NRW figure of 25% (f_{NRW}=0.25) of the average daily demand can be consideredacceptable. The factor for NRW cannot exceed 100% (as this would mean that all water produced is directly lost; not a single drop would reach the customers).

7.5 PEAK DEMANDS

Two peak demands have to be calculated: the daily peak demand and the hourly peak demand.

- The daily peak demand is used for calculating production and storage facilities (water treatment plants; transmission mains, pumping stations and booster stations feeding reservoirs, and reservoirs).
- The hourly peak demand enters into the hydraulic simulations for the design of the distribution network.

As NRW has a significant influence on peak factors, it is usually calculated separately.

7.5.1 Daily Peak Demand

7.5.1.1 Daily Peak Factor

As a rule, the daily peak demand is calculated by multiplying the average daily demand (please refer to Section 6.10.2) with a specific daily peak factor.

The decision, which value to applyas the daily peak factor,can be derived from two sources:

- Analyses of production figures in systems with similar features and in similar conditions
- Specific literature

The first approach is deemedto reflect local conditions better, but it has some hidden inaccuracies. NRW has an important influence in calculating the daily peak factor. An example is presentedin Table 5(assumption: losses only in the distribution system):

Table 5: Fictive Example of NRW Influence on Daily Peak Factors

Number	Item	Unit	Calculation	Case 1	Case 2
(1)	Average Daily Demand	m^3/d		1,000	1,000
(2)	NRW	m^3/d		600 (60%)	200 (20%)
(3)	Average Water Production	m^3/d	(1) + (2)	1,600	1,200
(4)	Daily Peak Demand based on customer metering	m^3/d		1,500	1,500
(5)	Peak Water Production	m^3/d	(2) + (4)	2,100	1,700
(6)	Daily Peak Factor		(5) / (3)	1.31	1.42

Therefore, even two similar systems can have different daily peak factors, if NRW is different. As long as there is no guarantee of having reliable data on raw water production and treated water consumption (the difference being NRW), the use of a daily peak factor derived from analyses of production and consumptionfigures of existing systems is deemed dangerous for applying to new schemes. It is thus suggested to use other standards for calculating the daily peak factor, for instance peak factors to be derived from figures for current and future population to be supplied by the system, or by the size of the system.

The daily peak factor is always above 1, as the daily peak consumption will always be higher than the average daily consumption.

In case detailed information on commercial and industrial consumers are available, the daily peak factors for each of these customer categories can be calculated separately by dividing the day with the maximum consumption by the consumption of the average day.

7.5.1.2 Calculation of the Daily Peak Demand

The daily peak demand corresponds to the required production andshall be calculated by applying the following formula:

(7.3) $DPD_i = ADD_i * f_{d,i} + ADD_i * f_{NRW,i}$

Or simplified:

(7.4) $DPD_i = Q_{tot,i} * (f_{d,i} + f_{NRW,i})$

With:

DPDi :	Daily peak demand (=required production) at time horizon i
ADDi:	Average daily demand (please refer to Section 6.10.2) at time horizon i
$f_{d,i}$:	Daily peak factor, to be applied to average daily demand without NRW at time horizon i
$f_{NRW,i}$:	Factor for NRW at time horizon i (for new schemes: invariable)

Please note that the factor for NRW is the same, whether applied to average daily demand or peak daily demand. The reason for this is that during peak demand times, the network pressure usually goes down, which has the effect of reducing NRW (especially real losses have a strong positive correlation with pressure). Thus, keeping NRW at the calculated level provides a certain security.

The maximum daily peak demand within all considered years is the design parameter for sizing the elements linked to the system such as water treatment plants, pumping stations and booster stations feeding reservoirs, and reservoirs.

7.5.2 Hourly Peak Demand

7.5.2.1 Hourly Peak Factor

As for the daily peak demand, the hourly peak demand is calculated by multiplying the average hourly demand (please refer to Section 6.10.3) with the hourly peak factor. In some countries, the hourly peak factor applies to the average hourly demand during the peak day.Caution has to be taken when comparing data on an international level.

Similar to the daily peak factor, the decision, which value to apply as the hourly peak factor can be derived from two sources:

- Analyses of production figures in systems with similar features and in similar conditions
- Specific literature

The same statements as for the daily peak factor may be made. It is thus recommended to rely more on data from specific literature (for instance peak factors to be derived from figures for current and future population to be supplied by the system), as long as no reliable raw water production and treated water consumption figures are available.

The hourly peak factor is always above 1, as the hourly peak consumption will always be higher than the average hourly consumption (irrespectively of whether during the average day or peak day).

In case detailed information on commercial and industrial consumers are available, the hourly peak factors for each of these customer categories can be calculated separately by dividing the hour with the maximum consumption by the consumption of the average hour.

7.5.2.2 Calculation of the Hourly Peak Demand

The following formula applies for calculating the hourly peak demand:

(7.5) $HPD_i = AHD_i * (f_{h,i} + f_{NRW,i})$

With:
HPD_i : Hourly peak demand at time horizon i
AHD_i: Average hourly demand (please refer to Section 6.10.2) at time horizon i
$f_{h,i}$: Hourly peak factor, to be applied on average daily demand without NRW at time horizon i
$f_{NRW,i}$: Factor for NRW at time horizon i (for new schemes: invariable)

Here again, the factor for NRW is considered invariable, independently of average day, peak day or peak hour. The reasoning is the same as that presented for the daily peak demand.

7.6 CHECKLIST

1. Are figures available for the average daily demand and the average hourly demand?
2. Are reliable figures for NRW assumptions available?
3. Has the correct approach been chosen for deriving daily and hourly peak factors?
4. Are parameters available for defining daily and hourly peak factors?
5. Have the peak factors been cross-checked for lying within reasonable limits?

7.7 DESIGN VALUES

The following design criteria and their respective values are proposed:

Table 6: Design Criteria and Values for Water Distribution Purposes

Main Parameter	Sub Parameter	Unit	Minimum	Maximum	Usual
Non-Revenue Water		% of total demand	5	60	25
Daily peak factor (f_d)	Village (<5,000)	factor	2.0	2.3	2.2
	Small town (<20,000)	factor	1.5	2.1	1.9
	Medium town (<100,000)	factor	1.5	1.9	1.8
	Bigger town (<500,000)	factor	1.3	1.7	1.6
	Big town (>500,000)	factor	1.2	1.6	1.5
	Alternative	factor	$f_d = -0.1591 * \ln(E$[4]$) + 3.488$		
Hourly peak factor (f_h)	Village (<5,000)	factor	4.5	7.0	5.5
	Small town (<20,000)	factor	3.5	4.5	4.0
	Medium town (<100,000)	factor	2.5	3.3	3.0
	Bigger town (<500,000)	factor	2.0	2.5	2.4
	Big town (>500,000)	factor	2.0	2.4	2.2

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[4] E: Number of connected people

	Alternative	factor	$f_h = -0.75 * \ln(E) + 11.679$

7.8 BIBLIOGRAPHY AND RECOMMENDED READING

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[3] Guidelines for Design of Small Public Ground Water Systems, OhioEPA, 4thEdition, 2010

[4] Guidelines for Human Settlement Planning and Design (the Red Book), Chapter 9 Water Supply, CSIR, 2005

[5] Technical Guidelines for the Development of Water and Sanitation Infrastructure, Department of Water Affairs and Forestry, South Africa, 2004

[6] DVGW (German Association for Gas and Water) Manual: Water Transport and Distribution, 1999

[7] Water Supply and Pollution Control (8th Edition), Viessman Jr., Hammer, Perez, Chadik

8. WATER SOURCES

Water extracted from a source is referred to as raw water. The exploitable raw water **quantity** during a definite time is denominated as the capacity of a source.

8.1 PURPOSE

In the context of public water supply design, the purpose of a raw water source is the reliable delivery of water.A source is **reliable** if sufficient water is available every day of the year.

8.2 KEY PRINCIPLES

The following key principles apply:

- Sources in proximity to the supply area shall prevail (economic consideration).
- The source must ensure a reliable supply up to the design horizon.
- In case there is no single source providing the required amounts of water, a combination of two or more sources has to be envisaged.
- The selection of the final source(s) to be used is an optimisation of the process of options (please refer to Section 13.6.1).
- The use of the source shall not lead to conflicts with other water users (or at least only if mitigation measures will be implemented prior to investing into source capping).

8.3 INVESTIGATIONS PRIOR TO DEFINING WATER SOURCES

The exploitation of a water source has to be conducted in a sustainable way. In particular, the extracted water quantity must not exceed the quantity, which is recharged by the natural hydro-geological or hydrological system. The admissible water quantity for exploitation has to be identified for each specific source on the basis of hydro-geological and hydrological investigations.

Thus, prior to identifying water sources to be used for a water supply system, investigations are required. These should cover amongst others:

- Identification of possible sources.
- Collecting available information on sources (location, elevation, water quantity and quality issues). This also includes the experiences of people living in the vicinity for a longer period.
- Assessing possible sources of pollution (potential or existing).
- Assessing rates of usage of these sources (avoid overexploitation and conflicts with other users).
- Cultural aspects to be taken into account.

By carrying out these advance investigations, the number of potential sources is usually already limited.

In case water quality and yields have not been monitored, but the source is identified as potentially appropriate, it is recommended to carry out a survey for a period of at least one year by measuring on a weekly basis the yield and on a monthly basis the water quality. The minimum yield measured during this period, lowered by a climate change factor or by a factor taking into account the rainfall of the year of measurement compared to a drought year, will define the source capacity (hydrological resp. hydro-geological assessments).

Prior to any design, the seasonal patterns of the source’s capacities shall be investigated for a minimum period of one year. During this time, measurements of the source capacity shall be conductedat appropriate intervals. Additional measurements are required during heavy rainwater periods, floods and droughts. For groundwater, a hydro-geological investigation programme specifying the intervals and locations of measurement is necessary in order to identify the seasonal pattern of source capacity.

In case only an intermediate yield was recognised, either the source must be omitted for supply purposes or an alternative source has to be identified as a back-up solution for the period of low or no-flow (this will not be feasible if the period of low flow or no-flow matches peak demand periods. In this case, this specific source should immediately be taken out of the list of potential water supply sources).

If two or more options for source tapping exist, a comparison of total costs shall contribute to the decision of which option to choose. Generally, the least expensive option shall prevail (please refer to Section 13.6.1).

8.4 SPRINGS

8.4.1 Spring Environment

Generally, a spring is groundwater leaking out to the terrain surface. The reason for that is the following typical underground configuration. Groundwater flows through an aquifer, which is aligned above a groundwater barrier (impermeable underground layer).

If the aquifer emerges to the terrain surface and if the energy line of the groundwater body lies above the terrain level, groundwater is leaking out. There exist different types of spring depending on the local hydro-geological configuration. Specific types include (i) outcrop spring, (ii) barrier spring, (iii) overflow spring, (iv) fissure spring and (v) fault spring.

Groundwater can leak out in horizontal or vertical direction depending on the type of spring. For details, reference is made to special literature [1].

a) Spring protection appraisal

The soil layer covering the terrain around and upstream the spring shall feature sufficient thickness in order to prevent the spring from pollution. The soil layer shows a filter function for seeping storm water. The filtration effectiveness depends on the thickness and the characteristics of the soil layer. However, no guideline values for the required thickness of cover layer can be defined due to the big variety of soil characteristics.

Instead, the verification of the reliable purification capacity of the cover soil layer necessitates physical, chemical and microbiological investigations of spring water. The investigations shall be conducted for the period of one year and shall comprise several water samples taken during different characteristic meteorological conditions (dry season, after storm water event, during rainy season, etc.). Any investigation results failing the water quality requirements indicate that the cover layer thickness is insufficient for purification of storm water seeping into the underground. In that case, an alternative spring shall be identified or mitigation measures of pollution shall be defined.

Additional micro-biological investigations shall be performed after the construction of the spring tapping in order to verify the proper implementation of the facility and to exclude any contamination caused by construction works.

b) Spring contamination risks

The catchment area of a spring shall be inspected for the existence of potential contamination sources. These include areas of agricultural use, wastewater disposal facilities or pits for sand and gravel exploitation. If any hazards for spring water quality are identified, precautionary measures shall be taken to exclude future contamination risks.

8.4.2 Spring Tapping

For the five specific types of springs mentioned in section8.4.1, par. 2, different methods of tapping are applied. As one template, the tapping of an outcrop spring is described as follows.

8.4.2.1 Tapping of outcrop spring

An outcrop spring usually appears in a sloped terrain and water leaks out in horizontal direction. These conditions are decisive for the mode of tapping.

In a first step, from the spring site, the soil layer is excavated upstream of the spring. During this work, it is important not to damage the impermeable underground layer. Otherwise, water would infiltrate below ground. In addition, the accumulation of water shall be avoided. Therefore, a drainage system shall be maintained during the excavation works.

The excavation shall continue into the hillside to that point where the coverage layer is of sufficient thickness. From there, a trench is excavated sideways until all places where water is leaking out are captured.

The spring tapping structures consist of an (i) infiltration gallery, a (ii) casing for discharge of infiltration water and a (iii) collection tank.

1. Infiltration Gallery

The infiltration gallery is aligned on the place of the excavated sideward trench. There, drainage pipes are aligned for the collection of infiltration water. The pipes shall be large enough for the biggest spring capacity and for a flow velocity of 0.2 – 0.4 m/s. The minimum diameteris recommended with DN 100. The drainage pipes shall avoid any water retention in the gallery (slope!).

The gallery is back-filled with gravel and stones with a diameter between 50 – 100 mm. Downhill of the gallery, a concrete wall is constructed to provide a sealed joint with the underlying impermeable soil layer in order to prevent water loss. Further, the gallery is covered by a plate of concrete in order to prevent the intrusion of terrain surface water. The plate is covered by soil material provided with plantations in order to hide the concrete structure.

2. Casing for Discharge of Infiltration Water

In the middle of the infiltration gallery, a casing of concrete is placed into which the drainage pipes end up. From the casing, collected infiltration water is discharged through a pipe to the collection tank.

3. Collection Tank

The tank for collection of infiltration water is made of concrete and is equipped with an aeration pipe. On the bottom, a separation wall is aligned dividing the tank into two sections. In the first section, the water discharged from the infiltration gallery is collected. In the secondsection, the pipes and fittings for water delivery to the reservoir are installed. Further, an overflow pipe is provided in order to prevent flooding of the tank. The manhole must not be placed above the collected water in order to prevent pollution.

This collection tank, also called raw water storage tank or raw water reservoir, is the hydraulic start of the supply system.

8.5 BOREHOLES / WELLS

Two different types of wells exist:

- Dug wells
- Drilled wells

8.5.1 Dug Wells

Dug wells are rarely used for public water supply; in most cases, drilled wells are more advantageous. Dug wells are appropriate for aquifers, whose groundwater table is close to the terrain surface, and for locations where no nearby pollution source exists. The shaft of the well has a diameter of 1.0 – 1.5 m. The construction of the well shaft is carried outby way of an open excavation pit. The walls of the shaft are to be sealed with prefabricated concrete rings (height 0.5 m) which are placed in parallel with the digging of the shaft.

The well shaft shall be extended into the aquifer to a level which is 2-3 m below the level of the minimum groundwater table. Thereby, the drawdown of the table due to pumped water extraction has to be taken into account.

On the bottom of the well, a layer of fine gravel[5]shall be applied with a minimum thickness of 0.3 m. Groundwater flows into the well from the bottom and from the sides. Therefore, the concrete rings in the aquifer shall be provided with slots to enable water intrusion. However, no slotted rings shall be placed in the zone above the aquifer (danger of pollution). In fact, the slotted rings shall be aligned 1.0 m below the lowest groundwater table.

Water is exploited by a submersible pump, which is mounted on the lower end of the vertical riser pipe. The upper end of the riser pipe is fixed on the horizontal cover plate or on the working platform of the well top. It is important that the pump and the riser pipe do not have any physical contact with the wall of the well shaft in order to avoid vibrations of the pump having a long-term negative effect on the wall.

The cover plate or the working platform has to sustain the weight of the pump and the vertical riser pipe and has to be dimensioned accordingly. The weight increases with the growing depth of the well and the corresponding increasing length of the riser pipe. This fact must be consideredwhen designing a dug well.

The fixation of the vertical riser pipe on the cover plate / working platform has to sustain the vibrations of the submersible pump and has to be assembled accordingly.

On the top of the well, a small chamber shall be provided for the protection of the well and for the installation of pump, pipework, fittings and monitoring equipment. The top of the well shaft shall be covered. The access manhole to the well chamber must not be located above the well top but shall be offset. The well chamber shall be locked against unauthorised access.

As the aquifer is shallow, dug wells are usually characterised by the following:

- Periodic changes in water quantity
- Periodic changes in water quality

8.5.2 Drilled Well

The advantages of a drilled well compared to a dug well are the following.

- Greater depths are possible
- Less raw water quality and quantity fluctuation (usually)

Prior to the drilling of any well, the potential water yield of the location must be verified by hydro-geological investigations. These shall be performed by professional hydro-geologists and shall also take into account the experience of local stakeholders.

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[5] The grain size of the gravel shall be in a range of 2-7 mm. Thereby, the grain size shall be widely equable showing a maximum coefficient of uniformity of d60 : d10 = 1.5. This entails a low filter resistance and a reduced risk of clogging through fine material (sand and silt).If the bottom of the dug well is located in loose rock (sand and gravel) of a characteristic grain size (d90) of maximum 10 cm, the grain size of the gravel layer at the well bottom shall be at least four times bigger than the characteristic grain size of loose rock (d90 gravel = 4 x d90 loose rock).

The well site identification includes two basic steps of investigation, in particular (i) a desktop study and (ii) a terrain investigation.

8.5.2.1 Desktop Studies

Desktop studies usually include the following:

- Analysis of hydro-geological data (maps, studies, groundwater monitoring data)
- Analysis of topographical maps (location rivers, terrain relief)
- Identification of fracture zones on aerial photographs, satellite images and maps

8.5.2.2 Terrain Investigations

After having performed the desktop studies, selected potential locations undergo an on-site investigation. The following investigation methods are applicable. The most appropriate options shall be selected depending on specific underground conditions and on the characteristics of the catchment area of the aquifer. The selection of the methods for case specific investigations shall be the task of the hydro-geological expert.

