DESIGN OF WATER SUPPLY (COLD AND HOT) SYSTEM OF A THREE BEDROOM BUNGALOW WITH ADEQUATE PRESSURE

BY

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DECLARATION

I hereby declare that this project titled "**Design of Water Supply (Cold and Hot) System of a Three Bedroom Bungalow with Adequate Pressure"** was done by me in the Department of Mechanical Engineering, Ahmadu Bello University, Zaria, under the supervision of Prof. D.S. Yawas. The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this work has been presented for another degree or diploma at this or any institution.

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CERTIFICATION

This project entitled **"Design of Water Supply (Cold and Hot) System of a Three Bedroom Bungalow with Adequate Pressure"** meets the requirements governing the award of degree of Masters of Science in Mechanical Engineering of the Ahmadu Bello University Zaria, and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

This project is dedicated to my father, late mallam Shaibu Abedo; rest in peace until we meet and live to part no more.

ACKNOWLEDGEMENTS

My gratitude goes to the Almighty Allah(Peace be unto His name) for His guidance, protection and provision from the start to the completion of this work.

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Finally, I wish to put on record the love, encouragement and support of my friends Tunde, Jide and Boje. You are so special to me.

ABSTRACT

This research is focused on the design of water supply (cold and hot) system of a three bedroom bungalow with adequate pressure. Polypropylene (PP) pipes imported from Italy and polyvinyl chloride (PVC) pipes made in Nigeria, the two most common plastic materials used for potable water supply lines were selected for the analysis and compared to find out which of them is more cost effective, provide better form fitting and higher life expectancy. The adequate flow pressure required for both pipes was found to be 20 Pa while the standard pipe size for the supply of both cold and hot water was found to be 19 mm. The average diameter of branched pipes supplying water to the three bedroom bungalow was 13 mm. For cold water supply, pipes number '1' and '2' had 34 loading units while pipes 3, 4, 5, 6 and 7 had respectively 3.5, 6.5, 4.0, 6.5 and 13.5 loading units (LU). The loading units for hot water supply to the building for pipes number '20', '21', '22' and '23' were respectively 4.5, 4.0, 4.5 and 11.5 LU. Pipes made of PP, though more expensive, are more durable and have higher life expectancy than the PVS ones, and are resistant to weather factors such as temperature and humidity. PP pipes are recommended to be used to run both cold and hot water supply to the building, while PVC pipes can be used to run only cold water supply to the building since they can be easily damaged.

TABLE OF CONTENTS

		Page
Title Page		i
Declaration		ii
Certification		iii
Dedication		iv
Acknowledgements		v
Abstract		vi
Table of Contents		vii
List of Figures		x
List of Tables		xi
List of Plates		xii
Appendix		xiii
Nomenclature		xiv
CHAPTER ONE		
1.0	INTRODUCTION	1
1.1	General Background	1
1.2	Statement of the Problem	2
1.3	The present Work	3
1.4	Aim and Objectives	3
1.5	Significance of the Research	4
1.6	Scope of the Work	4
1.7	Definition of Operational Terms	4
CHAPTER TWO		
2.0	LITERATURE REVIEW	7
2.1	Introduction	7
2.2	Water use in Residential Buildings	7
2.3	Residential Water System sizing	8
2.4	Distribution Systems	8
2.5	Water supply for Multi-storey Buildings	12
2.6	Water Storage Vessels	14

2.6.1 Requirements relating to installation and water storage tanks 15
2.6.2 Requirements relating to access to water storage tanks 16
2.6.3 Requirements relating to materials used in water storage tanks 16
2.7 Water Source 17
2.8 Treatment Facilities 17
2.9 Storage Systems 18
2.10 Fire Protection 19
2.11 Water Pressure 19
2.12 System Layout 20
2.13 Common Pipe Materials 21
2.13.1 Copper Pipes 21
2.14 Internal Piping System Fusion 22
2.15 Physical Properties required for Pipe Materials 24
2.16 Fittings 25
2.17 Fusion Device 25
2.18 Total Dynamic Head 25
2.7 Review of Related Past Works 26
2.8 Research Gap 28

CHAPTER THREE
3.0 MATERIALS AND METHODS 29
3.1 Materials 29
3.2 Design Considerations 29
3.2.1 Materials Selection 29
3.2.2 Cost 30
3.2.3 Estimating Water Demands 30
3.2.4 Water Distribution System 30
3.2.5 Adequate Pressure 30
3.3 Plan Layout of the Bungalow and Description 31
3.4 Design Analysis of the water supply System 32
3.4.1 Pipe Size Analysis 32
3.4.2 Cold water supply calculations 32

3.4.3 Hot water supply calculations 50

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION 56

4.1 Results 56

4.2 Discussion of Results 59

4.3 Cost Analysis 60

4.4 Polypropylene versus Polyvinyl chloride pipes 61

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION 62

5.1 Conclusion 62

5.2 Recommendation 62

REFERENCES 63

LIST OF FIGURES

FIGURE		PAGE
Figure 3.1	Site Plan water supply layout of the three bedroom Bungalow	31
Figure 3.2	Floor plan water supply layout of the three bedroom Bungalow	32
Figure 3.3	Conversion Chart: Loading unit of Flow Rate	34
Figure 3.4	Pipe Sizing Chart	35

LIST OF TABLES

TABLE PAGE

Table 2.1 Flow rate and pipe size acceptance solution from building code compliance document G12/AS1 20

Table 3.1Quantity and Loading units of appliancesfor pipe Number 1 33

Table 3.2 Quantity and Loading units of appliancesfor pipe Number 2 37

Table 3.3 Quantity and Loading units of appliancesfor pipe Number 3 39

Table 3.4 Quantity and Loading units of appliancesfor pipe Number 4 41

Table 3.5 Quantity and Loading units of appliancesfor pipe Number 5 43

Table 3.6 Quantity and Loading units of appliancesfor pipe Number 6 46

Table 3.7 Quantity and Loading units of appliancesfor pipe Number 7 47

Table 3.8 Quantity and Loading units of appliancesfor pipe Number 20 50

Table 3.9 Quantity and Loading units of appliancesfor pipe Number 21 51

Table 3.10 Quantity and Loading units of appliancesfor pipe Number 22 53

Table 3.11 Quantity and Loading units of appliancesfor pipe Number 23 54

Table 4.1 Summary of Cold Water Supply Calculations 56

Table 4.2 Summary of Calculated Diameters of Branched Cold Water Supply Pipes Discharging to Sanitary Appliances 57

Table 4.3 Summary of Hot Water Supply Calculation 58

Table 4.4 Cost analysis of the materials used for piping 60

Table 4.5 Labour and overhead cost 61

LIST OF PLATES

PLATE		PAGE
Plate 2.1	Copper pipe and fitting	22
Plate 2.2	Plumbing Accessories	23

APPENDICES

APPENDIX PAGE

Appendix 1:	Appendix 1: Mechanical Design Legend	66
Appendix 2:	Equivalent pipe lengths (copper, stainless steels and plastics)	67

NOMENCLATURE

PPR	-	Polypropylene pipe
PVC	-	Polyvinyl chloride pipe
LU	-	Loading unit
ρ	-	Density of water = 1 x 10^3 kg/m^2
P	-	Pressure (bar)
G	-	Acceleration due to gravity = 9.81m/s^2
H	-	Head of water available at the point of discharge (m)
s	-	Time (seconds)
l	-	Capacity (litres)
N	-	Number of branched pipes to appliances
D	-	Diameter of main pipe discharging to branched pipes (mm)
d	-	Diameter of branched pipes discharging to appliances (mm)

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Plumbing engineering responsibilities overlaps into the professional areas of civil engineering, mechanical engineering, chemical engineering and process engineering. Traditionally, the plumbing Engineering performs the calculations, size the equipment and prepare the pluming design and construction documents under the supervision of a licensed mechanical, fire protection or professional engineer (Ho, 2010). In most states the mechanical engineer supervises the plumbing engineer's responsibilities in the following areas: Design of process and fluid flow process; design of plumbing systems and design of heat energy transfer.