- Geo-electrical: Identification of fracture zones in the field using resistivity profiling
- Seismic: Identification of different underground layers and water bearing strata
- Borehole measurements of:
    - Electric resistance
    - Electric natural potential
    - Natural Gamma radiation intensity
    - Water content by Neutron–gamma method
    - Layer thickness by gamma-gamma method
    - Noise velocity in rock

The borehole measurements require the drilling of test boreholes entailing a considerable amount of work. Among the other investigation methods, the *Resistivity Anomaly (PLRA) Method* has proved to have the highest success rates. Therefore, this method is recommended especially for areas of low groundwater potential.

For the identification of methods for the investigation of terrains with difficult groundwater characteristics (e.g. semi-arid areas)a hydro-geological expert shall be consulted.

8.5.2.3 Test Pumping

For details of borehole design, reference is made to professional literature[1] and [4].

Prior to starting up the routine operation of a production well, a pumping test shall be performed. The purpose is to identify the realistic exploitation capacity of the well.

The pumping test needs a period of at least 120 hours. The pumping test comprises several phases in which the pump is operated with gradually increased flows (step-test). During each phase, the flow has to be kept constant. During each step test, the drawdown level of groundwater shall be constant for a duration of 12 hours [1] [4].

During each phase, the drawdown of the groundwater table is measured in groundwater standpipes located on the perimeter of the well at different distances from the well. From the drawdown data, the associated horizontal distance from the well and the actual flow, the permeability coefficient k_f of the aquifer can be calculated. For details on calculation approach and formula, reference is made to special literature [1] [4].

The result of the pumping test is a clear display of groundwater drawdown curves for different pump flows. The curves are analysed and the maximum admissible drawdown of groundwater in the well is identified. The corresponding pump flow is the adequate well capacity for long-term operation.

The admissible flow takes into account that no sand is present in the well and that the drawdown of the water table does not fall below the screened pipe. Further, the admissible inflow velocity at the screen pipe of 0.5 m/s shall not be exceeded.

a) Pump installation depth

The pump shall be installedat such a depth that the level of the inflow slots is at least 0.5 m below this water level, which corresponds to the maximum drawdown of the groundwater level. This shall avoid the drawdown of air by the pump (pump falls dry).

The maximum drawdown of the groundwater level shall not exceed 33 % of the aquifer thickness (i.e. the vertical distance between the bottom and the surface of the aquifer). This constraint has to be taken into account when identifying the required depth of the pump installation.

b) Well capacity

The capacity of the well is the maximum admissible extraction flow. This depends on the diameter of the borehole and on the water level in the borehole at the maximum admissible inflow velocity. The maximum admissible inflow velocity depends on the permeability of the aquifer.

For the calculation of the maximum admissible inflow velocity and of the well capacity, reference is made to special literature [1] [4].

The maximum admissible inflow velocity shall not be exceeded. If the well capacity hardly rises above this limiting value, thismeans the uneconomic operation of the well.

c) Borehole yield

The yield of a borehole is the flow, which can be extracted reliably and permanently (24 hours a day) in the long term. The prerequisite is that the groundwater recharge capacity of the aquifer must be equal to or higher than the capacity of the borehole. In other words, only the same quantity of water can be exploited in a definite period, as is delivered to the aquifer by the hydro-geological conditions in the same period. This approach corresponds to a sustainable exploitation of the aquifer.

d) Aquifer capacity

The capacity of the aquifer complies with its actual groundwater recharge flow. This may underlie seasonal fluctuations conditional on regional climatic and hydro-geological conditions (dry/wet periods). In this case, the minimum seasonal capacity has to be taken into account for the design of the borehole/well. The methodology for identifying the aquifer capacity is mentioned in Section 8.9.

8.6 SURFACE WATER

Surface water is extracted from (i) rivers, (ii) lakes and (iii) artificial reservoirs, via the construction of a dam. Due to different water qualities, a priority rankingof water extraction from surface waters exists as listed below (from high to low priority):

- Artificial reservoirs
- Lakes
- Rivers

8.6.1 Location of Intakes

8.6.1.1 Reservoir Intakes

The intake in artificial reservoirs and lakes is usually a water tower with openings at different levels, all connected to the same raw water main. The openings are operated either by manual or – preferably - by electrical valves. The idea of having different openings is to take the raw water from the layer showing the best (i.e. the least worse) raw water quality for a period of time, as raw water quality fluctuates depending on sunshine, temperature, rainfall and wind. Thus, the locations of reservoir and lake intakes are usually in an area with substantial depth, and not close to the shore.

In an artificial reservoir, the lowest water intake level shall be placed as deep as possible (by maintaining a dead water zone for natural sedimentation over its lifetime) in order to allow for the exploitation of as large a storage volume as possible.

8.6.1.2 Lake Intakes

Usually, as for reservoir intakes and where the water depth of the reservoir is important, a water intake tower is required, with openings at different water levels in order to select the water level showing the best characteristics (raw water quality) for a certain period through the year. In more shallow lakes, the water intake shall be aligned at a depth of minimum 3-5 m in order to enable constant temperature and water quality conditions. Shallow zones (bays, banks) shall be avoided.

8.6.1.3 River Intakes

The river water intake shall be located where no impact on the water quality are expected. Therefore, the catchment area shall be inspected for the non-existence of potential pollution sources. Thus, appropriate locations include.

- Downstream of a forested catchment area
- On an elevation which allows for a water supply by gravity
- Outside the curve of a river bend in order to minimize sedimentation problems
- Upstream of populated and agricultural areas
- Upstream of bridges, cattle watering, laundry washing and wastewater discharge points
- Upstream of industrial sites

Sites with favourable conditions for the construction and operation of water intake include the following features.

- Rocky ground
- No flooding risk
- Point on the outside river bend
- Point where the ultimate residual water volume of the source can be extracted

8.6.2 Supply Capacity

In an artificial reservoir, the available annual water supply quantity is the total inflow minus the total residual flow (ecological flow). The artificial reservoir shows an annual summation curve for inflow and (residual) outflow. The maximum difference between these corresponds to the maximum available daily supply quantity.

In a river, the available water supply flow is the actual inflow minus the residual flow (ecological flow). The designed supply capacity corresponds to the lowest daily flow minus the ecological flow. Due to the missing storage, the water depth is not relevant for supply capacity. However, for water quality reasons, the intake shall be placedon the outside of bends. There, the greatest depths exist and the best water quality is expected.

8.7 RAINWATER HARVESTING

Rainwater is collected from roofs of buildings and discharged by rainwater pipes into a tank for storage.

The collection pipes are downstream, but before the tank, a first flush diverter shall be aligned, which separates the polluted first flush at the beginning of the rainfall from the subsequent clean water. The volume of the diverted first flush shall be calculatedunder consideration of the expected quantity of polluted rainwater. This depends mainly on the roof surface. For identifying the required minimum specific volume of the diverted first flush (litre/m^2 roof area), reference is made to the design data of suppliers of first flush diverters.

For the diverters, prefabricated products of various designs and capacities are available on the market.

Rainwater can be used for washing, cleaning and other service purposes without further treatment.

Rainwater harvesting shall only be performed for private supply purposes. It shall not be part of a public water supply system because of its highly unpredictable yield. This requirement therefore only refers to the collection facilities consisting of private roofs.

In case a private person wants nevertheless to use collected rainwater for covering all human needs, it has to undergo a minimum treatment usually consisting of:

- Filtration (rainwater is slightly charged with pollutants from the air, e.g. dust, and roof contact)
- Disinfection
- Remineralisation (semi-burnt dolomite)

The capacity of a rainwater harvesting system is defined by the roof surface for rainwater collection, by the storage capacity of the tank and by annual rainfall patterns. The capacity of roof surface and tank shall be adapted to each other.

8.8 PRIORITY RANKING OF SOURCES

The types of water sources described above usually feature different water qualities. Therefore, a water supply design measure shall strive to exploit that source, which represents the best water quality. The ranking of sources according to their quality level is as follows, beginning with the best quality:

1. Spring
2. Groundwater – drilled well
3. Groundwater – dug well
4. Artificial basin
5. Lake
6. River
7. Rainwater

Springs as sources of water are best suited for situations where the spring is located far away from settlements or in rural areas that are sparsely populated.

The placement of rainwater at the end of the ranking list is not only for quality reasons but also due to its fluctuating quantity and unsteady availability.

The above ranking is based on long-term experience including hydrological and hydro-geological conditions. In some specific cases, the sequence of items in the ranking might change due to special local conditions. Thus, the final decision for exploitation of a source must be based on a separate water quality investigation.

8.9 ENVIRONMENTAL CONSIDERATIONS

The water source shall be exploited to such an extent that no adverse impacts on the surrounding environment emerge in the long-term view. In particular, an impairment of vegetation and wildlife in the surrounding areas shall be avoided.

As a consequence, the admissible extracted water quantity might be lower than the theoretically exploitable quantity. This requirement applies to water extraction from any source.

a) Rivers

For rivers, a residual flow has to be guaranteed (ecological flow, environmental flow). Its purpose is to preserve the ecological functions of the river and its embankment zones comprising flora, fauna, morphological river characteristics and recharge of groundwater. In addition, the residual flow allowsthe maintenance of the existing water quality. In particular, a decrease of oxygen content and the increase of algae growth shall be prevented. Thus, the required residual flow depends on the morphological, biological, physical and chemical characteristics of the river. Therefore, it has to be identified separately for each specific river.

For identification of the required residual flow, various approaches including calculation models have been developed, which consider hydraulic, hydrological, meteorological and biological parameter. For details, reference is made to special technical literature.

b) Springs

For each spring tapping, the specific environmental context of the spring and its surrounding area has to be assessedin order to identify the admissible water extraction. Based on the findings, any required residual flow is determined or omitted. The findings of the environmental assessment can also indicate that no residual flow is required.

c) Groundwater

In case of groundwater exploitation, the groundwater table shall remainlargely unchanged in comparison to the one before the extraction. The associated extraction flow corresponds to the admissible exploitation quantity of the aquifer complying with environmental friendliness. The admissible exploitation quantity is also referred to as the aquifer capacity.

Admissible extraction quantity

The admissible extraction quantity (aquifer capacity) for environmentally friendly exploitation has to be identified for each specific aquifer through an appropriate environmental assessment.

The aquifer capacity can be identified through (i) existing hydro-geological data/studies, (ii) hydro-geological investigations or (iii) long term monitoring of the groundwater level development. The monitoring is performed through several groundwater gauges (stand tubes) in the aquifer basin. It is important that the gauges are located outside the catchment area of the borehole/well. Otherwise, the local drawdown due to well operation would be measured and not the unaffected groundwater level.

The permanent monitoring of groundwater level is also necessary in order to recognise any long-term impacts of climate change phenomena on the aquifer capacity.

The identification of the amount of exploited water shall include environmental considerations. In many cases, a certain percentage of the source capacity shall be left unexploited (residual capacity) in order to avoid any negative impact on the surrounding vegetation and wildlife. Thus, the relevant design capacity of a source is the existing minimum capacity minus the residual capacity.

The exploitation of a water source has to be performed in such a way that environmental impacts are minimised. Hence, groundwater exploitation must not entail the lowering of the groundwater table to such an extent that vegetation or the capacity of other water sources are affected. In particular, the capacity of existing springs and wells located downstream from the envisaged source tapping must not be lowered.

If the groundwater feeds a river, the envisaged exploitation must be designed in such a way that the river does not run dry. Further, it must be avoided that the flow of the river is diminished to an extent that it affects flora and fauna or impairs surface water exploitation downstream.

The removal of surface water from a river has to ensure a residual flow that allows for unchanged living conditions for flora and fauna downstream ofthe point of water extraction.

8.10 SOCIAL AND CULTURAL ASPECTS

The exploitation of a water source has to be accepted by all local stakeholders. These include the inhabitants of the water supply area, the water service provider and those persons who are affected by the tapping of the source (downstream users).

Persons are affected, if construction works for source tapping are performed on their private property. In such a case, compensation must be negotiatedin order to gain the commitment of the concerned persons.

If a source is tapped which is actually used for private supply, the commitment of the concerned stakeholders for their connection to the designed public supply system must be obtained. This includes negotiations, in which the advantages of public water supply compared to private water supply must be reasoned (improved water quality, enhanced supply security, increased supply comfort).

The envisaged customers of a designed water supply system have to agree to the exploitation of a specific source. This condition must be verified during the design process. Potential objections to a specific source include cultural aspects. For instance, there might be reservations against spring water because people have become used to river water fetched from a nearby river since decades. Thus, they might be sceptic about the quality of spring water.

The verification of the social feasibility requires a stakeholder consultation process. If acceptance is not achieved, the design engineer has to refrain from using the subject water source and search for an alternative one.

8.11 PROTECTION OF WATER SOURCES

Water intakes for the exploitation of groundwater and springs shall be surrounded by a protection zone. The purpose is to prevent any adverse effects on the quality of the exploited water. This is achieved through the prohibition of any agricultural use and economic activity in the protection zone.

Reference is made to Draft 2 of the “Guidelines for Protection Point Water Sources”, available at the Ministry for Water and Environment, Department for Water resource Management.

8.12 MEASUREMENTS AND MONITORING REQUIREMENTS

Raw water quality must be periodically monitored for all water sources. Providence of facilities and equipment, where necessary, is considered part of a good design.

Raw water abstraction is to be monitored too. This usually requires a bulk meter (please refer to Section 10.11).This applies to all raw water facilities as presented hereunder.

8.12.1 Springs

For springs, the possibility to access the raw water storage tank is required. A simple tap on the transmission main close to the storage tank is sufficient, if the pipeline works as a gravity pipeline without free surface flow. In other cases, a tap can be incorporated into the wall to gain access to the water.

8.12.2 Groundwater

For monitoring a groundwater body, several observation wells are installed in different places. These wells are standpipes with small diameters DN 5 – DN 150. Exact elevation data are required for the top of the standpipes.

In the observation wells, the elevation of the groundwater table is measured periodically. By the calculative comparison of the elevation data of several wells (at least three) the inclination and direction of groundwater flow can be calculated.

The periodic monitoring of groundwater elevations enables an assessment of the long-term development of the groundwater table. Thus, any over-exploitation of the groundwater body can be identified and mitigation measures can be defined.

In addition, it must be ensured that raw water can be taken for analysis. For this purpose, there is usually a tap welded onto the pressurised pipeline within the fenced area of the well (restricted access).

8.12.3 Lakes and Artificial Reservoirs

For lakes and artificial reservoirs, raw water has to be taken from different water layers periodically in order to define the layer showing the best water quality. This will be the one used for water supply for a specific period, unless analyses demonstrate that due to changed conditions another layer is superior in terms of raw water quality, requiring less chemicals for treatment (operational and financial issue).

8.13 CHECKLIST

1. Has a water demand calculation been performed in order to know what the required minimum capacity of the source(s) is?
2. Is a complete list of potential sources available?
3. Does evidence exist of the characteristics of each potential source?
4. Are additional investigations required in order to gather missing information?
5. Shall potential sources be eliminated because of non-compliance with the water demand calculation?
6. In case that no single source is able to provide enough water, which sources can be bundled for a project?
7. Have issues of over-exploitation or conflicting water use been clarified?
8. Have cultural and social issues been clarified?
9. Have protection zones been defined?
10. Are current market prices for water catchment available?
11. Have financial calculations related to investment, operation and maintenance costs been performed?

8.14 BIBLIOGRAPHY AND RECOMMENDED READING

[1] Technical manual on water supply, Mutschmann Stimmelmayr (German/English), 15th edition

[2] Water supply design manual 2012, Final Draft, prepared by AIM Engineering by order of the Republic of Uganda, Ministry of Water and Environment

[3] Framework and Guidelines for Water Source Protection, Volume III, “Guidelines for Protection Point Water Sources”, draft 2, MWE, DWRM, June 2012

[4] Water Supply and Pollution Control (8th Edition),Viessman Jr., Hammer, Perez, Chadik

9. WATER QUALITY AND TREATMENT

9.1 PURPOSE

Water has to be provided in adequate and reliable quality. This is required in order to achieve the following goals.

- To avoid risks to human health.
- To ensure satisfactorywater properties acceptablefor customers for consumption and other use.
- To prevent corrosion to pipes and fittings.
- To prevent malfunction of water supply facilities.

Raw water, which does not meet the quality requirements, has to undergo treatment in order to fulfil the above listed goals for water quality in a reliable way.

9.2 KEY PRINCIPLES

The following key principles apply:

- Raw water quality must be determined by a series of investigations.
- Design parameters for a treatment plant must include all relevant raw water parameters analysed to be above standard.
- Design values of the treatment plant must take into account the highest potential raw water concentration of the respective parameter.
- In case that a long flow time is necessary between the raw water source and the treatment plant, the possibility that the water quality may change during transport shall be taken into account.
- Mixing raw water from two or more different sources must be thoroughly investigated with regards to additional potential harm.

9.3 RAW WATER QUALITY INVESTIGATIONS

Raw water shows very different quality properties depending on the type of source (spring, groundwater, surface water) and site-specific hydro-geologic conditions. Therefore, any raw water envisaged for public water supply purposesmust be investigatedas to its quality.

Basically, water quality is characterised by the following three groups of parameters:

1. Physical parameters
2. Chemical parameters
3. Micro-biological parameters

The scope of parameters for each group is defined in national and international standards. The national standard for Uganda is Uganda Standard US 201: 2008, National standard for drinking water[6].

For each quality parameter, the quality standard specifies an investigation method.

For water quality assessment, limiting values are specified for each parameter in terms of concentration or other characteristic data. The limiting value is the maximum admissible value, which complies with the required quality.

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[6] Ref. to Final Draft of the Water supply design manual 2012 by AIM Engineers, Section 5.

For all parameters exceeding the limiting values of the Uganda Standard US 201:2008, appropriate treatment measures have to be applieddduring the design stage.

Specific Micro-biological investigations requirements

In case of tapping of springs or construction of a well, micro-biological investigations have to be conducted twice. Once prior to the construction of spring tapping or well facilities and the second time after their completion.

The first investigation shall allow the assessment of water quality appropriateness for water supply purposes prior to the decision for construction. The second investigation shall serve for the verification that the completed spring tapping and well facilities do not affect the micro-biological quality of water. In other words, it has to be verified that the constructed facilities do not entail a micro-biological contamination of the water.

In case of the construction of a well, an investigation prior to construction might be impossible due to the lack of any borehole for sampling the subject aquifer. In this case, a small borehole for sampling purposes shall be drilled. This will probably be cheaper than the construction of a well envisaged for public supply.