A water supply system uses a combination of pipes (of different dimensions and materials), valves and outlets to deliver to the building users. Some water supply systems also use storage tanks and pumps. Designing a water supply system involves getting all of these elements right so that clean water is delivered to the user at the appropriate rate and temperature.

The design and calculations of water supply (hot and cold), drainage systems is important in the modern day building since most buildings now have central heating systems and pipes are conduit in building. In order to have a constant flow rate and avoid blockage of drainage pipes, calculations have to be done to get the required pipe size and fittings to use.

In the water distribution network and pipe sizing, allowance for pressure losses due to frictional resistance set in by fittings such as elbows, tees, bonds, taps and valves must be added to the actual length of the pipe (Bratsch-Blundel, 2008).

In the drainage system for a building, the drains from the plumbing fixtures are connected to vertical drain stacks that convey the waste and sewage to below the lowest floor of the building. The fixture drain traps must be vented to prevent their water trap seal from being siphoned by negative pressure or blown out by positive pressure in the drain piping. The fixture vent pipes must extend through the roof to outdoors. They can be run individually or be combined into one or more vents through the roof. This relieves and equalizes the pressure in the drainage stack to maintain the water seal in traps serving plumbing fixtures (Hongo *et al.,* 2007).

Wherever possible, the sanitary drainage system from a building should discharge to the public sewer by gravity. All plumbing fixtures located below ground level should be pumped into the public sewer or the drainage system leading to the sewer. The pump line should be as short as possible and looped up to a point not less than 0.6 meters (24 inches) above ground level to prevent back siphonage of sewage. The pump discharge rate should be controlled so as not to cause scouring of the internal bore of the pump line or the drainage or sewer system into which it discharges. High-velocity discharge rates may also cause the flooding of adjoining plumbing fixtures or overloading of the sewer itself. The sump pits for sewage pumps must have sealed covers, be vented to outdoors and have automatic level controls and alarms. Sewage pumps in a building should be duplex, with each pump having 100 % of the required pumping capacity for the building. Alternatively, an approved vacuum drainage system may be considered (Belobratova, 2011; Hongo *et al.,* 2007).

1.2 Statement of the Problem

Required pressure has been a major challenge in getting water to all the appliances in any facility since it is not possible that all the appliances are in use at the same time. Therefore, for economic reasons the scheme provide for a peak usage which is less than maximum demand (Ladd, 2005). With this method a unit rating is devised for each type of sanitary appliance based on its rate of water delivery. If water pressure is too low, this will be inconvenient for the building users. And if the pressure is too high, this will lead to wastage of water as well as high wear and tear on the system (Säärekõnno and Suurkask, 2007; Ladd, 2005).Pressure is crucial in design of hot and cold water systems. Lack of adequate pressure is one of the most frequent complaints in houses. The pressure available for water distribution within a building can come from various sources. If the pressure from the public mains is inadequate for building operation, other means must be provided for increasing the pressure to an adequate level.

1.3 ThePresent Work

To tackle the problem of inadequate pressure in houses, the present work focuses on the design of the water supply for a three bedroom bungalow, to ensure water supply at adequate pressure on all fixtures and equipment at all times and to achieve the most economical sizing of the pipes.

1.4 Aim and Objectives

The aim of this research is to design a water supply system for a three bedroom bungalow to ensure adequate pressure. The specific objectives are to:

i. Carry out the design analysis of the piping system
ii. determine the adequate flow pressure
iii. determine the flow rate at outlet
iv. determine the constant pressure range
v. determine the pipe size
vi. determine the loading unit

1.5 Significance of the Study

The importance of adequate pressure cannot be over emphasised. Where water is drawn from public water mains, the public water mains must supply water with adequate pressure to meet the peak demand of all buildings in the area otherwise there is high risk of back flow and subsequent contamination of the mains from the buildings (Ho, 2010).

1.6 Scope of the Study

This study is limited to the design of water supply system for a three bedroom bungalow of about eight occupants.

1.7 Definition of Operational Terms

Maximum flow: Maximum flow or maximum possible flow is the flow that will occur if the outlets on all the fixtures are opened simultaneously. An average flow is that flow likely to occur in the piping under normal conditions. Maximum portable flow is the flow that will occur in the piping under peak conditions. It is also called peak conditions or peak flow (Hazen, 2000).

Demand type: Some outlets impose what is called a continuous demand on the system. They are differentiated from the outlets that impose an intermittent demand. Outlets such as hose bibs, lawn irrigation, water cooling and similar flow requirements are considered to be continuous demand. They flow for an extended period of time. Plumbing fixtures draw water for a relatively short period of time and are considered as imposing an intermittent demand (Mui *et al.*, 2007).

Estimating demand: The basic requirement for estimating demand call for a method that:

i. Produces estimates that are greater than the average demand for all fixtures or inadequate supply will result during the period of peak demand.

ii. Produces an accurate estimate of demand to avoid over sizing.

iii. Produces estimate for demand of groups of the same type of fixtures as well as for mixed fixture types (Mui *et al.*, 2007).

Loading Unit (LU): A factor given to an appliance relating the flow rate at its terminal fitting to the length of time in use; frequency of use for a particular type; use of building; evaluate the 'probable maximum. It also relates the flow rate to the probable usage and consider design and minimum flow rates (Ho, 2010).

Flow pressure: It is essential that the term flow pressure can be thoroughly understood and not confused with static pressure. Flow pressure is that pressure that exists at any point in the system when water is flowing at that point. It is always less than the static pressure. To have flow, some of the potential energy is converted into kinetic energy and additional energy is used in overcoming friction which results in a flow pressure that is less than static pressure.

Flow at an outlet: There are many times when the engineer must undermine how many gallons per minutes are being delivered at an outlet. This can easily be determined by installing a pressure gauge in the line adjacent to the outlet and leading to the gauge while flow is occurring at a known flow pressure.

Constant flow: Pressures in the various parts of the piping system are constantly fluctuating depending on quantity of flow at any moment. Under these conditions the rate of flow of from any outlet will vary with change of pressure (Ladd, 2005).

Design load: In structural analysis, design load is the total load on a structural system under the worst possible loading conditions.

Fitting: Any apparatus, cistern, cock, equipment, machinery, material, tank, tap and valve; and any appliance or device other than a meter, which is installed or used in a fire service or inside service.

Direct Supply System: A plumbing system which conveys water directly from the government water mains to the point of usage without any transit water storage tanks.

Indirect Supply System: A plumbing system which conveys water from the government water mains to the point of usage through a transit water storage tank.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

As would be familiar from our residential settings, water in buildings is commonly used for cleaning, for personal hygiene, for heat transfer and for

Landscaping. Although water–consuming activities often remain similar, the sophistication of water infrastructure as well as the quantities and use patterns can vary significantly depending on the primary purpose of the building. For example, while showers and toilets are particularly important in residences, schools, hotels and office buildings, heat, ventilation and air conditioning (HVAC) systems and landscaping can be major users of water for shopping centers and other large commercial and institutional settings.`

2.2 Water Use in Residential Buildings

Owners of residential buildings need adequate supply of water for use in the following areas:

- Toilets and showers
- Drinking
- Wash-basins
- Laundry
- Landscaping
- Heating, ventilation and air conditioning (HVAC) system.