9.3.1 Sampling

The correct sampling of water is decisive for the reliabilityof water analysis results. It is of utmost importance that water characteristics and quality are not changed between the removal of the water sample and the subsequent analysis. Therefore, licenced institutions with professional staff shall be contracted for sampling and analysing in order to ensure water quality compliance.

To ensure representative results, it is important to withdraw the water sample from a point, which is as close as possible to the location subject to the analysis. For example, for investigation of raw water from a dug well, the sample shall be taken directly from the well and not from the transmission pipe downstream of the booster pump. The point of sampling shall exclude any influences on raw water quality through facilities outside the well.

The preconditions for a representative analysis (sampling point, analysis intervals) must be identified separately for each source.

9.3.2 Representative Results

The result of a water analysis must be representative for a specific source, a definite period and characteristic conditions. This means that the analysis result has to display that quality which will appear with high probability in the specific source (spring, well) during a certain period (day, week, month, season, year) under characteristic conditions (e.g. pumped groundwater, soil properties, wet season, dry season, etc.).

To get an idea ofthe raw water quality (at least temporarily), some parameters can be investigated by an on-site analysis. Portable equipment exists for on-site water quality analysis for numerous parameters in the form of test kits and portable analysis instruments. Further, the choice of analysis equipment shall take into account the specific characteristics of the water to be investigated. For example, the respective equipment shall be applied which fits to the concentration range of a parameter usually appearing in raw water of a specific region or source. This will facilitate the conduction of analyses without the need for sample preparation steps (e.g. dilution series).

9.3.3 Standards are Exceeded

If the investigation of a water source reveals a bad quality of water, the origin of the quality impact shall be identified, where possible.

- If quality impacts are caused by anthropogenic activities (e.g. wastewater disposal, animal breeding) potential relief measures must be considered. Options include the establishment of protection zones and the improvement of wastewater disposal.
- If quality impacts originate from the natural environment (underground conditions, seasonal floods),the option is to either look for another source or to define appropriate treatment methods.

Based on the series of analyses, for each parameter the maximum value exceeding the standards has to be takenas the design parameter for water treatment. In case the sampling period is short, it is recommended to add an additional reserve to the maximum value found.

9.4 WATER TREATMENT REQUIREMENTS

9.4.1 Basic Approach

The identification of the necessary types of raw water treatment shall be based on water investigation results under consideration of the following prerequisites.

- Reliable function
- Cost efficiency
- O&M friendliness
- Environmental friendliness
- Sustainability

In other words, a feasibility assessment of the water treatment must be conducted.

The required water treatment equipment must be operated in a simple way. The O&M requirements shall be adapted to the local framework conditions in terms of technical supply (spare parts, consumables, repair staff) and maintenance personnel.

Environmental friendlinessshall be achieved by a low demand for energy and consumables. Further, the treatment method shall generate as little operational waste as possible.

It must be possible to include the disposal of operational waste (gravel filter cake sludge) in ecological cycles. The chosen technology shall avoid the appliance of raw materials which cannot be regenerated (used-up active carbon powder) or which need advanced recycling technologies (granulated active carbon). This precaution shall enable meeting the goal of sustainable operation.

9.4.2 Location of a Treatment Plant

The water treatment plant shall be located as close as possible to the raw water source. This shall avoid impacts on the function of the transmission pipes upstream of the plant. Potential impacts include sedimentation of solids, plugging of inside pipe walls (limestone), and corrosion due to aggressive waters.

If the distance between the water treatment plant and the customers entails a retention time of more than one day, the risk of recontamination by microorganisms emerges. In this case, an additional disinfection stage has to be provided near the customers.

In case raw water is of such quality that an impact on transmission pipes and fittings can be excluded, the water treatment plant can be located as close as possible to the target community. The purpose is to avoid long retention times and the corresponding possible recontamination of treated water on the way to the customers.

9.4.3 Water Treatment Technologies

Quality impacts are caused by exceeding the limiting value of any water quality parameter. For each parameter,treatment technologies exist to reduce the content below the admissible concentration. An excerpt of these methods is briefly described below (Table 7 to Table 10) and subdivided for the three parameter groups physical, micro-biological and chemical. The biological contamination through algae is a special case.

Table 7: Most Common Water Treatment Technologies for Physical Contamination

Quality parameter	Treatment method	Comments
Suspended solids	Sedimentation	Pre-treatment (coagulation, flocculation, sedimentation) Aligned downstream filtration
	Horizontal gravel filter	Roughing filter, Aligned downstream sedimentation
	Up-flow filter	Roughing filter
Suspended solids	Rapid sand filter	Roughing filter
	Pressure filter	Aligned downstream roughing filters
Colour	Active carbon filter	Charged filter material (granulated active carbon) requires thermal regeneration (special plants required), Charged filter material (powder active carbon) is waste and must be finally disposedof by incineration or landfill deposit (environmental issue)
Odour	Active carbon filter	Ref. to line above

Contamination by bacteria is removed by disinfection. The specific methods are outlinedin Table 8.

Table 8: Most Common Water Treatment Technologies for Bacteriological Contamination

Quality parameter	Treatment method	Comments
	<u>**Disinfection**</u>	
Escherichia coli (E. coli) Etc.	1. Calcium hypochlorite solution	Solution is prepared on site from powder, Corrosive Calcium hypochlorite powder entails problems with storage
	2. Sodium hypochlorite solution	Instable standard solution, Standard solution availability in Uganda?
	3. Electrolytic on-site generation of sodium hypochlorite	No storage of Sodium hypochlorite solution required, Cheap raw material Sodium chloride (NaCl; salt)
	4. Chlorine gas	Antiquated due to safety risks, leaky gas pressure bottles entail the release of toxic chlorine gas to the ambient air
	5. Chlorine dioxide solution	Standard solution to be delivered, Most modern method, More efficient than chlorine gas, Longer endurance of disinfection (depot effect)
	6. Ozone gas	On-site production of ozone gas, Comprehensive plant equipment needed, Considerable O&M requirements, Cost efficient from a minimum capacity of 10,000 P.E.
	7. UV radiation	No chemical inserted in drinking water, High power demand, no enduring disinfection (no depot effect)

Algae are considered to be solid matter of biological origin. Therefore, similar treatment is applied as for the removal of solid matter. However, there are some differences in the design parameters. Whether algae need a pre-chlorination to be broken up should be the subject of an in-depth analysis carried out by relevant institutions.

Table 9: Most Common Water Treatment Technologies for Algae Contamination

Quality parameter	Treatment method	Comments
Algae	Horizontal gravel filter	Roughing filter
	Rapid sand filter	Roughing filter
	Pressure filter	Aligned downstream roughing filters

Table 10: Most Common Water Treatment Technologies for Chemical Contamination

Quality parameter	Treatment method	Comments
IronFe^{2+} ManganeseMn^{2+}	Oxidisation and subsequent pressure filtration	Prefabricated plants available
Carbon dioxideCO$_2$	Aeration - cascade water flow	Works by gravity, low CO$_2$ reduction rate
	Aeration - counter flow stripping tower	Power demand, Higher CO$_2$ reduction rate
CarbonateCO$_3^{2-}$ Hydrogen carbonateHCO$_3^-$	Dehardening	
AmmoniumNH$_4^+$	Biological filter for aeration and subsequent transformation of ammonium (NH$_4^+$) to Nitrogen (N$_2$)	
	Ion exchange filter	Filter regeneration requires chemicals (purchase, disposal, environmental issue)
ChlorideCl$^-$ SulphateSO$_4^{2-}$ Other anions	Ion exchange	Filter regeneration requires chemicals (purchase, disposal, environmental issue)
	Reversed osmosis	Power demand, Disposal of salt concentrate is of environmental relevance
CopperCu^{2+} ZincZn^{2+} Other heavy metals	Ion exchange	Filter regeneration requires chemicals (purchase, disposal, environmental issue)
	Reversed osmosis	Power demand, Disposal of salt concentrate is of environmental relevance
Organic compounds	Active carbon filter	Ref. to Table 5, line 6

9.5 SCOPE OF TREATMENT METHODS APPLICABILITY

Table 11highlights various treatment methods and indicates, for which quality parameters each specific method is applicable.

Legend: + applicable,

- not applicable

Table 11: Overview of Treatment Methods and Corresponding Quality Parameter

	Treatment method														
Quality parameter	Sedimentation	Up-flow filter	Horizontal gravel filter	Rapid sand filter	Pressure filter	Oxidisation and pressure filtration	Aeration - cascade water flow	Biological aerated filter	Biological Denitrification	Reverse osmosis	Ion exchange	Sodium hypochlorite solution	UV radiation	Ozone gas	Active carbon filter
Settleable matter (sand, gravel)	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Suspended solids	+	+	+	+	+	-	-	-	-	-	-	-	-	-	-
Colour	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+
Odour	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+
Hardness … Ca^{2+}, Mg^{2+}	-	-	-	-	-	-	+	-	-	+	+	-	-	-	-
Algae	-	-	+	+	+	-	-	-	-	-	-	-	-	-	-
Bacteria	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+
Ammonium NH_4^+	-	-	-	-	-	-	-	+	-	+	+	-	-	-	-
Carbon dioxide CO_2	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
Carbonate CO_3^{2-}	-	-	-	-	-	-	-	-	-	+	-+	-	-	-	-
Iron Fe^{2+}	-	-	-	-	-	+	-	-	-	+	+	-	-	-	-
Manganese Mn^{2+}	-	-	-	-	-	+	-	-	-	+	+	-	-	-	-
Lead Pb^{2+}	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-
Chloride Cl^-	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-
Nitrate NO_3^-	-	-	-	-	-	-	-		+	+	+	-	-	-	-
Nitrite NO_2^-	-	-	-	-	-	+	+	+	-	+	+	-	-	-	-
Pesticides	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+

Dissolved organic compounds[7]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+

9.6 SEQUENCE OF TREATMENT STAGES

The specific treatment methods must be aligned in the appropriate sequence (Table 12) to allow for an effective treatment. A wrong sequence will either reduce the effectiveness of specific methods or even impair their functioning. The following precedence is to be considered:

- Physical and mechanical treatment methods have to be aligned upstream of the chemical treatment steps
- Rough physical treatment has to take place upstream of the fine treatment
- Suspended matter has to be removed prior to dissolved matter
- Disinfection is the final treatment step

Very few treatment stages can be used as stand-alone technology (and only if there are no other parameters in the raw water requiring an additional treatment):

- Sedimentation, if raw waters have settleable solids only;
- Disinfection (sodium hypochlorite; UV; ozone), if raw waters are bacteriologically contaminated only;
- Aeration, if raw waters have excessive carbon dioxide concentrations only;
- Slow sand filtration, if raw waters have ammonium and/or organic biodegradable compounds slightly above standards only.

Table 12: Sequence of Treatment

Sequence of treatment

Sedimentation	Pressure filter	Oxidisation and pressure filtration	Reverse osmosis	Active carbon filter
Horizontal gravel filter	Aerationcascade water flow	Biological aerated filter	Ion exchange	UV radiation
Up-flow filter		Biological De-nitrification	Ozone gas	Sodium hypochlorite solution
Rapid sand filter				
Flocculation/Coagulation	Sedimentation	Filtration	Disinfection	

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[7] For example dissolved organic hydrocarbons.

9.7 TREATED WATER QUALITY MONITORING

9.7.1 Treated Water Quality Monitoring at Treatment Plant Level

A regular treated water monitoring is required at the level of the treatment plant in order to ensure that actions are taken at the operational level in case the treatment process is not fulfilling the standards. Usually, a laboratory is to be operated at the treatment plant itself, or a contract is given to a licensed laboratory.

9.7.2 Treated Water Quality Monitoring at Network Level

In a public water supply system, the required water quality must be ensured continuously at the point where it is delivered to the customer. In particular, these points are the house connections or the public standpipes. The design of the water supply system has to enable the reliable assurance of water quality at these points.

9.8 CHECKLIST

1. Is the water supply system envisaged for human consumption or other domestic use?
2. Which type of raw water source shall be exploited (spring, groundwater, surface water)?
3. Are quality data of the envisaged raw water source available?
4. Is narrative information of neighbouring inhabitants to the raw water source available?
5. Have quality impacts of the raw water source been reported by the neighbouring inhabitants?
6. Which periods of water quality fluctuation are expected within one year?
7. Which potential anthropogenic contamination sources are located close to the raw water source?
8. Which potential natural quality impacts on the raw water source are expected?
9. What is the required minimum number of quality investigations in the period of one year?
10. Which parameters are of relevance for the quality of the raw water source?
11. What is the required scope of investigation parameters?
12. What investigation intervals are required for representative analysis results of specific parameters?
13. Where is the closest point to the raw water source appropriate for water sampling?
14. What is the expected concentration range of specific parameters?
15. Which quality standardis applied for water quality investigation?
16. Where is the next capable institution to perform the water analyses?
17. Which parameters can be analysed on-site?
18. Which treatment steps are required according to water analysis results?
19. Which treatment methods are appropriate for the required treatment steps?
20. Are the investment costs for the envisaged treatment facilities affordable for the water service provider?
21. Is power supply needed for the envisaged treatment methods?
22. Are the needed consumables for treatment available in the region?
23. What are the cheapest options (investment and operation costs) of the potential treatment methods?

24. Can the required treatment facilities be constructed and/or supplied by local companies?
25. Are the envisaged treatment methods affordable for the long-term operation?
26. Is professional personnel available for the O&M of the foreseen treatment facilities?
27. Which kind of waste will emerge in the course of treatment plant operation?
28. How will the operational waste of the treatment plant be disposed?
29. Will an environmental impact occur from the disposal of operational waste of the treatment plant?

9.9 BIBLIOGRAPHY AND RECOMMENDED READING

[1] Water supply design manual 2012, Final Draft, prepared by AIM Engineering by order of the Republic of Uganda, Ministry of Water and Environment

[2] Technical manual on water supply, Mutschmann Stimmelmayr (German/English), 15th edition

[3] Water Supply and Pollution Control (8th Edition),Viessman Jr., Hammer, Perez, Chadik

10. WATER TRANSMISSION AND STORAGE

10.1 PURPOSE

The purpose of water transmission is to bring bulk water volumes in a concentrated way to the next infrastructural level. For raw water, it will be the routing from the source,either to the treatment plant (if required), or to the storage reservoir. For treated water, it will be the routing from the treatment plant to the storage reservoir.

The purpose of storage is to balance water production and water consumption.

10.2 KEY PRINCIPLES

10.2.1 Water Transmission

The following key principles shall be applied:

- As far as possible, and if topographic conditions allow, water transmission shall be by gravity; gravity is given when, in a hydraulic longitudinal section, the line of dynamic pressure (hydraulic gradient) never crosses the line of topographic elevations of the longitudinal section of the pipeline, i.e. no negative pressure occurs.
- As far as possible, the transmission pipelines should be kept as short as possible.
- Appropriate pipe diameters shall be selectedin order to enable the transfer of the required flows on the one hand (avoidance of undersizing) and to meet economic criteria on the other hand (avoidance of oversizing).The selection of the technically correct diameter must be madeby theapplication of the relevant hydraulic formulas.
- Merging transmission mains (pipe junctions) must have at their connection point very similar pressure levels (differences less than 0.2 bars);otherwise the flow characteristics will not be according to the predicted values.
- Each high point (local maximum) in the system must be equipped with an air-release valve, and each low point (local minimum) with a washout (scour valve).
- The pipe material shall be selected in accordance with water quality conditions (especially for raw water transmission) and pressure conditions (maximum pressure during transport) according to Ugandan and international standards.
- Definition of the best location for pumping stations is an iterative optimisation process.
- Water flows have to be monitored at inlets and outlets (if the distance between inlet and outlet is short, one bulk meter is sufficient).
- Accessibility to the sites must be possible at any time for technical staff for operational and maintenance reasons.

10.2.2 Water Storage

The following key principles shall be applied:

- As far as possible, the location for water storage shall be higher than the zones to be supplied. If topographic conditions do not allow for this, an artificial elevation has to be foreseen.
- The storage volume shall be selected in a way that the stored volumes plus on-going water production are sufficient to cover all foreseen operational demands.
- Water inflow and water outflow has to be monitored (bulk meters).

- Water overflow has to be restricted (ball valve with closing device) and forced emptying enabled (washout).
- Aeration must be catered for.
- Accessibility to the site must be possible at any time for technical staff for operational and maintenance reasons; accessibility for external people has to be restricted.

10.3 OPEN CHANNELS AND GRAVITY LINES

Open Channels

Open channels are usually used for bulk raw water supply only. Compared to gravity pipes (for raw water only), the following statements have to be made:

- An open channel does not restrict access to the conveyed water, animals might influence the water quality negatively.
- Algae might develop.
- Precipitation and surface runoff will easily enter into the open channel (in the rainy season).
- Construction costs for open channels are often higher than for pipes; only for significantamounts of bulk water may the economic situation be in favour of open channels.

Gravity Lines

Gravity lines are partly filled pipes.Both, open channels and gravity lines allow regulation of flows by two main elements: geometry (depth, width; radius) and slope.

For the dimensioning of pipes the use of thePrandtl-Colebrook equation is recommended whilethe Manning equation should be preferred for open channels.

10.4 GRAVITY PIPES

Gravity pipes are pipes where the full section of the pipesis used for water transport (as compared to gravity lines). They are pressurised pipes, but the energy input comes from the geodetic differences in elevation, not from artificial devices like pumps.

Wherever possible, gravity systemsshall be prioritised, as the operation costs for such systems are usually lower than pumped systems. In case two sources are available, one closer but requiring pumping, and another one further away but allowing for gravity supply, a financial evaluation has to be carried out in order to assess which one is the better financial solution, if no other elements are in favour of one of the two.

The static pressure for gravity pipes should be kept as low as possible (if necessary by means of pressure-breaking tanks or pressure-reducing valves), but as high as necessary (to avoid any negative pressure on the way). To ensure that no negative pressure will occur, a hydraulic profile (longitudinal section) has to be developed showing the elevations of the routing and the dynamic pressure on the entire route. At the feasibility level, or at the latest at the detailed design level, the routing has to be confirmed by a land survey carried out by professionals.

The selection of the required diameter must be made by application of the relevant hydraulic formulas including friction losses due to the distance. The optimum diameter is the smallest one reaching or exceeding the design flow without having any negative pressure on the way.