It is crucial that water supply systems are properly sized. Owners of residential buildings are often concerned about whether or not there will be enough water supply for their needs. “Enough” water means a sufficient quantity with sufficient pressure to meet the following needs:

- Everyday use – drinking, cooking, and water for plumbing
- Seasonal use – lawn and garden watering, car washing, and swimming pool
- Other special uses – animal watering, crop irrigation and water treatment devices that require backwashing.

A day's use may be concentrated into a period of one to two hours, often in different areas of the house at the same time (laundry, bathroom and lawn). The water supply system must be able to meet this type of peak demand. In addition to providing for regular household use, wells sometimes supply water for heating and cooling purposes. Some energy-conscious home owners install groundwater geothermal systems, which extract and concentrate heat energy from water and make it available for heating or cooling purposes. According to the well construction code in Michigan, there is no minimum gallons per minute a well must produce (Garett, 1998).

2.3 Residential Water System Sizing

A properly designed residential water supply system should deliver water at the desired quantity, quality and pressure to any outlet on the system during periods of heaviest use. To accomplish this, the peak demand for the home is determined and the well and pump are sized to meet or exceed the demand. If local geological conditions prohibit the development of a water supply with quantity to meet the demand, additional storage facilities are necessary.

2.4 Distribution Systems

Water distribution system can be classified into the following:

i. Piping Networks

Some of the earliest water systems in the United States were constructed using wooden water mains; however, cast iron, steel, and copper were the standard for these systems for much of the

20th century. Recently, advances in plastic pipes, for example high-density polyethylene (HDPE), have brought more of this type of pipes into water utility systems. Plastics have some significant advantages in weight and cost, but there are some issues with pressure ratings, and none of these pipes have been in the ground long enough for engineers to really understand the longevity of these systems. While many of the plastic pipe materials appear to have good long-life characteristics, connections may have less reliability.

When designing water distribution systems for residential buildings, it is important to analyse the criticality of water supply to each building type. While the loss of water supply to a classroom or office building could be merely an inconvenience, the loss of water supply to laboratory or animal care facilities for even a relatively short period of time could endanger critical research (Brook, 2011).

In addition, those buildings that on the surface do not appear to have critical water need may have HVAC equipment like a boiler or cooling tower that rely on makeup water. Should a water outage render those pieces of equipment inoperable, the building may no longer be habitable. Once these critical loads have been identified, the water system can be designed (or upgraded) so that the systems are looped and water can be fed to critical buildings from a variety of sources. A critical element of a looped system is providing a sufficient number of valves so that sections of pipe can be isolated for repair and maintenance without impacting water service. Typically, there should be a valve on each leg at each pipe intersection (three valves at a "T" and four valves at a cross) and valves on every building service. However, you can get away with fewer valves if there are several pipe intersections in close proximity. The best test is to study water system maps and perform "what if" analysis on the building impacts of water main breaks or repairs. If a particular section of pipe will "take down" several buildings in the event of a failure, analyze how to retrofit valves into the system in order to minimize the impacts.

Radial feed legs within the water system should be minimized due to reliability concerns. In addition, it is critical to minimize "dead legs" in the water distribution system. Dead legs are created when there is a long radial feed to a seldom-used load. Fire hydrant legs are a common culprit, but old feeds to abandoned facilities are sometimes cut off at the building rather than at the main, causing a dead leg that can create water quality problems in the system. The water in these dead legs is stagnant, and fluctuations in pressure and flow effect can draw some of this bad water back into the water mains, causing water quality issues. There is a downside to looped water distribution systems. Water will always follow the path of least resistance, so if there are different pipe sizes in the water distribution system, the water flow in the smaller pipes will be low. This can lead to water that has too long a residence time in the system, resulting in a degradation of water quality. In extreme cases, some of these smaller pipes can act almost as dead legs, leading to severe water quality problems. If there are a variety of pipe sizes in a looped distribution system, regular flushing can help alleviate these water quality concerns (Bhatia, 2012).

Additional design efforts should be put into minimizing pressure drops in the system. Most utility systems provide water at 50 to 80 psig. If the water is outside that range, efforts must be made to correct the situation. If the pressure is too high, a pressure-reducing valve (PRV) must be installed at the building entrance. If the pressure is too low, a booster pump and pressure tank are usually required. Note that providing a looped system will not usually help low water pressure problems; however, it can improve water flows in systems with marginal pressure (Virginia Publishing Code, 2006).

Water conservation measures are an important aspect of a sustainable future, especially in arid areas like the western United States where the scarcity of water becomes the primary topic of conversation in drought years. However, drinking water contaminant levels are concentrationbased; therefore, when more water (i.e., less conservation) is moving through a distribution system, it is more likely that the water quality will meet applicable limits. Another incentive to move large

quantities of water is to prevent the water from stagnating in pipes, where it can pick up rust and other contaminants that may not represent a health threat but make the water unpleasant to taste. Historically, water distribution systems have been designed to provide more than adequate flow capacity for the largest demand, which is fire flow. This can result in mains and service lines that are oversized for most of their use, which is the demand in the building, resulting in stale water that may be warm or bad-tasting and potentially contain disinfection byproducts. Implementing conservation practices while providing healthy and pleasant-tasting water is a balancing act. We must continually reduce a building's water demand through low-use fixtures, laboratory modifications, and other conservation measures, but still ensure healthy and pleasant water. One way to understand the impacts of water conservation measures on the distribution system is to model the system and test different scenarios. These computer-based models are time consuming to set up, but invaluable for testing out changes in the system before implementing them. Water modeling at Colorado State University, for instance, allowed utility engineers to determine that a section of pipe with a failing water vault was not required to maintain adequate flows in the system. As a result, an expensive repair was avoided and the pipe section can be cut off from the system (Brook, 2011).

ii. System Mapping

The importance of accurate distribution system maps cannot be overemphasised. Accurate maps provide effective distribution, system operation and maintenance and minimisation of repeated mistakes (e.g., closing a service at an incorrectly shown location). It is an effective planning tool for replacement and rehabilitation programs, identification of water quality problem areas (Water Supplies Department, 2016).

According to Bratsch-Blundel (2008), the following topics should be considered as the system maps are developed or upgraded:

Valve locations: These are important in times of emergency, such as main breaks. They are also important for planning unidirectional flushing, system replacement and upgrades.

Main locations, size and material: A pipe's size and material can affect flow and pressure characteristics at the delivery points. Accurate size and material information helps troubleshoot flow and pressure problems. Age of the pipe: Pipe age is helpful in water quality and flow modeling and helps guide replacement and repair programs. It also provides necessary information to help you comply with water quality testing regulations of contaminants such as lead and copper.

Locations and dates of breaks: This information is needed for system replacement and rehabilitation planning. Locations and dates of complaints: This information is needed for system evaluation, replacement, and upgrade planning.

Mapping can be performed using AutoCAD software, GIS software or both. If both are used it is important to have a process for establishing one type of software as the master, with the other being updated promptly after changes are made. (Domestic and Fire Protection Water Supply and Distribution Systems, 2009).