Pressure classes indicate up to which maximum pressure the use of a particular pipe is recommended. Pressure classes are usually expressed in bar. One bar corresponds to roughly 10 m water column. The pressure class (nominal pressure, PN in abbreviation) to be used for the selected pipe diameter must also take into account operational conditions:

- If there is any possibility of water hammer occurring (caused by a sudden shut-down of a valve for instance), the maximum pressure induced to the pipe during this pressure surge must be taken into account. The respective nominal pressure of the pipe shall be higher than this potentially occurring maximum pressure.
- If there is no possibility of water hammer (gravity flow conditions without any valves), the static pressure (as the highest occurring pressure) shall be used for defining the required pressure class.

To avoid air pockets, the design of the routing should try to minimise the number of high and low points by following the contour lines.The minimum slope should be set at 0.3% (3 m per km); for pipes >200 mm 0.2% can be applied.

In case the routing has to be done in such a way that one or more high points occur (peaks in the routing as shown in the hydraulic profile), each of these has to be equipped with an air-release valve.Washouts have to be foreseen for each lowest point.

10.4.1 Underground Installation

Gravity pipes shall be laid according to the respective Ugandan or international standards or according to the manufacturers' specifications. In any caseit must be ensured that the pipes are laid deep enough to avoid mechanical damage (minimum coverage), and so that no harm to the pipe may occur during laying and backfilling. A cross-section of a typical pipe-laying trench shall comprise at minimum:

- Sand or gravel bedding to avoid pipe cracks during compaction and future mechanical pressure. The bedding zone shall comprise a min layer of 10 cm of bedding material underneath the pipe bottom and shall enclose the whole pipeline. Also the minimum cover of the pipeline with bedding material shall be min 10cm above the pipe vertex.
- Backfilling zone from the top of the bedding zone to the surface level. Material excavated during trench digging can be reused for backfilling. Backfilling material is to be compacted in layerswith a maximum layer thickness according to Ugandan or international standards.
- Minimum depth of pipe installation, expressed as distance between pipe vertex and surface level.
- Minimum trench width depending on the pipe diameter to be installed and according to Ugandan and international standards.

When crossing a street used by bulk freight such as trucks/ busses etc. it is recommended to put the gravity pipes in a cover pipe of a bigger size and of a material resisting well to pressure (steel, ductile iron, concrete).

10.4.2 Installation above Ground

As far as possible, installation above ground should be avoided.Sometimes, due to adverse on-site conditions such as rocky ground, an above-ground installation may be necessary. When doing so, the following elements should be taken into account:

- Provide expansion joints to balance the effects of thermal changes.
- Pipes must be supported at each section end. This support has to carry not only the load of the pipe plus the load of the water when full, but also include a factor for additional external loads (such as children playing on the pipes); pipes should be strapped to the support allowing for horizontal movements.
- The number of supports should be sufficient to avoid sagging of the pipes.
- At bends, adequate thrust blocks have to be provided to cater for hydraulic forces.

- In sections with deep slopes, at directional and elevation changes anchoring must be provided.
- Heavy equipment such as valves need to have an independent support.
- Protection of the outer pipe layer against abrasion has to be provided.
- Assess the vulnerability from veld fire, animals and rodents.

10.5 PUMPS AND PUMPING STATIONS

Pumps are required to overcome unfavourable topographic conditions.

In this Chapter, pumping stations are used either to connect a water source to a treatment plant or reservoir (raw water pumping station), or from a water treatment plant to a reservoir (treated water pumping station).

Pumping stations are usually connected to a suction reservoir providing the water for pumping.

10.5.1 Types of Pumps

10.5.1.1 Manual Pumps

Manual pumps are installed directly over the well. The combination of well and manual pump is considered a water supply system by itself.

10.5.1.2 Centrifugal Pumps

Centrifugal pumps are the most commonly used pumps for water supply. They can be installed as wet pumps, i.e. in the water (in wells for instance), or dry (in pumping stations usually). According to the direction of the pump axis, they might be vertical pumps or horizontal pumps.

The selection of the right pump requires knowledge about the design flow and the total head to be provided (difference in elevation plus head losses plus remaining pressure at the outlet).

The selection shall ensure that the pump is working at or very close to its optimum.

Some centrifugal pumps have a positive suction head allowing an installation of the pump a few meters higher than the lowest water level of the suction reservoir (NPSH; Net Positive Suction Head). The exact definition of how many meters depends on the pump characteristics, they are usually provided by the manufacturers. Be aware that in this figure friction and other losses have to be included.

Motors for centrifugal pumps need electrical power provided either by the grid or by an alternative source such as solar panels and/or diesel generators. The design of the motor requires knowledge about the necessary energy for the pump plus sufficient reserve to avoid overloading the motor, especially at the start of the pump operation (switching on).

To avoid operational problems, each pumping station should have back-up capacities. This refers to pumps as well as to power supply.

10.5.2 Selection of Pumps

The selection of a suitable pump is a key element in the optimisation of operation costs. The right pump is the one which has its optimum working point (highest efficiency factor) at the intersection of the pipeline head curve and the pump characteristic curve(Q-H diagram).

It is, therefore, necessary first to acquire knowledge of the required design flow, then to develop the pipeline head curves for different diameters (still within economic considerations, please refer to Chapter 10.7).Lastly, it is necessary to check which pump is the best suited for the working conditions based on the required flow and the required energy input to overcome geodetic elevations as well as all losses. Professional software can support the respective calculations.

Calculation of pipeline head curves has to take into account all losses generated by the pipeline. This includes losses due to fittings, changes of direction, junctions, friction losses etc.

10.5.3 Best Location for Pumping Stations

The selection of the best location for a pumping station is usually an iterative process. Depending on the topography, there are two elements defining the optimum location:

- The distance between the pumping station and the final recipient (the closer the better)
- The difference in elevation between pump axes and outlet of the pressurised pipelineto the final recipient (the lower the better)

Topographical conditions often mean that both elements becomeadverse. Therefore, an optimisation process (financial calculations, please refer to Chapter 13.6) has to be carried out by checking the consequences for investment costs and operation and maintenance costs to find the optimum location. Sometimes, limiting conditions not of a technical nature may interfere in the decision where to put a pumping station (land availability, ownership issues etc.). This should be checkedprior to optimisation in order to reduce the number of possible sites. Other limiting conditions might be:

- Accessibility (cost for construction of an access road has to enter into the optimisation process)
- Connection to the electricity grid (cost for connection has to be compared to cost for an independent supply)

10.5.4 Power Supply

Any pumping station requires a power supply. Possibilities are:

- Connection to the electricity grid
- Solar power (photo voltaic)
- Wind power (wind mills)
- Generators

The selection of the best suitable technology depends on many conditions, the most important are:

- Distance from electricity grids
- Climate aspects (winds, sunshine)
- Environmental aspects

The definition of the most suitable technology is usually a process of financial optimisation. Especially the fact that neither wind energy nor solar energy is available all the time leads to the conclusion that a back-up power supply is always required.

In case that photovoltaic pumping systems (PVPs) are being used, the following must be taken into consideration:

- PVPs donot work during the night. Therefore, a 24h supply from the source to the reservoir is not possible. Reservoir sizes must be adapted accordingly depending on the actual daily demand distribution.
- PV facilities must be secured by means of a fence (in order to avoid theft and vandalism on the one hand and injuries through inappropriate handling with electric appliances (DC!) on the other hand).

10.5.5 Monitoring of Pumping Stations

Inflow and outflow shall be measured by bulk meters.Usually, only short pipe sections are available for undisturbed flow conditions. Therefore, ultrasonic flow meters are a good choice for reliable metering at the pressure side.

In addition, each pump must be monitored by means of registering working hours. Pressure gauges after the pump are required for each single pump.

Pressure switches allow for automatic pump starts.

10.5.6 Constructive Elements of Pumping Stations

The pumping station shall be designed in a way to ease operation. This includes sufficient space for daily operational duties as well as equipment to maintain and exchange pumps. Due to the weight of pumps, a fixed crane on rails is often required. All pumping stations must have an access road. The entry door shall be wide enough to enable a pick-up to enter into the pumping station for loading and unloading. Sufficient aeration has to be provided. There must always be at least one pump as a stand-by capacity. Independently of the power provided, an alternative system based on a diesel generator is a must.

10.6 BOOSTER STATIONS

Booster pumps should be avoided in any new design, as they usually increase O&M costs compared to pumping stations. In existing schemes, however, it is sometimes necessary to increase flows by adding a booster pump.

The direct delivery of water from booster pumps to customers should be avoided. It is often better to have the booster pump feeding a (small) reservoir providing water by gravity.

Booster stations are pumps installed in a pipeline in order to increase the pressure. Compared to pumping stations, they lack thus a suction reservoir, getting the water directly from the pipe. Booster stations are usedeither to increase flows by augmenting velocities (booster station on transmission mains), or to increase pressure (booster station in distribution network), for instance to supply parts of a distribution zone at higher elevations that the water would either not reach at all with the existing pressure, or only with insufficient final pressure at customer levels.

Booster stations are usually managed automatically by pressure sensors; one downstream, one upstream.

The design of booster stations on transmission mains has to take into account the pressure at the entry of the booster pumps and the remaining pressure to be provided by the pumps to overcome the friction losses due to the distance (depending on the different diameters), additional losses due to fittings and changes in direction (horizontal and vertical) and diameters and a minimum remaining pressure at the outlet.

With the installation of a booster station, the pressure at its entry will change compared to previous flow conditions, i.e. will be reduced, as the booster station will have the side effect of increasing flow velocities even upstream. The entry pressure under the new flow conditions has to be calculated by application of the relevant hydraulic formulas before calculating the required remaining pressure to be provided by the booster.

The design flow should allow the booster station on the transmission mains to work for at least 20h per day duringa peak demand day. A booster station designed for working less than that on peak demand days will usually be suboptimal on the level of electricity consumption.As friction losses risetogether with velocity,it will generate higher electricity costs for the same water volume to be pumped, even if (in fact: because) the time for pumping is shorter.

10.7 PRESSURISED PIPELINES

The selection of the required diameter must be made by application of the relevant hydraulic formulas including friction losses due to the distance (depending on the different diameters), additional losses due to fittings and changes in direction (horizontal and vertical) and diametersand a minimum remaining pressure at the outlet. The head losses for the relevant diameters are to be calculated and an optimisation to be performed by calculatingconstruction costs and operation costs for each diameter for a specific time period. As a general guideline, the optimum diameter is often around a flow velocity of 1 to 1.5 m/s.

Sometimes, the pressurised pipeline does not need to be extended up to the final recipient. If it has to cross a topographic high point from where a gravity supply to the final recipient is possible, this option often turns out to be more economical than to prolong the pressurised pipeline up to the recipient. Therefore, it might be advantageous to slightly deviate from the shortest routing in order to allow for a longer section with gravity supply. The required elevation that shall be reached by the pumping station has to be calculated backwards, starting from the elevation of the outlet by adding friction losses.

The material of the pressurised pipeline shall resist all operational pressures, during pumping (especially when the pumps start, the operational pressure may exceed the nominal pump pressure by up to 30% if the pumps have no speed regulation) as well as when pumps are not working (static pressure). The material shall be able to resist dynamic changes in pressure too (water hammer caused by a sudden shutdown of pumps, for instance because of power failure).Water hammer simulations with specific software shall be carried out using the design parameters in order to define the required material specifications for the pipes (maximum pressure), or usage of professional literature.

In order to cope with sudden pressure changes, a pressure vessel(surge vessel or surge tank) has to be foreseen to mitigate pressure variations due to rapid changes in velocity of water. This will have a positive effect on the lifetime expectation, and will in addition reduce technical water losses by fittings leaking due to heavy pressure changes (saving operation and maintenance costs). Sizing of pressure vessels goes hand in hand with pump selection. Specific formulas or software must be applied. The location of the pressure vessel should be as close as possible after the fittings on the pressure side of the pump, still in the pumping station.

Pressurised pipelines shall always be underground to avoid radial movements when pressure changes occur. The minimum specifications given in Section 10.4.1 are valid for pressurised pipelines too.

Pipe junctions (two pressurised mains joining each other) need to be calculated with specific programs to assess the conditions at the junction point; if the pressure differences are significant, the water flows will not be as predicted. Water production, that is pumping from both pumps, will try to reach a pressure balance at the junction point. In other words, if the difference between the two pressure levels is significant, both pumps will change their working conditions:

- The pump providing more pressure will increase its production, providing higher velocities and thus higher friction losses to compensate the lower energy level of the second one at the junction point.
- The pump providing less pressure at the junction point will reduce its flow in order to reduce velocity and thus increase the pressure at the junction point by having less friction losses.

As an overall result, if the pressure differences are significant, neither pump will work close to or at its optimum point. This can have negative consequences on O&M costs, but also on water availability.

In any case, the hydraulic sizing of junction pipes needs to be assessed thoroughly, ideally using hydraulic software.

10.8 FITTINGS

In general, valves and fittings facilitate the operation of the water supply system. A careful design of the routing of the pipeline will minimise their number and related costs.

At the detailed design level, a cost assessment has to be carried out to check whether the fittings should have the same diameter as the main pipe or can be one dimension smaller. This assessment includes the cost for the smaller fitting plus reducers compared to the cost for the larger fitting. It has to be ensured that flow velocities in fittings of smaller size are not excessive.

Depending on the size of the valves and their strategic importance within the system, separate bypasses can be envisaged to allow continuing operation during maintenance of the valve. This becomes necessary when the size and/or the weight of the valve will result in a longer time for maintenance.

Note: All fittings must be at least of the same pressure class as the pipes they are connecting.

10.8.1 Section Valves

Section valves serve to facilitate maintenance of the pipes by isolating one section from the others. Their place of installation usually depends on the topography and on the routing. They are usually installed next to air-release valves and scour valves. In longer sections, where no air-release valves or scour valves exist, section valves should be installed within a maximum distance of 1-2 km from each other. Ensure that after each section valve, an anti-vacuum valve is installed (at the higher end of the specific section).

The design has to be carried out in such a way that an easy removal of the valve is possible (extension piece/ mounting adapter, flange adaptor coupling for flanged valves for instance). The most frequent types of valves used for this purpose are gate valves or butterfly valves.

10.8.2 Air Valves

These valves are used to release air from the pipeline, during normal operation (degasing due to changes in pressure) and during the pipe filling process. A missing or improperly working air-release valve will reduce the hydraulic capacity of the pipeline, causing in the worst case a full stop of water flow. Air-release valves are usually installed with an adjacent gate valve and an extension piece for easy removal and repair.

The idea of installing a public standpost instead of an air-release valve (by opening the tap the air will be released) is not generally recommended; the air passing through the mechanical water meter will measure an artificial consumption (and the velocity of the propeller when air passes through it is many times higher than for water). Consumption figures, and thus demand management, is then incorrect. Special water meters not measuring air would be an appropriate solution (ultrasonic water meters for instance), but they are more costly than mechanical ones.

Air valves are a possible source of contamination of the water inside the pipes. Therefore, appropriate measures have to be taken to avoid this. Sizing is usually done depending on pipe diameter and flow velocity in the pipe.

While de-aeration valves are usually sufficient on smaller diameter pipes (distribution network), in most cases the installation of an aeration/de-aeration valve, which allows air flow in both directions, is recommendable on the mains. When a specific section of the main is emptied – either during maintenance or during operation because of lack of water supply – the water volume has to be replaced by air coming into the pipe by the air valves.

Precautions must be taken against the intrusion of dirt and contaminants to the main through the air valve. Therefore, air valves always must be protected in a locked (but not airtight) chamber.

10.8.3 Scour Valves

Scour valves serve to drain a section of a main between two isolating valves completely. The scour valve is part of the washout, consisting usually of a valve chamber, the drainage pipe (approx. half the size of the main pipe, but minimum DN 80) and the hand-operated scour valve, and an open drain to lead the drained water to the next suitable water body in order to minimise erosion.

10.8.4 Break PressureTanks

A break pressure tank (BPT) is required to avoid too high pressure in the pipeline. It is usually combined with a balancing tank. The location of the BPT shall be selected in order to ensure gravity conditions in the downstream part of the pipeline until its final destination. If the BPT is not connected to a balancing tank, it must be constructed as a two-chamber system, separated by a submersed wall. Sizing is usually done by using a hydraulic retention time of 5minutes.A submerged wall shall be foreseen in order to avoid air intrusion into the outgoing pipe by significant water level fluctuation due to waves generated by the incoming jet of water.

In case several BPTs are required or the flow is important, an alternative design for using the water for hydropower should be envisaged, before conveying it to its final destination for water supply. Financial comparisonsshall be made by contacting suppliers to find out the current market price and to make an estimate about financial sustainability.

10.8.5 Pressure-Reducing Valves

Pressure reducing valves are valves which allow the regulation of the pressure in the pipeline. Upstream of the pressure-reducing valve,a dirt box (strainer) has to be provided to avoid mechanical damages to the valve. On the outlet side of the valve, a pressure-relief valve has to be installed, to prevent the possible build-up of pressure resulting from failure of the pressure-reducing valve to operate correctly. Pressure gauges upstream and downstream of the dirt box are necessary. A by-pass pipe, including an isolating valve, is a must. Currently, the best pressure-reducing valves are plunger valves. Beside proactive maintenance, they have no maintenance cost.

10.8.6 Non-Return Valves

Non-return valves are usually necessary at pumping stations in order to avoid that water in the pressurised pipeline can flow back through the pumps.

Valves combining a section valve and a non-return valve are calledstopcocks. They are required at customer connection level to prevent backflow if the distribution network is under repair or faces a major leak.

10.8.7 Extension piece / mounting adapter

It is recommended to install an extension piece / mounting adapter along with each valve in order to allow for easy installation and de-installation during operation and maintenance.

10.9 VALVE CHAMBERS

Valve chambers have to be designedin a way to allow for sufficient working space, especially for using a spanner to fix or open bolts. The roofing of the valve chamber shall be easily removable (lockable cover) to allow for the exchange of the valve. Ventilation for adequate airflow has to be provided. As far as possible, the bottom level of the valve chamber shall be on the final ground level. The design engineer shall make provision for a division between the inside floor of the valve chamber and the pipeline. Special pipe pieces for crossing the walls shall be provided. The pipe material for the section inside the chamber shall not be flexible.