2.5 Water Suply for Multi-Storey Buildings

For plumbing purposes, the term “multi-storey” is applied to buildings that are too tall to be supplied throughout by the normal pressure in the public water mains. These buildings have particular needs in the design of their sanitary drainage and venting systems. Water main supply pressures of 8–12 metres (25–40 feet) can supply a typical two-storey building, but higher buildings may need pressure booster systems. In hilly areas, the drinking-water supply pressures will vary depending on the ground elevatio2`324n. In these cases, the water authority may have to specify areas where particular supply pressures can be relied upon for the design and operation of buildings. Where a building of three or more storeys is proposed a certificate should be obtained from the drinking-water supply authority guaranteeing that the present and future public drinking-water supply pressure will be adequate to serve the building. If the public water pressure is inadequate, suitable means shall be provided within the building to boost the water pressure. Pumps are not a solution to the problem of inadequate drinking-water supply. Where public drinking-water supply systems are overburdened and cannot provide adequate pressure on a continuous basis, water must be stored on site during periods when adequate pressure is available to fill a gravity storage tank. The size of the storage tank will vary according to the daily water demand of the building, and the availability of adequate pressure available in the public water mains. It should not be excessively oversized to avoid stagnation due to inadequate turnover.

Multi-storey buildings can usually be divided into zones of water pressure control. The lower two to three storeys can generally be supplied directly from the pressure in the public water main. Upper storeys, usually in groups of five to eight storeys, can be supplied from pressure-boosted main risers through a pressure reduction valve for each group. Systems can be up-fed or down-fed. Up-fed systems usually originate from a pressure booster pump set or hydro-pneumatic tank in the basement of the building. Down-fed systems usually originate from a rooftop gravity tank. Where a building is divided into water pressure zones, care must be taken not to cross-connect the piping between two or more zones. This is a particular problem when domestic hot water is recirculated from a central supply system (Ladd, 2005).

Where hydroneumatic tanks are used for storage, the tank is filled to one third to a half full by a float level device that controls the drinking-water supply source (a well pump or pressure booster pump). The pressure is maintained at the desired operating level by an air compressor. As the building uses water from the tank, the water level and air pressure drop. When the water level drops to the “on” setting of the float level control, the well pump or booster pump starts and raises the water level in the tank to the “off” level. This restores the pressure in the tank. If some of the captive air above the water has been absorbed by the water, the air compressor starts and restores the air charge, raising the system pressure to the normal level. Hydropneumatic tanks are typically made of steel or glass fiber and must be rated for the system operating pressure. Steel tanks must have a protective coating of suitable composition for drinking-water contact on the inside to protect the tank from corrosion and avoid contaminating the water. They should be checked on a regular basis to ensure that the protective coating is intact and the water remains potable. Smaller hydropneumatic tanks can also be used to help control pressure booster pumps, allowing them to be cycled on and off by a pressure switch. The captive air within the tank keeps the system pressurized while the pump is off. When the water pressure drops to the “on” pressure setting, the pump starts and raises the volume and pressure of the water in the tank. No air compressor is needed where tanks have a flexible diaphragm between the air and the water in the tank, charged with air at initial start-up. The size of pressure tanks for booster pumps must match the capacity of the pump and the peak system demand so that the pump “off” cycle is longer than the “on” cycle and the pump does not cycle too frequently (Ladd, 2005).

2.6 Water storage vessels

Separate water storage vessels are an integral part of many dual supply systems. This section deals with requirements for the storage of water supplied from the water main or other drinking-water sources. In the design of these systems, it is important to ensure that the required air gap is established between the drinking-water supply inlet and the overflow spill level of the fixture. Water storage tanks are appropriate for use in the following circumstances:

- Sanitary flushing
- Supply of drinking-water
- Firefighting
- Air-conditioning
- Refrigeration
- Ablutions
- Prevention of cross-connections
- Make-up water
- Contingency reserve.

2.6.1 Requirements relating to installation and protection of water storage tanks:

- Tanks must be installed on bases, platforms or supports designed to bear the weight of the tank when it is filled to maximum capacity, without undue distortion taking place.
- Metal tanks (and other tanks when similarly specified) should be installed with a membrane of non-corrosive insulating material between the support and the underside of the tank.
- Tanks must be supported in such a manner that no load is transmitted to any of the attached pipes.
- Tanks must be accessible for inspection, repairs, maintenance and replacement.
- Tanks must be provided with a cover, designed to prevent the entry of dust, roof water, surface water, groundwater, birds, animals or insects.
- Insulation from heat and cold should also be provided.

- Tanks storing potable water should not be located directly beneath any sanitary plumbing or any other pipes conveying non-potable water.

2.6.2 Requirements relating to access to water storage tanks:

- Adequate headroom and side access must be provided to enable inspection, cleaning and maintenance of the interior and exterior of the tank.
- Where the interior depth of any storage tank exceeds 2 metres, access ladders of standard design should be installed and entry safety codes complied with.

2.6.3 Requirements relating to materials used in water storage tanks:

- The internal surfaces of tanks should be coated with a protective coating approved for drinking-water contact applied in accordance with the manufacturer's instructions if the tank is to supply drinking-water (Barta, 2007).
- Storage cylinders should be made of non-corrosive material.
- Tanks, pipes, heating coils and related fittings should all be of a similar metal to prevent electrolysis, which is more likely to cause corrosion in hot water systems than in cold.
- If steel is used for the tank and piping, it should always be heavily galvanized.

A college or university must provide potable water and manage its water distribution system to serve hundreds to thousands of people each day. Those that do not own and operate the water distribution system serving their facilities should work closely with their water purveyor to ensure that reliable water of high quality is delivered to their facilities. The water quality must meet regulatory limits and must be aesthetically pleasing.

The potable water will be used for drinking, but it may also serve a plethora of other uses such as research, instruction, cleaning, irrigation, animal husbandry, and fire protection. Many universities use non-portable water for irrigation and other applications as well. This chapter addresses some of the issues and topics encountered when a typical university supplies safe and pleasant water through its potable water utility.

The major elements of water supply are the water source, treatment facilities, storage systems, and the distribution system. A small college or university in a rural setting may be responsible for all of these aspects of water supply, including identifying and caring for the source. However, most colleges or universities are located within a municipality or water district that supplies treated water to their distribution system; therefore, the distribution system is the focus of most universities' potable water utility.

2.7 Water Source

Water sources are generally divided into two types: surface water and groundwater. Surface waters include lakes and rivers. Groundwater is usually pumped up from dozens to hundreds of feet below the ground surface. A third water source category includes "ground water under the influence of surface water", which is shallow ground water or a spring that is subject to surface water intrusion or contaminant migration from the surface.

2.8 Treatment Facilities

The size and source of a water system dictate the type of treatment required. The smallest and simplest systems require disinfection as a minimum treatment. If the source is surface water or groundwater under the influence of surface water, then filtration may also be required. Larger systems must implement treatment that meets turbidity requirements and contaminant levels and includes disinfection. Complex water treatment systems may consist of numerous unit operations, from basic multimedia filtration to ultrafiltration or reverse osmosis (Sultana, 2007). It is important for system operators to have a basic understanding of where their water comes from and how it is treated so that if problems arise, the situation can be assessed and addressed efficiently. Municipal water treatment operators are typically eager and available to provide tours of and information about their treatment facilities to college and university facilities personnel. Getting to know the personnel at your local water utility and learning what resources they have available is also valuable in the event of an emergency situation (such as a water main break or cross-connection).

2.9 Storage Systems

Areas with relatively flat topography may need elevated tanks in order to consistently get sufficient water pressure. These water towers provide additional benefits, including balancing the supply over daily variations in consumption patterns or extreme consumption such as firefighting. The towers continue to provide water for a period of time if there is a pump failure or power outage. One of the significant benefits of water storage tanks is that the system pumps can be sized to meet lower flow volumes. This is because during times of high demand, tank levels can be drawn down. However, operators must watch the "residence time" in these tanks so that water quality does not deteriorate substantially. These facilities need regular maintenance, including painting (both inside and out), periodic disinfection, and regular checks to ensure that all vent screens are intact.

In addition to storage tanks that might serve a whole campus, it is common to have booster pumps and storage tanks on buildings too tall to be served by street pressure. Static pressure losses accrue at 0.433 psi/foot, so there is a loss in static pressure of about 5 psi for each story in a multistory building. Most fixtures require pressures in the range of 25 to 35 psi in order to function properly. If a booster pump is used in a building with fire sprinkler protection, backup generation is required so that fire sprinklers can still operate in the event of a power failure.

2.10 Fire Protection

Campus fire protection is generally part of the domestic water distribution system. Fire flow requirements for each building include many factors such as occupancy load, size of building, construction materials, and usage. The state fire marshal and local fire protection districts set fire flow requirements or necessary fire protection measures for each building on campus. Typically, fire flow requirement for campus facilities vary from 1,500 to 3,500 gpm at 20 psi residual pressure (Klein *et al.,* 2007; Virginia Publishing Code, 2006).

Arriving at a reasonable accurate estimate of the maximum probable demand is complicated due to the intermittent operation and irregular frequency of use of fixtures. Different kind of fixtures are most frequently used on arising or retiring and not surprisingly during television commercials. Kitchen sinks find heavy usage before and after meals laundry trays and washing machine are most likely to be used in the late morning (Winnipeg, 2014).

2.11 Water Pressure

Pipe diameter: The smaller the internal diameter of the pipe the lower the pressure and flow rate. Note, that the pipes are generally classified by their inside nominal diameter, but it is actually the internal diameter that counts.

- Pipe length: longer pipe will result to a lower flow rate.
- Number of bends and fittings: the more the fittings and more the bends in a length of work the lower the flow rate.
- Water temperature: higher temperature will increase the pressure and flow rate.

Table 2.1: Flow rate and pipe size acceptance solution from building code compliance document G12/AS1

Fixtures	Flow rate (1/S)	Flow rate/(min)
Water closet (basin and shower)	0.10	6
Bath	0.30	18
Sink: standard tap	0.12	7
Sink: aerated tap	0.10	6
Laundry tub	0.12	7
Dish washer & washing machine	0.20	12

(Source: UNESCO, 2008)

2.12 System layout

In the design process, the layout of the plumbing system will largely follow room layout. There are many things to consider which relates to code of compliance, building users comfort, sustainability.

When planning a water supply layout the following must be considered

- Pipe runs and length: keep pipe runs as short as possible. Pass pipes close to the fixtures to minimize the number branches and unnecessary elbows, tees and joints. Having longer pipes runs and more fixtures will reduce flow rate and increase the use of materials.
- Point of entry into the building: this should be through a utility space such as garage, laundry and include an accessible isolating valve. Line strainer and pressure limiting valve if required.
- Water heating system: locate centrally to reduce the length of pipe that runs to the fixture because longer pipe runs require more water to be drawn off before hot water is

discharged. Install a separate point of use. Use water heater for fixtures that are more than 10m from the main water heater.

- Noise prevention: avoid running pipes over or near bedroom and living room area.

Back flow is the unplanned reversal of flow water (and contaminant) in to the water supply system. The system must be designed to prevent contamination and back flow.

- Mains connections: when water source is a main supply, the network utility operator is responsible for the water supplied to the boundary. The property owner is then responsible for providing the pipe work to bring the water into the building. An isolation valve must be fitted at the point of connection to allow for maintenance and repair of the building's water supply system if required.

Pipe material and specification:

The pipe used in a building must not contaminate portable water supply, and must be suitable for the water pressure, flow rate and temperature of the water. This will be influenced by the material used and wall thickness.

2.13 Common Pipe Materials

Common materials used include:

i. Copper
ii. Poly-butylenes (PB)
iii. Un-plasticized polyvinyl chloride (UPVC or PVC-u)
iv. Polyethylene (PE)
v. Polypropylene (pp-3 or PPtype 3)

2.13.1 Copper Pipes

Copper pipes is a naturally corrosive resistance metal .while galvanized steel will eventually leak and brake because of corrosion damage. Copper is light weight, which makes it easier to work with (saving on labour cost) and also easer to extend over a long over long stretches without support and it is less expensive.

Copper pipe is bacteriostatic, meaning it is resistant to bacterial growth, which keeps the water in your home clean. If there is fire, it releases no harmful toxic gases due to resistance to burning (NAHB Research Center, 2006).

Plate 2.1: Copper pipe and fitting (Bhatia, 2012).

2.14 Internal piping system (IPS) Fusion

IPS fusion system is a copolymer made up of the union of propylene and ethylene monomers, its range of use widens towards low temperature areas, including temperatures below zero. Also, this raw material was specially chosen for the great resistance it grants to the products that are subject to high temperature and pressure over time.

Plate 2.2: Plumbing Accessories (Graham, 2012)

2.15 Physical properties required for Pipe Materials

The physical properties required include:

i. Low thermal conductivity: Reduce the spreading of the heat of the fluid that circulates inside the pipe i.e. prevent the condensation that normally occurs on the external surface of metal pipes under specific hydrometric conditions.

ii. Great elasticity: It allows a better absorption of the tension created by the lineal dilation of the pipes. And has excellent behavior with vibrations or telluric movements.

iii. Impact resistance: Resists to construct - or – transport mistreat or those that occur while functioning with hammer.

iv. High resistance to temperature and pressure over time.

v. Eternally rust proof

vi. Ensures a high rust proof

vii. Ensures high flow over time: Internal surface are completely smooth and have a minimum friction coefficient. Contributing to minimize load loss. They also avoid the building up scale.

viii. Maximize the use of network pressure

ix. Light and easy to handle

x. High resistance to chemical: Excellent behavior with hard water and water with acidic and alkaline components. It Suitable for the conduction of liquids with highly aggressive contents.

xi. Completely non toxic

xii. No transmission of odor or flavor to the transported liquids

xiii. Not affected by galvanic currents, microbial corrosion and parasail currents.

2.16 Fittings

Corner elbow: IPS has exclusively designed the “rapid flow” corner elbow for its accessory line. It is an ideal price to reach the corner of the installation with a three way derivation, optimizing the time and space available.

2.17 Fusion device

It is a 1000W heating iron thermostatically regulated. It can work with fusion welding sockets of all diameters. It has a small design in front part so that it can be inserted in d wall gutters.

2.18 Total dynamic head

The head of the pump is the pressure drop summation of:

i. Friction drop in piping and fittings up to the remotest point
ii. Addition of static pressure drop due to highest located fixture.
iii. Addition of terminal pressure added to the faucet out let.

The total dynamic head for booster application is calculated as follows (Graham, 2012):

$$TDH = He + Hr + Hc - Hs \qquad (2.1)$$

Where:

He: is the vertical height difference between the booster discharge and the highest point of use.

Hr: is the friction losses of all the piping, valves, elbows etc. of the system.

Hc: is the desired discharge pressure at the top of the system.

Hs: is any suction pressure coming into the booster from the water supply line. The head of water available can be calculated using the following expression adapted from Zormah (2013):

$$h = \frac{p}{\partial g}$$

$$p = \partial g h \quad (2.2)$$

Where:

P = water pressure from the main supply in: 2.0 bar = 2.0 x 10^5 N/m^2

δ = density of water = 1x10^3 kg/m^2

g = acceleration due to gravity, 9.81 m/s^2.