10.10 RESERVOIRS

10.10.1 Types of Reservoirs

10.10.1.1 Raw Water Reservoir

A raw water reservoir may serve different purposes:

- to balance water production at the source (if the source has fluctuations in water production during a day)
- as starting point for a gravity scheme, when the source is caught by different pipes bringing different flows
- as suction reservoir, if pumping is necessary
- on a larger scale (dams) it is used for balancing a yearly demand (securing water distribution in periods of low natural water inflow)

10.10.1.2 Treated Water Reservoir

Subsequent to the final water treatment stage there is usually a treated water reservoir. Its duty is to store water at the treatment plant itself, either for operational reasons (water consumption at the treatment plant), or to buffer any malfunction of the treatment plant requiring its shut down (for operational or maintenance reasons). Related todownstream infrastructure, this reservoir can have different functions and can act as a balancing reservoir and/or suction reservoir.

10.10.1.3 Intermediate Reservoir

An intermediate reservoir is a reservoir used to feed other reservoirs. Sometimes, part of a distribution system is also connected to it in a separate outlet. The most important objectives of intermediate reservoirs (applicable for larger schemes only) are:

- Reduction of the size of the diameter of the main distribution pipes
- More evenly balanced pipeline pressure
- Division of the distribution system into smaller sections;easier to manage and monitor
- Reduction of the size of the main storage reservoir

10.10.1.4 Balancing Reservoir

A balancing reservoir is situated between water source/water treatment plant/intermediate reservoir and distribution network. It is thus directly supplied by a transmission main (or directly located at the water source/water treatment plant), and it feeds a distribution network via one or more distribution mains leaving the reservoir. It serves to balance production and demand.

10.10.1.5 Counter-Reservoir

A counter-reservoir is a special type of balancing reservoir, fed by a pipe acting as both transmission and distribution main. In other words, the distribution system is located between the water source/treatment plant/pumping station/intermediate reservoir and the counter-reservoir. This kind of reservoir is usually of a smaller size than a classic balancing reservoir, as the peak demand is covered from both sides; first from the water source/treatment plant/pumping station/intermediate reservoir, and second by the counter-reservoir. On an operational level, water leaves the counter-reservoir during hours of higher demand,while itwill be refilled during hours of lower consumption (especially during the night). Its sizing has to take into account the variation of production (if any) and especially the consumption for each single hour during a day of peak demand.

10.10.1.6 Mixed Type Reservoir

In rare cases, reservoirs might be used as counter-reservoirs for one distribution zone, but also as balancing reservoirs for another zone. Sizing of the storage volume for these reservoirs has to consider both hydraulic cases.

10.10.1.7 Roof Tank

In regions where people are accustomed to installing roof tanks connected to the public water supply (not used for rainwater harvesting), the volumes of these roof tanks can be taken into account for balancing the peak demand. This will lead to a reduction of the required public storage capacity. Even if the roof tank volumes exceeds the required public storage capacity, meaning that in principle no public storage would be required, it is nevertheless wise to keep a minimum amount of water to be publicly stored for operational reasons (as a minimum to guarantee for operational surplus and fire suppression; the latter where applicable, and dead water zone).

10.10.1.8 Rainwater Storage Tank

The volume of rainwater storage should not be considered at all for sizing public storage volumes. There is no guarantee that rain is evenly available during a year. In case that these tanks are fully empty, all consumers will have to rely on public supply.

10.10.1.9 Suction Reservoir

Suction reservoirs are located at pumping stations. Their duty is to ensure that the pumps have always enough water and will not run dry. A sensor-based automatic switch-off of pumps has to be foreseen when a minimum water level in the suction reservoir is reached. A usual value for sizing is 2 hours of pumping activity to be stored in the suction reservoir plus a dead water zone.

In case the pumping station is just after the final water treatment, the treated water reservoir at the water treatment plant is usually used as a suction reservoir too.

10.10.1.10 Filter Backwash Reservoir

Reservoirs for filter backwashing (at conventional water treatment plants) are installed after the conventional treatment, but usually before final disinfection, especially if disinfection is provided by chlorine. During backwashing, the biofilm developed in the filters, which support chemical processes such as oxidation of iron and manganese, will not be harmed. Their storage size depends on operational parameters.

10.10.2 Determining Required Storage Capacities

The total storage capacity of a reservoir depends on the following parameters:

- Balancing volume
- Operational surplus
- Fire suppression storage (where applicable)
- Dead water zone

The sum of the storage capacities for these 4 parameters brings us to the total storage capacity. The total volume for bigger schemes shall not exceed one day of production to avoid recontamination in the reservoir(s).

10.10.2.1 Balancing volume

Balancing the daily peak demand has usually the highest impact in the definition of the required storage capacity. Balancing is required to cater for peak outflows, while the inflow is more or less constant. The balancing volume is usually the predominant element in determination of the required size of the reservoir.

10.10.2.2 Operational Surplus

In order to have enough water during the daily peak demand even in case of a major break upstream of the reservoir it is usual to foresee an operational surplus volume corresponding to 2 hours of average hourly consumption. For smaller schemes, where no technical staff is available to carry out major repairs immediately, the operational surplus can be higher.

10.10.2.3 Fire Suppression Storage

The fire suppression storage is the amount of water that will be used for fire fighting, if the scheme has been adapted for it (hydraulic simulations defining the size of the distribution pipes as well as the scheme being equipped with hydrants).

10.10.2.4 Dead Storage

The lowest part of the storage volume is usually considered as dead water zone. Dead in the sense, that this volume ensures that the reservoir will not run dry during normal operation. It corresponds to the volume between the bottom level of washout pipe and the bottom level of the lowest main leaving the reservoir.

10.10.2.5 Elements for Sizing Reservoirs for Distribution Purposes

The following table compiles the required volumes to be taken into account when sizing a reservoir that will provide water to a distribution network:

Table 13: Elements for Sizing Reservoirs for Distribution Purposes

Reservoir Type	Balancing volume	Operational surplus	Fire suppression	Dead zone
Intermediate reservoir	X	X	----	X
Balancing reservoir	X	X	X	X
Counter reservoir	X	X	X	X
Mixed type reservoir	X	X	X	X

10.10.3 Locations of Reservoirs

All reservoirs feeding a distribution system should be located as close as possible to the distribution system. This avoids long travel time between the reservoir and the distribution network, resulting in possible water quality deterioration. Another point is that the reservoir should allow for descent pipe pressure in the distribution network. With this approach, the minimum elevation should be 20 m above the lowest point of the distribution network and the maximum around 60 m.

10.10.4 Constructive Approaches

All reservoirs shall be equipped with the following features:

- Inflow and outflow bulk meter(s) each connected to the inflow and outflow pipe(s) respectively
- Ball valve
- Water level gauge

- Overflow pipe and wash-out pipe
- Fittings and valves on all pipes with exception of the overflow pipe
- Aeration pipe
- Lighting (where applicable)
- Lightning protection (where applicable)
- Fence (where applicable)
- Access road (where applicable)

The decision on the number of chambers for a reservoir comes from an operational point of view. For small reservoirs (up to approx. 500 m³ storage volume) one chamber is usually considered sufficient. For bigger reservoirs, two or even more interconnected chambers shall be foreseen, but each of these shall be able to be shut down independently for maintenance reasons. Each chamber has thus to be equipped with ball valves, water level gauges, overflow and wash-out pipes, and aeration pipes. Additional valves will be necessary to isolate each chamber from the others.

The material for the reservoir and the pipes inside the reservoir shall be water tight and resistant against any possible impact caused by water quality issues (aggressiveness; corrosion etc.) or by gas delivery of residual chlorine.

10.11 BULK METERING

Bulk metering is required to monitor flows and assess what happens between inlet and outlet. If the difference reaches or exceeds 5% between inflows and outflows of pipelines, a technical survey shall be carried out to identify the reason(s).

The diameter of the bulk meters shall preferably be one dimension smaller than the pipe, second best case is the same diameter as the pipe.The bulk meters shall be foreseen with two reduction pieces, two section valves, a back-flow preventer and an upstream strainer. Head losses due to these features have to be taken into account in the hydraulic calculations.

The decision whether a mechanical bulk meter or another type such as an ultrasonic or electromagnetic meter shall be applied depends on criteria such as:

- Size of the diameter of the pipe
- Costs for procurement, installation, operation and maintenance
- Ease of maintenance and accessibility of spare parts
- Continuous or intermittent supply

For smaller schemes, and in order to minimise cost, the decision will usually be in favour of mechanical bulk meters (Woltmann type). Electromagnetic and ultrasonic flow meters are usually more suitable for bigger urban schemes.

Each bulk meter on transmission mains, which is not to be located within pumping stations or reservoirs, shall be installed in a valve chamber.

In order to minimise turbulences and thus incorrect readings the location of the water meter in gravity pipelines shall meet the following requirements:

a) Minimum distance upstream of the water meter without change in direction (horizontal and/or vertical) or in diameter: 5xDN (better: 10xDN)

b) Minimum distance downstream of the water meter without change in direction or in diameter: 3xDN (better: 5xDN)

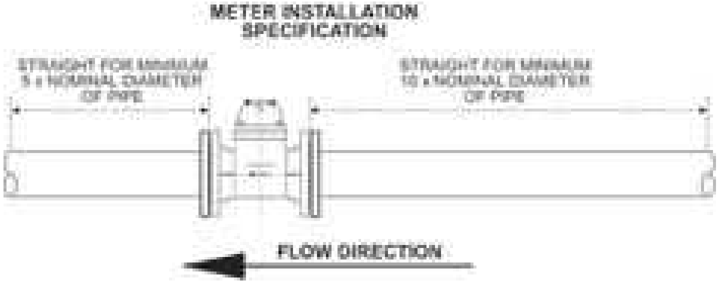

Figure 1: Meter Installation Specification

Source: http://precisionmeters.co.za/water-meter-installation-Guidelines/

10.12 CHECKLIST

1. Is it obvious where the mains need to be situated?
2. Have the foreseen locations of the mains been optimised?
3. Have the optimal diameters of the mains been identified?
4. Have longitudinal section drawings for all mains been drafted, either to ensure that the mains are gravity mains, or to calculate the required pumping heads?
5. Have air release valves and washouts been foreseen in all high and low points of the mains?
6. Have sufficient valves and fittings been foreseen in order to facilitate the operation of pipes?
7. Have the right numbers of valves and fittings been taken into account for financial calculations and friction losses calculations?
8. Have potential locations for pumping stations been identified?
9. Have the required pumping characteristics been defined on basis of the optimised pressure mains?
10. Have the optimal locations for pumping stations been identified?
11. Have the right pumps been selected?
12. Is the function of each reservoir known for determining its type?
13. Have potential locations for reservoirs been identified?
14. Has the storage volume for each reservoir been defined depending on its type and other considerations?
15. Have roof tanks to be taken into account for minimising the size of reservoirs and if yes, of which reservoirs?
16. Have optimal locations for reservoirs been identified?
17. Have sufficient bulk meters been foreseen in order to facilitate the operation of the system?

10.13 DESIGN VALUES

The following design criteria and their respective values are proposed:

Table 14: Design Criteria and Values for Water Transmission and Storage

Main Parameter	Sub Parameter	Unit	Ranges		Usual
			Minimum	Maximum	
Mains	Minimum velocity	m/s	0.3	0.6	Depending on hydraulic retention time
	Maximum velocity	m/s	1.5	3.5	Depending on friction losses
	Optimum velocity	m/s	1.0	1.5	Around 1.0 m/s
	Minimum slope gravity pipes	m/km	2.0	3.0	Function of diameter
Water storage reservoirs	Balancing volume	%	30% of daily max	50% of daily max	_NB_
	Operational surplus	Hours of average hourly demand	1	3	2
	Fire suppression	l/s; 2 hours storage time	10	50	Depending on the size of the town
	Dead Water zone	% total storage volume	2	5	Depending on design

_NB_: All sizing of reservoirs must take into account (a) the inflow to the reservoir, which depends on pumping schedule, peak day factor and (b) the outflow from the reservoir that depends on the water consumption pattern. The latter one could be based on previous experiences in small towns having piped water supply infrastructure, assuming that the consumption reflects the demand (no suppressed demand).

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11. WATER DISTRIBUTION

11.1 PURPOSE

Water distribution is the delivery of potable water into the service area, where the customers are.

11.2 KEY PRINCIPLES

The following key principles shall apply:

- Sizing of the pipe diametersshall be defined by hydraulic modelling of all relevant load cases.
- The design shall be carried out to respect minimum and maximum pressure requirements.
- The design shall optimise the diameters of the pipe.
- The design shall take care of future operations.

11.3 NETWORK DESIGN

An optimised network design is a core element of a well-functioning distribution system. This will be reflected in customer satisfaction, ease of operation and future operation and maintenance cost savings.

Network design usually consists of the following elements:

- Reservoirs and/or pumping stations.
- Transmission mains (for bigger schemes: connecting two reservoirs without customer connections).
- Distribution mains (the bigger pipes heading out of a reservoir or pumping station into the distribution network). All mains together are considered as primary network.
- Secondary network, connected to the primary network, and diverting the water further into the distribution area. Customer connections on secondary pipes are usual.
- Tertiary network consisting of small pipes to which customer connections are made. The tertiary network is usually connected to the secondary network, in some cases it might be connected to a main.
- Customer connections (the last level of the distribution system), with the smallest pipe diameters, usually connected to the secondary or tertiary network.

11.3.1 Network Types

Basically, three network types can be distinguished:

- Serial net work
- Antenna network (also known as branched parallel or branched tree)
- Mashed network (also known as looped network)

11.3.1.1 Serial Network

A serial network usually supplies a small community. It consists of one distribution main to which connections are made directly.

11.3.1.2 Antenna Network

An antenna network is usually a network for small communities. It consists of one distribution main, from which single lines head towards the customers. These single lines are not interconnected, the shape of the whole system looks like an antenna.

11.3.1.3 Mashed Network

A mashed network is a network where distribution pipes are interconnected, creating loops. This network is the usual situation for urban areas. The advantage is that one zone can be fed from two sides, this balances flows, pressure and related pressure losses.

11.3.1.4 Mixed Network

Some networks, supplying more than one settlement, might be of a mixed type. For the main settlement, it is a mashed network, whereas a transmission main might be extended to supply further villages that are equipped with antenna networks.

11.3.2 Materials

The main requirementsfor materials are:

- Good resistance against pressure changes
- Good resistance against mechanical pressure
- Good resistance against aggressive on-site conditions (where applicable)
- Economical and easily available
- Easy to install

The main materials used for networks are ductile iron (mainly for main pipes), polyethylene (PE), PVC, galvanised iron (GI) and glass fibre reinforced pipes.

All types of pipe are available in a variety of pressure classes (PN classes, refer to Section 10.4). The selection of the respective necessary pressure class shall be carried outin accordance with the results of hydraulic modelling (maximum static pressure). For reasons of reducing maintenance costs, it is often chosen to use one pressure class higher than the hydraulic model would result in (for instance: PN 10 pipes for networks with a maximum pressure of 6 bars).

11.3.3 Pressure Requirements

Two kinds of pressure have to be taken into account during modelling:

- Dynamic pressure
- Static pressure

11.3.3.1 Dynamic Pressure

Dynamic pressure is the pressure occurring during the operation of a system or subsystem. The usual limiting value (lowest pressure) occurs at hourly peak flow, as due to the highest consumption the velocity is the highest and the related friction losses too. During hourly peak flow, the minimum pressure in all points of a distribution network should not go below

- 2 barsin areas with favourable topographic conditions, i.e. when the reservoir can be put in an elevated area like a hillslope.
- 1 bar in unfavourable topographic conditions, i.e. flat areas.

This has to be verified with a hydraulic modelling.

11.3.3.2 Static Pressure

The static pressure is the maximum pressure occurring in a system or subsystem. It is easily calculated as the difference in elevation between the maximum water level in the respective reservoir and the lowest pipe elevation (not ground elevation!) in the system or subsystem fed by the respective reservoir.

The static pressure shall not exceed 60 m (6 bars). A higher static pressure may damage fittings, especially at house connections, and indoor equipment, requiring more maintenance and related costs.

In case the static pressure exceeds 60 m, the following possibilities can be applied:

- Change the network design. Perhaps the lowest parts, where the static pressure exceeds the limiting value, could be fed by another lower reservoir.
- Change the location of the reservoir (rarely possible).
- Think about installing an additional balancing reservoir, the former one becoming a mixed reservoir by functioning as an intermediate reservoir to the new one and as a balancing reservoir for its own distribution network subsystem.
- Install a throttling valve or pressure-reducing valve. This option is the last one to be taken into account usually, especially in pumping schemes, as it means destroying energy that was put into the system by pumps, resulting in financial losses to the operator.

11.3.3.3 Zoning

Zoning is the subdivision of a network into areas of similar elevations for reasons of pressure and NRW management. Therefore, pressure requirements usually limit the lines of equidistance of the respective distribution subsystem to roughly 35-40 m (20 m minimum pressure during daily peak consumption versus 60 m maximum static pressure). The distribution network in the zone can be a mashed type or an antenna type.

Each zone shall be supplied by one balancing reservoir. By having a bulk meter installed on the distribution main heading from the reservoir, the inflow volumes into each zone will bemonitored (relevant for NRW calculations). The reservoirs in the different zones should be supplied with independent distribution lines without any connections. Settlements or households along such distribution mains should be supplied by a parallel distribution line.

11.3.3.4 Pressure Management

Pressure management is especially important if the pressure into a distribution network is not provided by gravity (reservoir), but by a pumping station. The pumps to be used are frequency regulated centrifugal pumps; their rotation speed directly responds to pressure changes in the distribution network. The pressure values are provided by sensors installed on the distribution pipes (usually in valve chambers at the lowest and/or furthest points).

In gravity distribution schemes, pressure management is part of operations.

11.3.4 District Metered Area

Installing DMA is one of the most important elements in assessing NRW figures during operation, in order to prioritise zones where actions have to be taken to reduce NRW. It should thus be a key principle to define DMA already during design stages to ease future operation.

A District Metered Area (DMA) is a part of a distribution system that can be hydraulically isolated from others. It has usually either one or maximum two distribution mains entering into the distribution zones, each main having a bi-directional bulk meter installed (if the distribution main is not directly connected to a reservoir, where a mono-directional bulk meter is sufficient). The area covered by one DMA should include 1,500 connections at most (at the final stage of urbanisation). During design, and depending on the level of urbanisation, it is wise to foresee smaller DMA in order not to exceed this limit when all plots are built onin the future.