2.19 Review of Related Past Works

Niskanen (2003) worked on the design, construction and maintenance of a gravity-fed water system in the Dominican Republic using water from a natural occurring mountain spring. The researcher constructed a spring to collect the water and scheduled 40 PVC pipes to transmit the water to the communities. A break-pressure box was constructed half- way down the mountain to reduce water pressure in the pipeline. The water exits into a 10,000 Gallon water storage tank above the community. The researcher engaged seventy-five homes in the project and each worked for a private tap in their home. Over 600 PVC pipes were used and installed in over 4.8 Kilometers (3 miles) of hand-dug trench. The final cost of the water system was US$10,175.

Ladd (2005) presented a comprehensive evaluation of contemporary plumbing water distribution system design, and explained all the intricate details pertaining to the probabilistic nature of demands. The researcher pointed out that the contemporary methods for designing minor distribution systems have come under recent scrutiny, and that issues have been raised regarding the accuracy of water demand estimation procedures for plumbing systems, namely, Hunter's method. He stressed that the much smaller travel times occurring in plumbing distribution systems, small diameter pipes are sufficient to provide for the intermittent demands incurred by only a subset of fixtures. The estimate of the probability of fixture use as the ratio of the duration to time between uses should be evaluated over a peak usage period. According to him, the lag times between fixture uses are relatively long. These facilitate long contact durations between the pipe wall and the water throughput, which promotes water quality related activities. The researcher utilized EPANET, a commonly used hydraulic modeling software package to evaluate network behaviour.

Helena de Oliveira *et al* (2007)worked on assigning a fixture unit weight to the plumbing fixtures and converting it into equivalent gallons per minutes based on theory of probability usage. He observed that all the fixtures are not used simultaneously. The duration of use are different and times between uses are different. He estimated the flow rate through various fixtures by capturing average flow and the time span of a single operation for different fixtures.

Ho (2010) in his work on the design of cold and hot water systems applied probability theory with caution to determine maximum frequencies of use and estimated the average water usage rates and time. The theory is valid with large number of fittings. He observed that a small increase in demand over design level will cause a slight reduction in Pressure/flow (unlikely to be noticed by users). The researcher finally deduced that most fittings are used only at irregular intervals and it is unlikely that all the appliances will be used at the same time.

Brook (2011) in his work on water supply to a duplex found an average time between successive usages from records collected in hotels and apartment houses during the period of heaviest usage. This made it important to evaluate how many fixtures could be operated simultaneously. Since it is likely that all fixtures in the building will be operated simultaneously. He considered all building with 20 flush valves and 20 flush tanks and applied the probability theory to determine how any of these 20 fixtures will be operated at any given instant with the condition that this occurrence will not exceed more than one percent of the time.

2.20 Research Gap

From the above review, it can be seen that water supply in houses with adequate pressure in all appliances at all times has not been feasible, hence this work is undertaken to fill in the gap.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Materials

Polypropylene (PP) pipes, Polyvinyl chloride (PVC) pipes, fittings and fixtures

3.2Design Considerations

For the design of a water supply to a residential building, considerations include:

3.2.1 Materials Selection

Materials are selected based on availability, cost and durability. Two most common materials currently used for potable water supply lines are copper and plastic (polypropylene and polyvinyl chloride). The materials for the plumbing piping were selected to offer the following advantages:

i. Corrosion resistance and low friction loss;

ii. Small in diameter and can be used in tight places;

iii. Inhibit bacteria growth, thereby making the water safe to drink;

iv. Resistant to flame;

v. Prone to withstand earthquakes;

vi. Provide good form fitting;

vii. Indefinite life expectancy unless unusual water conditions or manufacturing defects are present.

Polypropylene and polyvinyl chloride satisfy most of these requirements.

3.2.2 Cost

The disadvantage of copper pipes is higher cost, condensation concerns, heat conductivity, system noise and tube can kink. Hence, polypropylene (PP) and polyvinyl chloride (PVC) are used for this work.

3.2.3 Estimating Water Demands

A fundamental consideration in the sizing of a plumbing water system or its components is an estimate of the amount of water expected to be used by the customers. Estimating demand depends on the water usage patterns and is usually unique for a particular system. For instance, a difference can exist for a residential and a non-residential system. A water usage pattern may also be unique because of the individuality of consumers on the system and their expectations to use water whenever and however they wish.

3.2.4 Water Distribution System

The potable water systems must achieve the following basic objectives:

i. Deliver an adequate volume of water to the most hydraulically remote fixture during minimum pressure and maximum flow conditions;

ii. Provide adequate water pressure to the to the most hydraulically remote fixture during minimum pressure and maximum flow conditions;

iii. Prevent excessive water velocity during maximum flow conditions.

3.2.5 Adequate Pressure

Municipalities usually maintain water pressure in their distribution mains within the range of 35–45 psi. There are localities where the pressure maintained is much less or greater. The local utility will furnish the information as to their minimum and maximum operating pressures.

When utilizing only the public water main pressure for the water distribution system within a building, it is very important to determine the pressure available in the mains during the summer months. It is good practice to assume a pressure available for design purposes as 10 psi less than the utility quotes (Bhatia, 2012).