In principle, each pressure zone shall be organised as an individual DMA, as the bulk meter at the reservoir's outlet will assess the flows.

Small systems (rural ones) might have a distribution system requiring just one pressure zone and thus one DMA.

11.3.5 Separation of Sections

In order to ease maintenance, each node shall be equipped with isolation valves to allow for repairs to the system with minimal disturbance of service. The number of valves at each node should not be less than the number of lines at that junction minus one.

11.3.6 Minimum Pipe Section

When applying the fire fighting load case, it might turn out that a minimum diameter is required. This diameter shall then be applied wherever a bigger one is not required for hydraulic reasons, assuming that this minimum diameter feeds at least one hydrant.

The type (underground, aboveground), number, location and distances of fire hydrants shall be assessed during the network design by discussion with the relevant authorities, if applicable.

11.4 NETWORK MODELLING

The reason for applying a hydraulic network modelling is to define the optimum diameters for each pipe section, avoiding under- and/or oversizing.

Network modelling shall be performed by using internationally accepted software. Be aware that the quality of the results of hydraulic modelling depends on the quality of input data.

Network modelling shall, as far as possible, use existing roads for pipe sections. This is because of ease of access for future operation and maintenance. Before network modelling, the locations for reservoirs (please refer to Section 11.3.3.3), pumping stations (if required) and public standposts shall be defined.The zone which each reservoir should feedshouldbe roughly defined. The designer can then carry out the work of defining pipelines (primary, secondary network) and pipe sections (from consumption node to consumption node).

Network modelling needs to be carried out to define the required diameters of the pipes of the distribution network. Network modelling has to be carried out for at least two load cases:

1. Maximum hourly consumption (lowest pressure in the system)
2. Zero consumption (highest pressure in the system)

It might in future be advisory to introduce another load case: fire fighting during average hourly demand at peak day consumption for instance. Before doing so, norms and standards have to be elaborated to define the water flows required for fire fighting (defining the network diameters) and the duration of the fire cases to be taken into account (defining the fire suppression storage volumes in reservoirs).

Each consumer has to be linked with one node; nodes may integrate several consumers (such as households for instance), just one consumer (big consumer), or a mixture of households plus one or more big consumers. The sum of all consumptions has to fit with the calculated maximum hourly demand (please refer to Section 7.5.2).

NRW is usually evenly assigned by dividing its figure by the length of the distribution network. This provides a specific NRW figure expressed as m^3/h/km resp. l/s/m. Therefore, for each section, multiplying this specific NRW figure with the length of each section gives the additional NRW to be added to the consumption figures resulting in the total consumption for each node.

Network modelling usually asks for the following input elements (minimum requirements):

- Elevation of water level in reservoirs.
- Characteristics of pumps.
- Distances between two adjacent and hydraulically connected nodes.
- Node details (elevation, total consumption at the relevant load case).
- Connections of nodes and distances between these.

The minimum requirements for the output per load case are:

- Pressure levels for each node.
- Diameters of pipes between nodes (some programs might optimise it by themselves between limits that have to be defined as entrance parameters, such as minimum pressure during maximum hourly peak flow; others require a manual entry that might be rectified after performing the calculation in order to optimise the system. To simulate existing systems, where the pipe diameters are known, the optimisation option should in a first step not be selected in order to know what is going on in the existing system; in a second step to optimise the systemthe simulation can be performed).
- Velocities for each single pipe section (between 2 nodes).
- Performance of the pumps.
- Optional: storage requirements in reservoirs (for bigger schemes).

Based on the output results, the designer can undertake optimisations in order to improve the hydraulic functionality of the design.

11.5 CHECKLIST

1. Are maps and plans of the distribution area available subject to design?
2. Are the elevations known for all required upstream infrastructure and the nodes of the network?
3. Do data exist of the hourly peak consumption of the network?
4. Are locations for reservoirs, pumping stations and stand posts defined?
5. Are the zones to be supplied from each reservoir defined in a preliminary way?
6. Has a preliminary network design been performed including zoning, nodes and DMA definition?
7. Is software for network modelling available?
8. Are the load cases to be calculated defined?
9. Are consumption figures known for all load cases?
10. Have peak hourly consumption figures been allocated to each node?
11. Have the minimum and maximum requirements of the hydraulic network model been considered?
12. What is the outcome of the hydraulic network modelling and is there a need for optimisation (velocities too high, pressures too low or too high)?
13. Has the hydraulic network model been optimised, so that no section lies beyond the minimum and maximum requirements?

11.6 DESIGN VALUES

The following design criteria and their respective values are proposed:

Table 15: Design Criteria and Values for Water Distribution

Main Parameter	Sub Parameter	Unit	Range	Recommended
Distribution network	Minimum pressure	bar	1.5-2.0	2.0
	Maximum pressure (static pressure)	bar	4.5-6.0	6.0

11.7 BIBLIOGRAPHY

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[5] Technical Guidelines for the Development of Water and Sanitation Infrastructure, Department of Water Affairs and Forestry, South Africa, 2004

12. CONSUMER CONNECTIONS

12.1 PURPOSE

Consumer connections are the most downstream elements of the public water supply system. Consumer connections ensure that potable water is delivered to a place where the consumer can use it directly (public standposts) or, for easier use,via extensions to the consumer's own premises (yard taps, house connections).

12.2 KEY PRINCIPLES

The following key principles shall apply:

- A consumer connection includes the connection to the distribution system (pipe saddle), the pipeline, the section valve, the stopcock, the mono-directional water meter, the strainer, and all necessary fittings.
- A consumer connection shall provide water in sufficient quantity and with enough pressure to satisfy consumers' needs within the technical standards.
- Each consumer should have only one connection (large scale industries might be an exception).
- Determination of the required diameter of the connection pipe has to take into account the purpose of water use, the number of customers, and the hourly peak consumption (applicable for big consumers only).
- The connection shall minimise the distance between consumer and distribution pipe.

12.3 HOUSEHOLDS

12.3.1 House Connections

A house connection is a connection to a premise, from where the inflow is conveyed to different points of end usage.

For single-family houses, a diameter of ½" or ¾" is sufficient. For two-family houses, the usual diameter will be ¾".

For multi-storey buildings, the required diameter has to be bigger; depending on the number of apartments, it might go up to 2 ½" (rarely above that). The required diameter shall be defined based on the expected number of people living in the building (number of apartments multiplied with average number of people within one household).

12.3.2 Yard Taps

A yard tap is an extension of a connection into the backyard of a premise, where a single tap will be used for water usage. As there is no parallel water consumption (just one or maximum two taps), a diameter of ½" isdeemed sufficient.

12.3.3 Public Standposts

Public standposts have to provide water for people having no direct connection to their premises.

The number of standposts to be installed within a distribution system shall derive from two elements:

- The number of people to be supplied by standposts (please refer to Section 6.4) up to the design horizon; the maximum number of people supplied by standposts, calculated for each year, has to be taken as design parameter (it might be that the maximum will occur before reaching the design horizon).
- The maximum distance between standposts.

The location of each standpost has to be clarified before the start of the technical design in order to meet consumers' demands and expectations.

The number of taps to be installed on a standpost shall be defined depending on the maximum number of people expected to cover their water demand out of the respective standpost.

12.4 OTHER CONNECTIONS

Small commercial entities do not usually need a connection bigger than for one-family or two-family houses. For bigger commercial entities, a separate assessment has to be carried out as presented in Section 6.8.1. Restaurants and hotels usually have hourly peak demands exceeding the one calculated for the whole system, reference is made to professional literature (see bibliography). This hourly peak demand will then determine the required diameter to be used.

For industries, the required diameter for the water connection has to cover the maximum hourly demand of the respective industrial complex. This maximum hourly demand usually occurs during the shift when administration staff are also present. As the water requirements for processing are often of little variability (to be checked for each industry connected or to be connected), the difference between average hourly demand and hourly peak demand will come from the staff consumption patterns. The total (current or future; the maximum rules) number of staff expected to be present at the same time will determine the hourly peak demand and thus the required diameter.

For institutions, the approach is close to the one applied for industries; the input parameter is the maximum number of staff (current or future, the maximum rules).

12.5 WATER METERING CONSIDERATIONS

The market provides customer water meters of different types and metrological classes (currently A to D).

The following considerations should be observed:

- The better the water meter (the higher the letter of the metrological class), the more accurate it will measure consumption.
- The more accurately water consumption is measured, the more accurate invoicing and billing can be.
- The more accurately water consumption is measured, the lower NRW will be (administrative losses are reduced).
- The more accurately water consumption is billed, the lowerare the financial losses for the operator.
- The lower the financial loss for the operator, the lower the tariff can be.
- The lower the tariff, the higher will be the willingness to pay and the affordability.

For mechanical meters, recalibration in time is a must (operational issue).

Bearing in mind that Class B mechanical meters start reading when a flow of approx. 30 l/h is reached or exceeded, an important part of consumption will not be measured and will increase NRW figures. Thus, it is important to select customer meters of at least Class C.

During supply interruption, if air enters the pipes, restarting supply operation may lead to air flowing through the customer meters and – for mechanical meters – to artificially increase consumption figures, possibly resulting in customer complaints, in case no air valve is connected between the air inflow point and the customer meter.

In case for specific reasons a system has to cope with intermittent supply without having a realistic chance of installing continuous supply within a reasonable period (to be defined case by case), water meters shall be installed which are not affected by air.Table 16depicts the characteristics of mechanical Class C meters and ultrasonic customer meters:

Table 16: Comparison of Mechanical Class C and Ultrasonic Meters

Item	Class C mechanical Meters	Ultrasonic meters
Investment Cost	Lower	Higher
Accuracy at Low Flow conditions	+/- 2%	+/- 3%
Accuracy in Rolled Conditions	Lower	Unchanged
Affected by Air	Yes	No, if not installed in a high point
Affected by Water Quality	Yes, if propeller blocked	No
Recalibration Requirement	Yes, every 5 years	No
Battery exchange	No	Yes, ≈ 12 years

Customer meters shall always be equipped with a strainer and a back-flow preventer/non-return valve. The water meter as well as the valves up- and downstream shall be sealed in order to avoid an unauthorised operation of the water meter.

12.6 CHECKLIST

1. Is it obvious / known where standposts shall be installed?
2. Is it clear how many consumer connections of specific types are required and approximately, where they shall be aligned in the distribution network?
3. Is the expected connection point for big consumers known (being a main consumption node, this affects also the hydraulic modelling)?
4. Have the diameters for each type of connection been defined?
5. Is it clear which kinds of water meter are to be installed?

12.7 DESIGN VALUES

The following design criteria and their respective values are proposed:

Table 17: Design Criteria and Values for Public Standposts

Main Parameter	Sub Parameter	Unit	Minimum	Maximum	Usual
Maximum walking distance to standpost	Rural area	m	0	500	
	Urban area	m	0	200	
Maximum number of users per tap	Rural area	people	1	300	300
	Urban area	people	1	250	250

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13. COSTING AND COST EFFICIENCY

13.1 PURPOSE

The purpose of costing and cost efficiency is to keep the necessary total cost as low as possible (looking for the financially best solution).

13.2 KEY PRINCIPLES

The following key principles apply:

- Costing is based on current market prices.
- Cost efficiency is given when the technical requirements are met sustainably at the lowest price.
- Definition of cost efficiency requires the financial comparison of options and, within options, of variants.
- Design (infrastructural) elements even within variants need to be optimised to get the best solution.
- The overall cost for options has to be compared to affordability.
- Tariff calculations need to be performed to be compared to affordability.
- In case affordability cannot be met, alternatives have to be discussed.

13.3 INVESTMENT COST AND RELATED COST ITEMS

13.3.1 Investment Cost (Capital Expenditures)

Capital expenditures are the costs arising from the creation of new infrastructure, the rehabilitation or extension of existing ones.

13.3.2 Depreciation

Depreciation is the amount of money that is retrieved from the initial investment amount on a yearly basis. Yearly depreciation of an asset is calculated as its initial cost divided by its financial lifetime expectation according to Ugandan Standards or acknowledged figures.

Depreciation is usually not used for design duties, but it enters into financial calculations.

13.3.3 Reinvestment Cost

When coming to the end of technical lifetime expectations, reinvestments have to be foreseen. This enters into calculations of comparable options, as well as into tariff calculations.Different parts have different lifetimes. Civil works, such as pipes and reservoirs have long lifetimes, whereas electrical and mechanical parts such as pumps have shorter lifetimes. Reinvestments, meaning the complete exchange of parts, are considered as high as initial investments.

13.3.4 Residual Values

The residual value is the value of an asset at the end of financial calculations, when its lifetime (or the lifetime of the replacement by means of reinvestment) has not expired. It is calculated as the initial amount of investment (or reinvestment) minus: the yearly depreciation multiplied with the number of years that have passed since the investment or reinvestment.

13.3.5 Financial Cost

Financial cost isthe cost of borrowing or otherwise acquiring the financial resources to provide the assets needed for a service-Itis made up of interest payments on debt and dividend payments to equity providers. Financial costs are usually neglected in cost assessments; in case that the State or one of its organisations is responsible for investing into water supply schemes, the financial cost may enter into calculations of state borrowing capacities performed at the level of the Ministry of Finance for instance [2].

13.4 OPERATION AND MAINTENANCE COST (O&M COST)

Costs for O&M have to be calculated on a yearly basis, starting from the year when the system will be put into operation up to the final year of financial calculation (please refer to Section 13.6). In case that in the first year of operation the system will not work for the full 12 months of the calendar year (because investments are expected to be finalised in September for instance), a pro rata approach shall be applied.

13.4.1 OPEX (Operation Cost)

Operation costs are the costs required for operating the system. These usually include:

- Cost for staff (salaries, allowances, wages etc.)
- Cost for energy (fuel, electricity)
- Cost for chemicals (treatment, laboratory)
- Cost for taxes, levies and other royalties
- Office related costs (internet, telephone, mobile, office supplies)
- Cost for training and international travels
- Cost for external monitoring and auditing

Operation cost calculations need to be based on a good assessment of the number of staff; their salaries and related wages and other levies. Cost for energy is to be calculated based on the yearly amount of required water production (for raw water pumping stations) or on the yearly amount of water to be pumped.The ratio between electricity and fuel (the latter one to cover the hours of insufficient electricity supply) has to be thoroughly assessed. For such an assessment reference values shall be taken from water supply systems which are operated well and where the operator enjoys a good reputation (i.e. is performing a decent job by all standards). This will ensure a realistic ratio.

Operation cost are often subdivided into fixed costs (costs invariable to water production; mainly staff related costs) and variable costs (related to water production and distribution; basic examples are chemical costs for water treatment and electricity cost for pumping). Any sound financial comparison has to split these costs; as the financial calculation to be performed on a year-to-year basis is based on the amount of water to be provided for the specific year. The unit rate for variable cost (UGX/m^3) can then be multiplied with the yearly amount of water to be produced/pumped.

13.5 MAINTENANCE COST

Maintenance cost coversthe corrective maintenance (repair works) and proactive maintenance (ensuring technical lifetime expectations).

Yearly maintenance cost can easily be estimatedas a certain percentage of the respective investment. Usual figures are given below:

- Civil works: 1% of investment value
- E&M: 2.5% of investment value

These values have to be considered as average; over the lifetime cycle of a reservoir for instance, in the first years of operation practically no maintenance is needed at all, it accumulates later on to give within the lifetime expectation the abovementioned average percentages.

Cost items not entering into these two definitions (such as cars for example) can either be calculated separately, or assumed to belong to E&M.

For existing systems, the existing assets shall be calculatedaccording to current market conditions (as if they would be created today). This can be done by applying specific current unit rates to each element, assuming that the asset inventory is up to date and reflects real conditions.

13.6 FINANCIAL COMPARISONS

In this Section, variantsare understoodto bealternative solutions for a specific infrastructural element within the same supply scheme (same water source). Options are the comparison of different schemes (different water sources) aiming for the same result (supplying the same area).

In both cases, the financial comparison has to take into account:

- Investment values
- O&M cost
- Reinvestments
- Residual values

13.6.1 Financial Comparison of Options

Options are defined as different solutions of source use in order to supply the same area. As different sources usually have different characteristics (raw water quality, elevation, distance) they will define different schemes. To assess which source is in the long run the best financial option, an optimisation has to be carried out to make all options comparable. This is usually one of the main duties at feasibility design stage.

By taking into account all cost elements, the options are made comparable and a sound decision may be derived.

One tool for calculation is for instance the Dynamic Prime Costmethod. By using this method, the following parameters are required for the calculation (carried out on a year-to-year basis):

- Calculation horizon (starting year, final year)[8]
- Investments, reinvestments, residual values in the last year of the financial calculation horizon
- Amounts of produced water (in m^3/y)
- Operation cost (invariable fixed cost; variable cost)
- Maintenance cost
- Private operator's profit (where applicable)
- Amount of sold water (produced water minus NRW)
- Discounting factor (average inflation rate or higher)

The total costs are discounted, as well as the total volume of water sold. The total cost divided by the total volume of water sold gives the average unit cost of water expressed in UGX/m^3.

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[8] Note: the time horizon for financial calculations may differ from the technical design horizon

13.6.2 Financial Comparison of Variants

Within one option (same water source), there might be several variants. For instance, the following variants can be compared to each other:

- Different locations of water treatment plants (one requires an access road but allows gravity supply whereby another one can be constructed near to an existing road but needs pumping).
- Different possible treatment technologies (for the same raw water quality).
- Different locations of pumping stations (please refer to Section 10.5.2).
- Different locations of reservoirs.
- Pumping directly into a particular reservoir versus pumping to a high point and having from there a gravity supply to the same reservoir.
- Etc.

Prior to entering the option comparison, defining within one option the best variant for the different core elements is a prerequisite. Only after having tackled the financial comparison of variants, the elements of the supply system can be defined by finding for each of them the financially best solution.

A common tool for the comparison of variants is the Lean Cost Analysis. It requires less input parameters than the Dynamic Prime Cost calculation but provides similar results.

13.6.3 Need for Optimisation

Some elements need to be designed based on an approach oriented towards optimisation (especially during the detailed design stage; on the feasibility level, some basic assumptions can facilitate the preliminary design). This refers especially to:

- Diameters of main pipelines (raw water transmission mains, treated water transmission mains, distribution mains and secondary/tertiary distribution network; pressurised mains and pipelines).
- Pumps.
- Storage capacities of the different reservoirs.

Optimisation starts after having defined options, and within these options different variants. Comparison of options and variants are a core element of a good design.

13.7 AFFORDABILITY

Tariff calculations are required in order to compare average cost for water supply with affordability.

13.7.1 Tariff Calculation

Tariff calculations can be performed by using the Dynamic Prime Cost approach (please refer to Section 13.6.1).

As a result, the average cost for one m³ water is calculated. In case the margin for the private operator for covering benefits was not yet entered into the Dynamic Prime Cost Calculation, it has to be added now (either as an absolute figure per m³, or as a percentage of the tariff). As a final result, the final water price is known and can ultimately be compared for affordability.

13.7.2 Affordability Levels

By assuming that on average not more than 5% of household income shall be allocated to expenses for water and sanitation [7] [8], and that in the long run sanitation is often more expensive than water supply, it is reasonable to take 2% of household income as a target value for water supply. Household income levels have to be assessed by means of a socio-economic survey.

As this 2% has to cover the expenses of one individual household, the usual approach is to calculate the water demand for an average household by multiplying an average daily specific consumption with the average number of people in a household. This gives the daily average amount of water to be used; multiplied with 30.5 gives the amount per month. The calculated 2% household income divided by the water consumption per month gives as a result the affordable level of water, expressed in UGX/m³.

The affordability level might well interfere with the technical design in order to immediately exclude options that are not within or at least close to it. It is thus of outmost importance to find out the affordability level before even starting the process of technical design, as it will directly guide the design engineer to what is feasible with respect to affordability.

In case affordability cannot be reached, the following main possibilities have to be assessed (list not exhaustive):

- Political level:
    - Stopping all actions for water supply (option zero).
    - Check whether the service area can be reduced to one that is densely populated and leave extensions to currently less densely populated areas for the future.
    - Subsidisation of O&M
    - Cross-subsidisation by having higher tariff levels for non-domestic customers (where applicable).
    - Installing block tariffs with higher rates upon a certain consumption level, the lowest block rate is then cross-subsidized by the people who can afford a higher consumption (to be thoroughly assessed).
- Design level:
    - Increase the number of public standposts and reduce the number of yard taps and house connections (to be clearly mentioned in the report so that LGU can take appropriate decisions on limiting the number of connections). This will reduce water consumption and thus reduce capital cost and O&M cost (especially appropriate for systems with high cost of water treatment and/or energy cost).
    - Change the water source (if applicable) to gravity supply.
    - Find alternative designs in order to reduce cost.

13.8 CHECKLIST

1. Are current market prices known for all different cost items?
2. Have different options of the supply scheme been identified?
3. Have variants within the options of supply schemes been identified?
4. Have the investment costs been calculated on the basis of current market prices?
5. Have the elements of all variants been optimised within all options?
6. Are reliable data for operation costs available (fixed cost, variable cost)?
7. Have maintenance cost been calculated on the basis of investment cost (new systems or system extensions) resp. on the basis of current market values (existing systems)?
8. Are data available on yearly amount of water to be produced and to be sold (consumed)?
9. Has the best variant been defined for each option by applying the Lean Cost Analysis (or a similar method)?
10. Has the best option been defined by applying the Dynamic Prime Cost calculation (or a similar method)?
11. Has a tariff been calculated for the best option (including private benefits for the operator, where applicable)?
12. Are data on affordability available (survey)?
13. Has a rate of 2 % of household income been calculated to be applied for water consumption?
14. Has an average amount of water been calculated to be consumed by an average household within one month?
15. Has the monthly water bill been compared with the level of affordability?
16. Have measures been defined for saving costs in case that affordability is exceeded?

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14. WASTEWATER, SANITATION AND HYGIENE

14.1 PURPOSE

The purpose of sanitation and hygiene is to avoid sickness and disease as a consequence of human contact with used water, polluted with human excreta or other pollutant substances and causing diarrhoea and other sicknesses. Many sicknesses, also those which are common in Uganda, are water borne and their spreading can be reduced, if not avoided, by following the principle rules of sanitation and hygiene.

In the context of these guidelines dealing with water supply, the purpose of sanitation is to dispose of the used water, which has earlier been supplied to the consumer, in a controlled way.

14.2 DEFINITIONS

Sanitation: The World Health Organization (WHO) defines sanitation as a group of methods to collect human excreta and urine as well as community wastewaters in a hygienic way, where human and community health is not affected. Sanitation methods aim to decrease the spread of diseases by adequate wastewater, excreta and other waste treatment, proper handling of water and food and by restricting the causes of diseases. Sanitation is a system to increase and maintain healthy life and environment. Its purpose is also to ensure people have enough clean water for washing and drinking purposes. Typically, health and hygiene education is connected to sanitation in order to make people recognize where health problems originate and how to achieve better sanitation by their own actions. An essential part of sanitation is building and maintaining education on sewerage systems, washing up and toilet facilities.

Wastewater(also waste water), is any water that has been adversely affected in quality by anthropogenic influence.

Municipal wastewater is wastewater that accrues in households through activities like washing, showering, cooking, cleaning, bathing, and using flush toilets.

Industrial wastewater is water that has been contaminated in some way by anthropogenic industrial or commercial activities. In most industries, wastewater effluents result from the following water uses:

- Sanitary wastewater (from washing, drinking, toilets).
- Cooling (from disposing of excess heat to the environment).
- Process wastewater (including both water used for making and washing products and for removal and transport of waste and by-products).
- Cleaning (including wastewater from cleaning and maintenance of industrial areas).

Greywater, or sullage, gets its name from its cloudy appearance and from its status between fresh, potable water and sewage water ("blackwater"). In a household context, greywater is the leftover water from baths, showers, hand basins and washing machines only. Some definitions of greywater include water from the kitchen sink. Any water containing human waste is considered blackwater. Greywateris wastewater generated from domestic activities such as laundry, dishwashing, and bathing, which can be recycled on-site for uses such as landscape irrigation and constructed wetlands.

Blackwater is wastewater containing faecal matter and urine. It is also known as brown water, foul water, or sewage. Blackwater usually originates from the use of flush toilets.

Stormwater (or storm water) is water that originates during precipitation events. Stormwater that does not soak into the ground becomes surface runoff, which either flows directly into surface waterways or is channelled into stormwater sewers or combined sewers, which eventually discharge to surface waters, in the case of combined sewers, after passing through wastewater treatment plants. Stormwater is of concern for two main issues: one related to the volume and timing of runoff water (flood control, dimensioning of sewers and WWTP overflows) and the other related to potential contaminants that the water is carrying, i.e. water pollution.

Drainage: The objective of drainage is to remove unwanted water from the neighbourhood in a controlled and hygienic manner in order to minimize public health hazards, inconvenience to residents and the deterioration of infrastructure. It includes

- The removal of greywater. Greywater drainage systems include on-plot disposal, surface water drains or sewers.
- The removal of stormwater. Stormwater drainage systems include on-plot storage (with subsequent infiltration into the ground or evaporation), rapid removal systems (open channels, roads-as-drains, sewers), and temporary retention systems.

Developed sanitation servicesare defined in WHO's and UNICEF's Joint Monitoring Program (JMP)"Global water supply and sanitation assessment 2000". The following methods are considered as developed sanitation services:

- public sewer
- septic tank
- pour-flush latrine
- pit latrine with slab
- ventilated improved pit
- ecological sanitation

The following sanitation methods are considered as **undeveloped**:

- service or bucket latrines (where excreta are manually removed)
- public latrines
- open latrines
- excretion to environment

Basic sanitationwas defined in UN's World Summit on Sustainable Development (WSSD) in 2002. By itsdefinition basic sanitation consists of:

- development and implementation of efficient household sanitation systems
- improvement of sanitation in public institutions, especially in schools
- promotion of safe hygiene practices
- promotion of education and outreach focused on children, as agents of behavioural change
- promotion of affordable and socially and culturally acceptable technologies and practice
- development of innovative financing and partnership mechanisms
- integration of sanitation into water resources management strategies in a manner which does not have a negative impact on the environment

Ecological sanitation is considered to be any sanitation system that reuses the water and nutrients in human excreta or domestic wastewater.

14.3 SANITATION REQUIREMENTS AS A CONSEQUENCE OF WATER SUPPLY

14.3.1 Disposal of Greywater

Where the volume of water supplied is restricted by the provision of communal standpipes, with potable water being carried to the house manually, it is not necessary to provide individual household sewer connections to carry the greywater away. Instead, wastewater can be disposed of at a central point near the communal standpipe, e.g. a sanitary point, where also laundry washing and physical hygiene measures such as showering or bathing are possible. Structural measures must be taken in order to ensure that the system cannot be easily blocked by solid wastes.

The need to carry water provides an effective restraint on the amount of greywater generated, even when a yard tap is provided. It can be assumed that until there is a household piped water system, greywater can be removed by carrying it to piped disposal points not more than 100 m from the dwelling. However, when an unrestricted water supply is provided inside the dwelling, a piped disposal system must also be provided to all houses with such a house connection.

14.3.2 Disposal of Blackwater

Blackwater contains pathogens that must decompose before it can be released safely into the environment. It is difficult to process blackwater if it contains a large quantity of excess water, or if it must be processed quickly, because of the high concentrations of organic material. However, if blackwater does not contain excess water, or if it receives primary treatment to de-water it, then it can be easily processed through composting. The heat produced by naturally occurring thermophilic microorganisms, will heat the compost to over 60 degrees Celsius, and destroy potential pathogens. The compostis eventually reduced to safe fertilizer after about 1 year. Blackwater can be completely avoided by making use of dry toilets, composting toilets and vermicomposting toilets (i.e. basic, undeveloped and developed sanitation).

Poverty and indebtedness are key reasons for the absence of household latrines, either constraining the ability of households to save towards the cost of a latrine, or leading to prioritisation of available income to items other than sanitation. Contrary to the common perception, it can be said that on-plot sanitation can also be appropriate for low income urban areas as long as smell and insect nuisance, emptying problems and other operational problems can be impeded.

14.3.2.1 On-plot sanitation

On-plotsanitation refers to types ofsanitation that are contained within theplot boundaries occupied by adwelling. Commonly, on-plot sanitation is equivalent to 'household latrine',but may also include facilities sharedby several households living together on the same plot. Amongst the mostcommonly found on-plot sanitationtechnology types are:

- Unimproved pit latrines
- Lid-covered pit latrines
- Ventilated improved pit latrines
- Double-pit pour-flush latrines
- Pour-flush toilets to septic tank
- Bucket/pan latrines
- EcoSan toilets, dry toilets, composting toilets

On-plot systems are appropriate for low-income urban areas, and should be considered as viable, sustainable technology choices. There is a variety of systems found to be working well on small plotsizes, with limited odour/insect nuisance, without significant operational problems, and to the satisfaction of the end-user. One of the most important features of the work on on-plot sanitation is that it focuses on the perceptions of the users.

Establishing the concerns of the users of on-plot systems in urban areas and reflecting these in the decision for a certain sanitation option is a critical task.

14.3.2.2 On-site sanitation

On-site sanitation includes communal facilities which are self-contained within the site, in contrast to sewerage and dry latrines where excreta are removed from the site.

14.3.2.3 Off-site sanitation

Off-site sanitation is normally a water based sewerage system, where the effluent is removed from the site by gravity drains and a conventional sewer network, to a place where it can be safely treated. This system is effective where high population densities exist. This system has advantages and disadvantages [9][10]:

Advantages:

- Efficient and safe removal of organic matter, nutrients and pathogen bacteria
- Can be adapted to high population urban areas
- Can be managed with good control of the system

Disadvantages:

- High cost of construction
- Requires highly skilled personnel to construct and maintain the system
- High water and energy demand
- Requires a continuous water supply

14.3.3 Factors affectingthe Choice of a Sanitation Technology / Option

The primary reason for installing a sanitation system in a community is to assist in the maintenance of health and it should be seen as only one aspect of a total health programme. The choice of a particular sanitation system by a community will be influenced by several factors, such as the following:

- The system should not be beyond the technological and financial ability of the community insofar as operation and maintenance are concerned.
- The system should take into account the level of water supply provided, and possible problems with greywater management.
- The likelihood of future upgrading should be considered, particularly the level of service of the water-supply system.
- The system should operate well despite possible misuse by inexperienced users.In a developing area the system should require as little maintenance as possible.
- The chosen system should take into account the training that can be given to the community, from an operating and maintenance point of view.
- The system should be appropriate for the soil conditions.
- The community should be involved to the fullest extent possible in the choice of an appropriate system.
- The system must be compatible to the material used for anal cleansing.
- The local authority / operator should have the institutional structure necessary for the operation and maintenance of the system.

- The existing housing layout, if there is one, should not make the chosen system difficult to construct, maintain or operate.
- Environmental factors should be considered: surface pollution, possible groundwater contamination, etc.

There are two ways to handle human waste. It can either be treated on site before disposal, or removed from the site and treated elsewhere. In either case, the waste may be mixed with water or it may not. On this basis the following four groups may be distinguished:

- Group 1: No water added – requiring conveyance: Chemical toilets (temporal use only).
- Group 2: No water added – no conveyance: Pit latrines (improved or unimproved), dry toilets.
- Group 3: Water added – requiring conveyance: waterborne sanitation with flush toilets and sewers, shallow sewers or conservancy tanks.
- Group 4: Water added – no conveyance: Flush toilet with septic tank, LOFLOs, Aqua-privy toilet.

The selection of the most appropriate sanitation system is influenced by technical, cultural, financial and institutional factors. The quantity of water available for use in sanitation systems is of special importance. If there is too little water or unreliable water supply, sewerage will not function. If there is a high volume of water supplied, on-plot systems will not be able to deal with the quantity of wastewater generated.

14.4 SANITATION SOLUTIONS

Human excreta (mainly solid excrement) contain pathogens. Many diseases can spread through excreta, if treatment (excreta) has not been handled adequately and safely. Diseases such as diarrhoea, cholera and typhoid fever spread easily from excreta to hands and thereafter to mouth causing infection. Adequate excreta handling methods (collection, storing, and treatment procedure) enhance human health. Therefore sanitation programmes can be of great importance in providing good human health.

If excreta handling is not carried out properly there remains a risk of pathogens spreading to surface waters along with rainwater. In case of prolonged inadequate excreta handling groundwater contamination may also appear, thus possibly contaminating valuable sources for water supply. Excreta attract flies, rats and other harmful animals, which can further spread diseases and worsen the health conditions of humans.

There are several technical solutions and variations for treatment of human urine and solid excrement depending on the existing culture and building possibilities. Most of these solutions, when properly planned, built, used and maintained, ensure safe and adequate sanitation and provide significant health benefits. In order to attain all health benefits mere technical solutions are not enough, but sanitation and hygiene education is also needed. In order to enhance human health with latrines / toilets, the following issues should be taken into account:

- Existing social groups and political influence
- User of the latrine should be isolated from (their) excreta
- Prevention of community exposure to excreta through e.g. contaminated water
- Prevent the possibility of flies and other harmful animals coming into contact with excreta and prevent the transmission of pathogens to humans
- Excreta must be covered and/or pathogens made harmless

There are many factors contributing to the selection of the sanitation solution. In making the selection it is important to carry out a baseline survey and map cultural, technical, social and economic factors. Sanitation methods should be chosen to motivate users for the usage and maintenance of the facilities. To meet the needs of users, participation from the users' side in sanitation planning is very important. Sanitation solutions predetermined by means of a top-down approach are usually not long-lasting and in the long run culturally inappropriate solutions will not be used by the target population.

Examples as to which information should be considered in planning sanitation solutions:

- Background information on users e.g. population profile, age and gender distribution, cultural background
- Availability of water and wish to use it on sanitation (culture/ religion)
- Availability of sewerage system; is wastewater treatment organised; routes and waste water pools of possible sewerage systems
- Ground analysis (soil type, hardness, permeability); is it hard to dig the ground; availability of workers and digging equipment; is there a need for supporting structures for pits (e.g. sandy soils)
- Deepness of ground water and bedrock
- Closeness to wells and/ or surface water sources, water storages and water supply sites
- Climate; is there a lot of rain in the area and occurrence of extensive surface water runoffs
- Quality and distances to existing sanitation facilities, other sites for excretion
- Refuse tips for solid wastes, places for disposal
- Availability of economic resources for reliable maintenance
- Availability of knowledge to build latrines and improve hygiene
- Culture of handling latrine waste
- Possibilities for separation and usage of urine
- Way of defecation (squat, sitting)
- Usage of separate urinal; availability of separate seat andpossibilities to manufacture seats locally

14.5 DESIGN CRITERIA

For dimensioning of sewers, septic tanks and wastewater treatment plants, a water demand calculation and an estimation of accruing daily amounts of wastewater has to be carried out. The results of the water demand calculationas described in earlier chapters of these Guidelines are the basis for this assessment.

The design of a sewer system includes the determination of

- The peak sewage flow which must be carried
- The diameters of sewer pipes and the gradients to which they are laid, both related to the peak flow
- The design and location of manholes
- Specification of materials and construction methods

The choice of methodology and the detailed sizing of a wastewater treatment plant have to take into account a number of aspects, such as the following:

- Availability of land/ real estate
- Availability of funds and suitable construction materials
- Ecological factors (e.g. nature preserve), properties of receiving water body
- Flooding areas
- Design capacity
- Quality and quantity of influent
- Infrastructure cost

- Climatic constraints
- Existing infrastructure (e.g. mixed/ combined sewer, sanitary sewer, storm water sewer, cesspits and septic tanks)

An exact knowledge of the required parameters is to be assessed during the feasibility stage or even at the detailed design stage of the sanitation facilities.

14.6 HYGIENE PROMOTION

Hygiene promotion is a way of encouraging practices to preventdiarrhoeal disease in the home. This chapter describes the backgroundto this approach and the advantages that it has over hygiene education,which has been a standard approach until now.

Hygiene Promotion is a planned approach to preventing diarrhoealdiseases through the widespread adoption of safe hygiene practices and attitude change. It begins with, and is built on what local people know, do and want, as it must be acknowledged that"education" about germs and diarrhoea will lead directly to behaviourchange, or have a major impact on diarrhoeal diseases.

Infectious diarrhoeas (including dysentery, cholera and typhoid) are caused by infectious agents such as viruses, bacteria and parasites. These agents enter humans via the mouth and are passed out in faeces.