3.3 Plan Layout of the Bungalow and Description

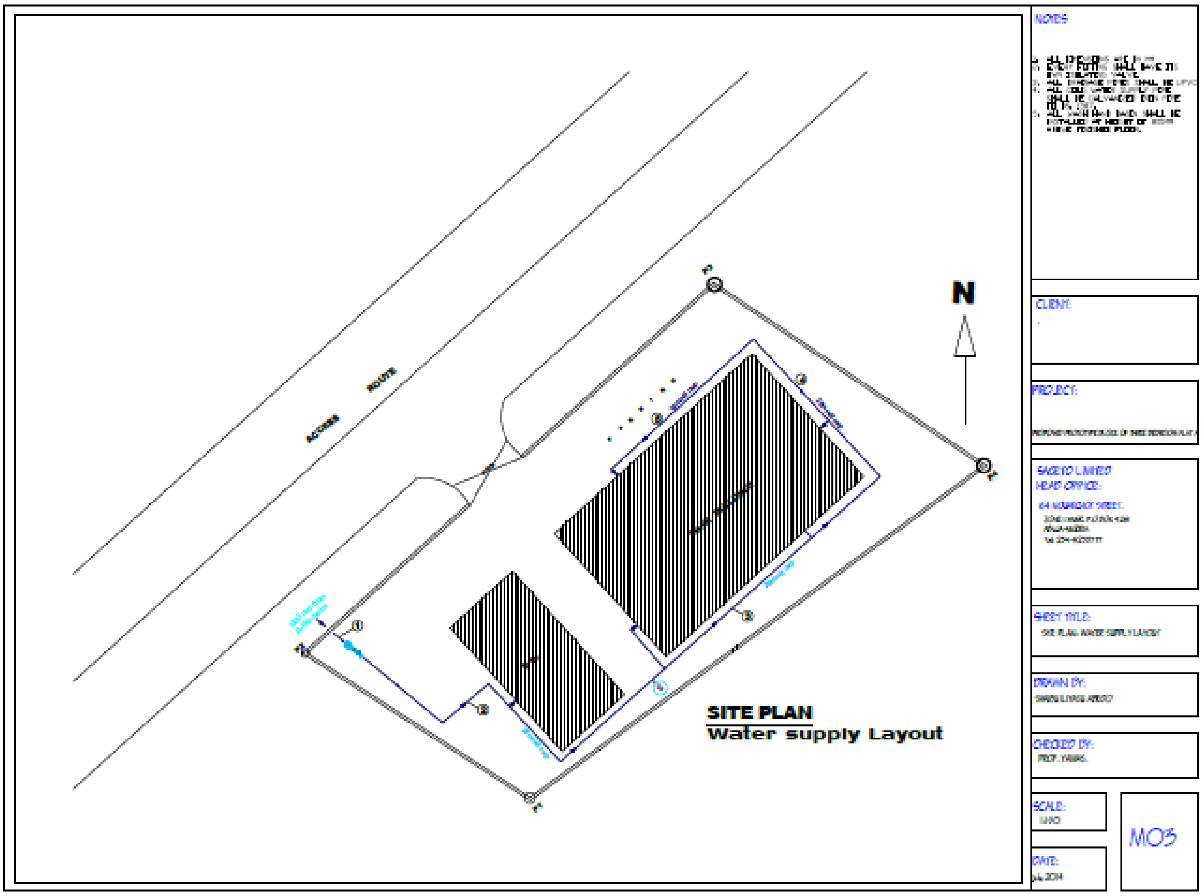

Figure 3.1: Site plan water supply layout of the three bedroom bungalow

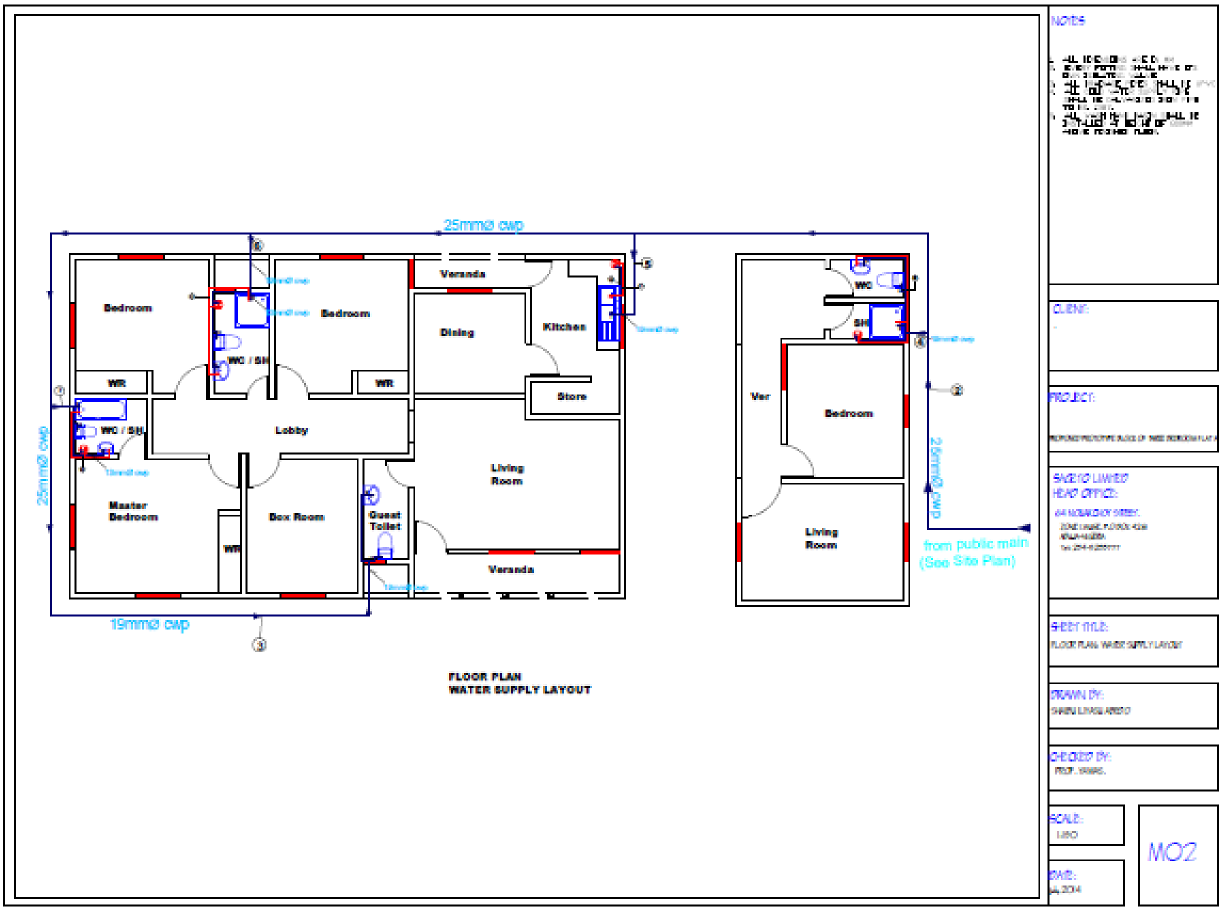

Figure 3.2: Floor plan water supply layout of the three bedroom bungalow

The bungalow consists of three bedrooms. The site plan water supply layout is depicted in Figure 3.1 and the floor water layout depicted in Figure 3.2.

3.4 Design Analysis of the Water Supply System

3.4.1 Pipe Size Analysis

3.4.2 Cold Water Supply Calculations

Refer to Figures 3.1 and 3.2:

All pipes shall be PPR to BS 1010

Column 1: Pipe Number 1
Column 2: Loading Units

Table 3.1: Quantity and Loading units of appliances for pipe Number 1

Description of Appliances	Quantity	Loading Units (LU)	Sub-Total
Bath Tub (BT)	1	10	10 LU
Shower Tray	2	3	6LU
Water Closet (WC)	4	2	8 LU
Kitchen Sink (KS)	1	4	4 LU
Wash Hand Basin (WHB)	4	1.5	6 LU
Total Loading Units			34 LU

Column 3: the flow rate = 0.62l/s

Where l = litre and s = second

Column 4: Estimated pipe diameter (mm) = 32mm

Column 5: Measured pipe run (m);