How do people catch diarrhoea?

Figure 2 shows the famous f-diagram, visualizing the different routes thatthe microbes of diarrhoea take from faeces, through the environment,to a new person. For example; microbes in faeces on the ground by awell can get into the water (fluids) and be drunk by a child, hands thathave not been washed after going to the toilet can carry microbes ontofoods, which are then eaten, infecting another child, who gets diarrhoeaand spreads more microbes.

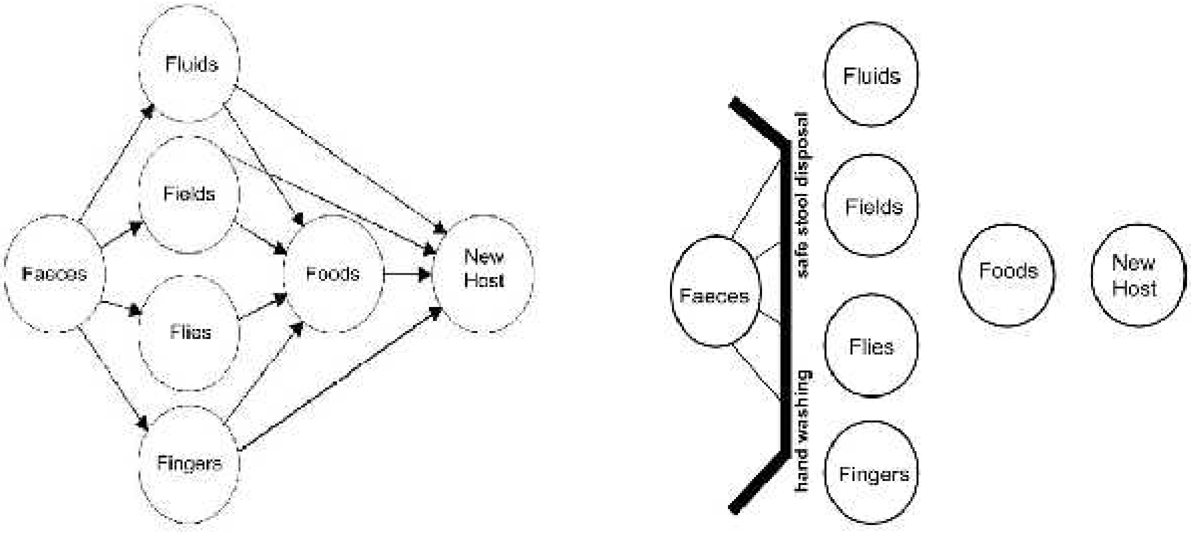

Figure 2: The F-diagram, showing the transmission pathways of germs and how to break it.

<u>The origin of diarrhoea is mainly human excreta.</u>One gram of human faeces can contain [14]:

- 10,000,000 viruses

- 1,000,000 bacteria
- 1,000 parasite cysts
- 100 parasite eggs

The aim of the water and sanitation engineer must be to break this transmission chain. If faecal materialcan be prevented from getting into the environment inthe first place, then other measures such as purifyingwater, storing food correctly or keeping away flies become less of a priority. That is why, especially for water and sanitation engineers the first priority should be to care for:

- Safe stool disposal
- Handwashing with soap after stool contact

14.7 CHECKLIST

1. Has the amount of wastewater been calculated / estimated that will be accrued in the water supply system of concern?
2. Has the safe disposal of accruing wastewater been verified?
3. Has the community covered by the designed water supply / sanitation system been involved in the planning process and have the respective residents agreed the suggested sanitation solution?
4. Have the concerned residents understood the implications regarding the operation and maintenance requirements of the suggested sanitation solution?
5. Will there be sufficient funds available to operate and maintain the suggested sanitation system?
6. Does the suggested sanitation system prevent effectively the contact of the residents to sewage and to human excreta in general?
7. Is the suggested sanitation solution culturally accepted?
8. In case of on-plot sanitation: Are facilities / resources for hygienic pit emptying locally available?
9. In case of off-plot sanitation: Is effective wastewater treatment available?
10. Has the possibility of future upgrading been considered?
11. Have the underground conditions including groundwater conditions been acknowledged?
12. Have proper drainage and disposal of greywater been considered?
13. Have proper drainage and disposal of stormwater been considered?

14.8 BIBLIOGRAPHY AND RECOMMENDED READING

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15. ENVIRONMENTAL AND CLIMATE CHANGE ASPECTS

15.1 DEFINITIONS

Environment

The term “environment” is to be understood as comprisingthe following factors: human beings, fauna, flora, soil, water, air, climate, landscape, and the interaction between all these factors. Each human activity (e.g. agriculture, construction, traffic, industry) entails a certain influence on one or more of these environmental factors. This influence, also denominated “environmental impact”, shall be minimised in order to protect the environmental factors from any impairment.

Climate change

The findings of climate research point out that the world climate is actually undergoing a perceivable change process. Specific indicators include amongst others the elongation of dry periods, modification of annual rainfall patterns and the increase or reduction of annual rainfall quantity. These indicators appear to different extents depending on the geographic zone on the globe. Therefore, any possible climate change indicators have to be identified for specific zones on the basis of available research results.

15.2 INTERNATIONAL CONVENTIONS OF CLIMATE CHANGE RELEVANCE

International conventions and treaties addressing the climate change topic show also a direct or indirect relevance to water management. Consequently, they are also relevant for water supply and wastewater measures in the long-term view. An excerpt of important conventions is presented in Table 15 including information sources, goals and features. The table also presents international institutions that are decisive for climate change research and policy making for precaution measures.

Table 15: International conventions of climate change relevance

No.	Denomination	Main issues	Data source
1.	United Nations Framework Convention on Climate Change, UNFCCC, 1994	Goal: - To prevent dangerous human interference with the climate system	http://unfccc.int/essential_background/convention/items/6036.php
2.	Kyoto Protocol, 1997	Additional protocol to the UNFCCC Goal: - Definition of mandatory targets on greenhouse-gas emissions for the world's leading economies	http://unfccc.int/kyoto_protocol/background/items/2879.php
3.	United Nations framework on Climate Change, (UNFCC), 1994	Goal: - To consider on international level measures to limit average global temperature increases and the resulting climate change, and to cope with whatever impacts	http://unfccc.int/2860.php
4.	Convention on the Protection and Use of Transboundary Watercourses and International Lakes, 1992 (UNECE Water Convention)[9]	Goal: - Protection and ecologically sound management of transboundary surface waters and groundwaters, - To control and reduce transboundary impacts	http://www.unece.org/env/water.html

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[9] UNECE: United Nations Economic Commission for Europe

No.	Denomination	Main issues	Data source
		- To use transboundary waters in a reasonable and equitable way Features: - Task Force on Water and Climate being responsible for activities related to adaptation to climate change, including flood and drought management - Guidance on Water and Adaptation to Climate Change providing recommendations for governments - Task Force's pilot projects - Task Force's platform for exchanging experience	
5.	UNECE Protocol on Water and Health, 1999	Additional protocol to the Convention on the Protection and Use of Transboundary Watercourses and International Lakes, Goal: - To protect human health and well-being by better water management, including the protection of water ecosystems - To prevent, control and reduce water-related disease	http://www.unece.org/env/water/pwh_text/text_protocol.html
6.	United Nations Convention to Combat Desertification, 1994	Goal: - To link environment and development to sustainable land management Features: - Addresses the arid, semi-arid and dry sub-humid areas (drylands)	http://www.unccd.int/en/about-the-convention/Pages/About-the-Convention.aspx
7..	Intergovernmental Panel on Climate Change (IPCC)	Goal: Preparation of reports about the status of scientific, technical and socioeconomic knowledge on climate change, its causes, potential impacts and response strategies	http://www.ipcc.ch/index.htm

15.3 PURPOSE

In the context of designs for water supply, environmental and climate change aspects shall be considered for the following purposes.

- The design of a water supply system has to strive for such technical solutions that entail as low an impact as possible on the environment.
- Prior to the implementation of a water supply project, the effects of the project on the environment have to be assessed thoroughly.
- The design of a water supply system shall consider potential modifications of water sources capacities conditional on climate change effects during the design horizon.

15.4 KEY PRINCIPLES

Environmental considerations shall be included in the design process from the very beginning. Thereby, the following requirements shall be fulfilled:

- The environmental considerations for water supply system components shall encompass all environmental factors, which are potentially affected by the intervention.
- During the design, all stakeholders concerned by potential environmental impacts shall be identified. They shall be included in a consultation process in order to develop an acceptable design solution.
- For each specific system component (water intake, transport main, water treatment plant, etc.), the effects on the environment shall be assessed.
- The design engineer shall assess the environmental effects of system facilities for the period of the given design horizon.
- The design process shall delineate different options of water supply system configuration and shall perform a comparative assessment of the corresponding specific environmental effects.
- The appraisal of environmental effects shall be part of the feasibility assessment of the design project.
- A completed design project must undergo an environmental impact assessment prior to its implementation.
- The environmental impact assessment (EIA) is an official process, which has to be conducted according to a specific legislation.

During the design process, climate change considerations shall cover the following requirements.

- The appraisal of water source capacities shall include suitable safety factors taking into account potential climate change impacts during the given design horizon.
- The potential climate change impacts on water sources are different for specific geographic zones and should be identified separately for the region subject to water supply design projects.

15.5 ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT

15.5.1 EIA Objective

The objective of the EIA process is to identify, describe and appraise the direct and indirect effects of the project on all environmental factors in the project area. The results are described in an Environmental Impact Review (EIR) or in an Environmental Impact Study (EI study).

If negative impacts of the foreseen project are identified, the EI study shall recommend appropriate mitigation measures. If mitigation measures are not possible, the EI study shall recommend whether the project cannonetheless be implemented or,if not, shall propose modifications to the project.

The EIA process does not include the approval or disapproval for project implementation. The EIA only verifies the environmental compliance. In Uganda, the National Environmental Management Authority (NEMA) issues the approval for project implementation based on the findings of the EI study.

15.5.1.1 Institutional and Legal Framework

Projects that have potential significant impacts on the environment are required to undergo an Environmental Impact Assessment (EIA). The EIA process is to be performed according to the National Environment Management Policy (1994). Projects whose EIAs are based on the World Bank Environmental Assessment Policy or the EU directive for the environmental impact assessment (85/337/EEC) must also fulfil the requirements of the National Environment Management Policy. The EIA report has to be submitted by the client (or by the Consultant on behalf of the client) to the National Environmental Management Authority (NEMA) for approval.

15.5.1.2 EIA Requirements

The application for the project approval by the National Environmental Management Authority has to include the project design documents and the EIA report with adequate data related to potential environmental impacts and including suggested mitigation measures. During the EIA process, consultations need to be heldin accordance with the National Environment Act Cap 153 with the stakeholders that will be affected by the proposed water supply project.

15.5.1.3 The EIA Process

Environmental Impact Assessments shall be conducted according to the Environmental Impact Assessment Regulation, S.I. No. 13/1998.

The EIA process is performed in three phases.

- Phase 1 – Screening
- Phase 2 – EnvironmentalImpact Study (EIstudy)
- Phase 3 – Decision making

Screening

- The goal of the screening is to recognise whether a project shows or does not show significant environmental impacts. If no impacts are expected, no further EIA activities are necessary.
- In case impacts are assumed an environmental impact review (EIR) must be conducted to identify mitigation measures.
- If the EIR findings are insufficient, an in depth EI study must be performed.
- The methods for carrying out screening include:
    - Using a list of projects for which an EIA is automatically required that excludes activities which do not require EIA because they are insignificant or are exempted by the National Environmental Management Act
    - Legal (or policy) definition of proposals to which EIA does or does not apply,
    - Using criteria for case-by-case screening of proposals to identify projects with potentially significant environmental effects.

Environmental Impact Study

- Scoping: Definition of the scope of works for the assessment of potential environmental impacts
- Identification of environmental impacts and classification in three levels
    - Minor impact
    - Moderate impact
    - Major impact
- Differentiation between (i) direct impacts and (ii) indirect impacts
- Appraisal of spatial extent of impacts, in particular (i) limited and (ii) wide
- Definition of timely extent of impacts, in particular (i) short term, (ii) long term, (iii) temporary
- Proposal of mitigation measures and / or project modifications
- Preparation of an environmental monitoring plan for (i) construction and (ii) post-construction period

Decision making

- Review and approval of EIstudy
- Decision for project approval or denial

15.5.1.4 Legislation templates from other African Countries

South Africa

The *EIA Regulations 2006* of the Republic of South Africa are a template for national environmental legislation. They are based on the *National Environmental Management Act 1998 (NEMA)* and determine the procedures for the procurement of the environmental permission of a project.

On the basis of the NEMA, additional legal documents have been issued which regulate in detail specific topics of the EIA domain. In particular, specific areas in the country are identified including their environmental features, socio-cultural characteristics and environmental management requirements.

Other documents define the type and extension of infrastructure and land use measures, which are subject to a mandatory EIA process.

Further, specific forms of documents are issued for specific stages of the EIA process, which define the scope of information to be collected and of investigations to be conducted. This allows for a standardised reporting structure, which is important for a consistent EIA process.

Details about the national environmental legislation of South Africa are available on the EIA homepage of the Government as follows: http://www.westerncape.gov.za/eng/directories/services/11537/10199

Kenya

The Government of Kenya has developed a comprehensive legal framework in the domain of environmental management, which can be drawn on as a template for the conduction of the EIA process in various domains. An overview about environmental legislation, policies and specific document types is provided on the homepage of the National Environment Management Authority of Kenya (NEMA) as follows.

http://www.nema.go.ke/index.php?option=com_content&view=article&id=337&Itemid=670

Appraisal:

The two above-mentioned examples of national EIA legislation and associated documentary framework are assessed as an appropriate template because they are addressed to specific regional conditions in Africa.

15.5.1.5 UNECE Guidelines for consideration of climate change aspects

Subsequent to the *Water Convention and to the UNECE Protocol on Water and Health* (Table 15), the UNECE has published a comprehensive guideline document, which provides technical advice to the contracting parties for the implementation of the Convention and Protocol in the context of climate change.

Document title:	**Guidance on water and Adaptation to Climate Change, 2009**
Data source:	http://www.unece.org/index.php?id=11658

Target groups:

- Decision makers and water managers working in ministries and other authorities
- National and local authorities for water supply and wastewater disposal
- National and local authorities for water resources management
- National authorities for water quality monitoring and related hygienic policies

- National and local authorities for river basin management and flood protection
- Stakeholders (public and private) concerned with the topics of water and health
- Stakeholders in the sectors of agriculture, forestry and nature conservation

The Guidelines are addressed primarily to governments and authorities. However, they serve also for the support of technical designers of water and wastewater systems in the stage of project identification and conceptual design. A useful tool for this is *the Checklist for self-assessment of progress towards adaptation to climate change* in the Annexe of the document.

2. UNECE Guidelines for consideration of extreme weather events

Another UNECE guideline document focussing on extreme weather events was published in 2011.

Document title:	**Guidance on Water Supply and Sanitation in Extreme Weather Events, 2011**
Data source:	http://www.unece.org/index.php?id=29338

This document describes effective ways to minimize impacts of extreme weather events on water supply and sanitation systems and to reduce related health risks.

15.5.2 Socio-economic Impact Assessment

The understanding of the socio-economic consequences of a water supply project is a precondition for the long-term success of a project and for the guarantee of project benefits. Therefore, the assessment of the socio-economic consequences forms part of an integrative design process.

The assessment of the project effects on the social conditions of people in the project area represents the Socio-economic Impact Assessment (SIA). The assessment of socio-economic conditions is different from the assessment of the environmental factor *human being* encompassed by the EIA.

The assessment of the factor *human being* addresses human health and living conditions of persons. The assessment of socio-economic conditions on the other hand is orientated to the behaviour of people in their community and on respective changings due to the implementation of a new water supply project.

1. Objectives

- To identify the commitment of stakeholders with the project
- To identify potential positive effects of the project on everyday life situations
- To identify improvement effects on the economic situation
- To identify any adverse project effects on the socio-economic conditions of stakeholder communities

2. Conduction of SIA

- Collection of socio-economic data from official data bases
- Site investigation through questionnaires
- Data evaluation
    - Identification of impacts and concerned social groups
    - Determination of unacceptable social impacts and respective reasoning
- Proposal of mitigation measures
- Socio-economic monitoring during project implementation

The performance of the environmental and socio-economic impact assessment for the same design project is called the ESIA process.

15.6 CLIMATE PROOF DESIGN

The potential influences of climate change result in the following aspects of water supply design which have to be considered in every single project:

- Change of annual rainfall patterns possibly entailing the elongation of dry periods
- Change of annual river flow patterns possibly causing increased frequency and duration of flood and low water flow
- Possible reduction of water sources capacities, i.e. potentially reduced discharge of a spring or falling groundwater table caused by reduced recharge

The design has to take into account these potential influences through the consideration of safety factors for the evaluation of hydrological data and for the dimensioning of facilities. Specific design measures encompass the following:

- For water exploitation, the water source design capacity shall be lower than the actual minimum capacity
- For rainwater harvesting, the collection and storage capacities shall be extended in order to bridge extended dry periods
- For river water extraction, the design of water intake facilities shall be adapted to increased flow fluctuations. Specific measures comprise the following:
    - To increase the storage capacity of artificial reservoirs
    - To align the water intake pipes at a low elevation to allow for water extraction during low flow levels
    - To place water intake structures at locations which are not exposed to future flood risk
    - To take into account extended water treatment options in order to cope with deteriorated water quality conditional on increased frequency and size of floods.

15.7 CHECKLIST

1. Which environmental factors are potentially affected by the designed water supply measure?
2. Which stakeholders are concerned by the potential environmental impacts?
3. Which climate change influences on hydrological and hydro-geological conditions are expected for the design horizon in the geographical zone of the design project?
4. For which water supply system components have climate change aspects to be taken into account?
5. Which level of EIA conduction is required for conduction of the EIA process?
6. Which documents are needed for the application for the conduction of the EIA process?

15.8 BIBLIOGRAPHY AND RECOMMENDED READING

[1] Water supply design manual 2012, Final Draft, prepared by AIM Engineering by order of the Republic of Uganda, Ministry of Water and Environment

[2] Council Directive 85/337/EEC of 27 June 1985 on the assessment of the effects of certain public and private projects on the environment