This is the actual total length of pipe

Number 1 = 6m

Column 6: Length of pipe equal to all fittings resistance

= 1 No. 32 mm diameter elbow

= (1 x 1.0) m = 1m

Column 7: Effective length of pipe equal to the

Measured pipe run and length of pipe equal

To all resistances = (6+1) = 7m

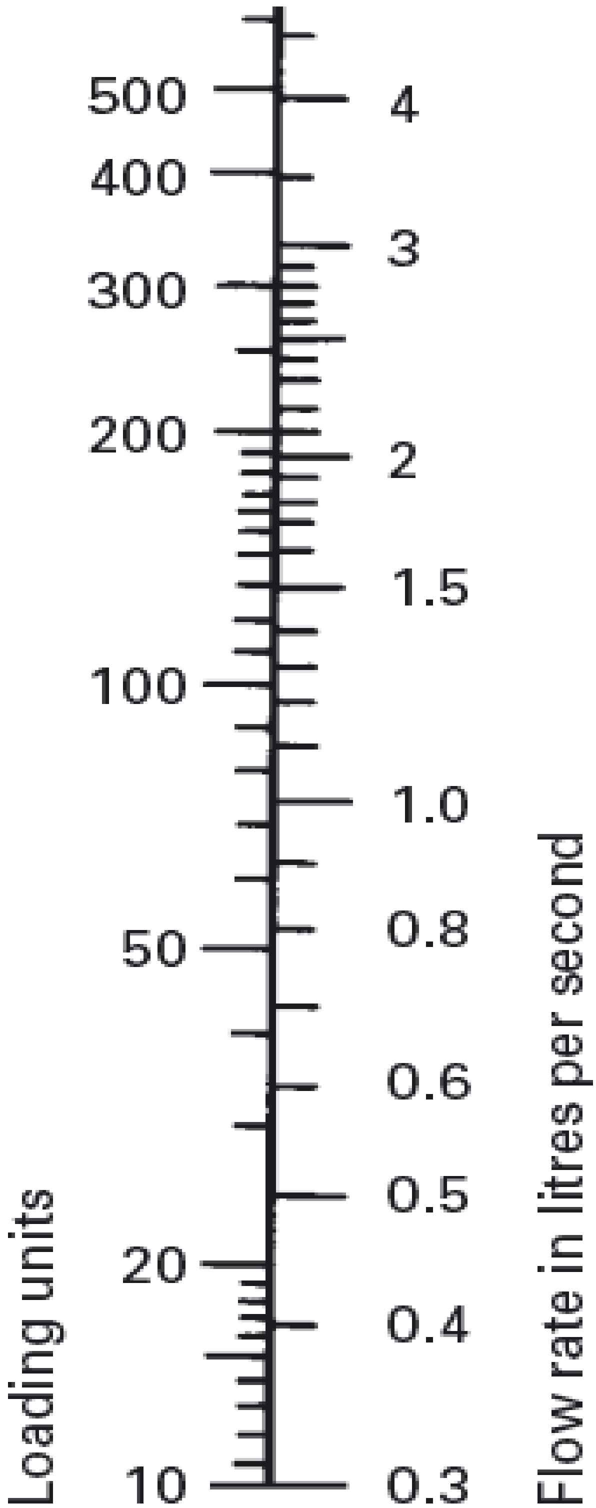

Fig. 3.3: Conversion Chart – Loading Unit of Flow Rate (Graham, 2012)

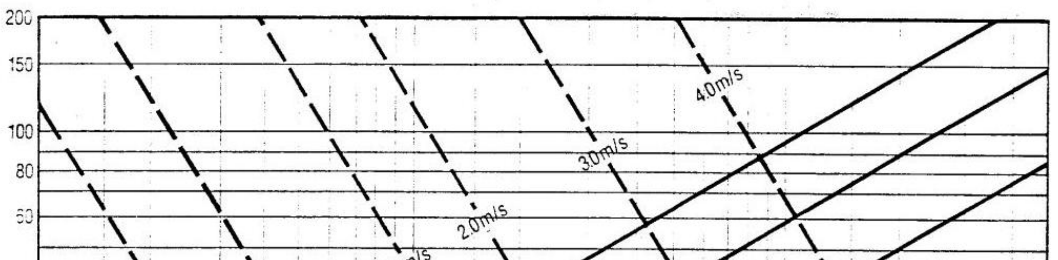

Fig 3.4: Pipe sizing chart (Graham, 2012)

Column 8: Loss of Head in meters per meter run of pipe (m/m run) can be obtained from

Fig. 3.2, rate value 0.62 l/s = 0.028m/m Run

Column 9: Head consumed is equal to effective length of pipe x loss of head in metres per meter run

= (7 x .0.028) m = 0.196 m = 0.20 m

Column 10: Total head consumed (m) = 0.20m

Column 11: Head available at point of discharge (m)

Is equal to the head available at the source on the public water main line.

Data available indicates that the average water Pressure on the public water mains = 2.0 bar.

Head of Water available can be obtained from the Bernoulli's equation adapted from Zormah (2012):

$$h = \frac{p}{\partial g} \tag{3.1}$$

Where:

P = water pressure from the main supply line = 2.0 bar = 2.0 x 10^5 N/m^2

ρ = density of water = 1 x 10^3 kg/m^2

h = Head of water available at the point of discharge (m)

$$h = \frac{p}{\rho g}$$

$$= \frac{2.0\times10^6}{1\times10^3} \times 9.81$$ =20 m

Appliances are installed 1m above floor level

So h = (20 – 1) m =19 m

Column 12: Final pipe size (outside diameter in *mm*) since the head of water available at the point of discharge is greater than the total head of water consumed, then the estimated pipe diameter of 32 mm is satisfactory.

Therefore the diameter of pipe number 1 selected is = 32 mm

Column 1: Pipe Number 2

Column 2: Loading Units

Table 3.2: Quantity and Loading units of appliances for pipe Number 2

Description of Appliances	Quantity	Loading Units (LU)	Sub-Total
Bath Tub (BT)	1	10	10 LU
Shower Tray	2	3	6LU
Water Closet (WC)	4	2	8 LU
Kitchen Sink (KS)	1	4	4 LU
Wash Hand Basin (WHB)	4	1.5	6 LU
Total Loading Units			34 LU

Column 3: From Fig. 3.1, the flow rate = 0.62l/s
Where l = Litre and s = second

Column 4: Estimated pipe diameter (mm) = 25mm

Column 5: Measured pipe run (m);
This is the actual total length of pipe
Number 2(See Site Plan drawing) = 92m

Column 6: Length of pipe equal to all fittings resistance
= 3 No. 25mm diameter elbows + 4No. 25mm dia.
Tee = (3 x 0.7) + (4 x 1.8) m = 9.3m

Column 7: Effective length of pipe equal to the
Measured pipe run and length of pipe equal
To all resistances = (92+9.3) m = 101.3m

Column 8: Loss of Head in meters per meter run
of pipe (m/m run) can be obtained from
graphA2, rate value 0.62 l/s = 0.028m /m Run

Column 9: Head consumed is equal to effective length
of pipe x loss of head in metre per meter run
= (101.3 x .0.028) m = 2.84m

Column 10: Total head consumed = total head consumed
in pipe No.1 + head consumed in pipe No.2
= 0.20+ 2.84 = 3.04m

Column 11: Head available at point of discharge (m)
is equal to the Head available at the source
on the public water main line.

P = water pressure from the
Mains supply line = 2.0 bar.

Data available can be obtained from the Formula

$$h = \frac{p}{\rho g}$$

P = 2.0 bar = 2.0 x 10^5 N/m^2

ρ = Density of water = 1 x 10^3 kg/m^2

g = Acceleration due to gravity = 9.81m/s^2

h = Head of water available at the point of discharge (m)

$$\therefore h = \frac{p}{\rho g} = \frac{2.0x10^5}{1x10^3} x\ 9.81$$ = 20m

Appliances are installed 1m above floor level

So h = (20 – 1) m = 19m

Column 12: Final pipe size (outside diameter) mm since the head of water available at the point of discharge is greater than the total head of water consumed, then the estimated pipe diameter of 25mm is satisfactory.

Therefore the diameter of pipe number 2 selected is = 25m

Column 1: Pipe Number 3

Column 2: Loading Units

Table 3.3: Quantity and Loading units of appliances for pipe Number 3

Description of Appliances	Quantity	Loading Units (LU)	Sub-Total
Water Closet (WC)	1	2	2 LU
Wash Hand Basin (WHB)	1	1.5	1.5 LU
Total Loading Units3.5LU			

Column 3: From Fig. 3.1, the flow rate = 0.3 l/s

Column 4: Estimated pipe diameter (mm) = 19mm

Column 5: Measured pipe run (m);
This is the actual total length of pipe
Number 3 = 20m

Column 6: Length of pipe equal to all fittings resistance
= 2 No. 19mm diameter elbows + 1No. 25mm dia.
Tee = (2 x 0.6) + (1 x 1.4) m =2.6m

Column 7: Effective length of pipe equal to the
Measured pipe run and length of pipe equal
To all resistances = (20 +2.6) m = 22.6m

Column 8: Loss of Head in meters per meter run
of pipe (m/m run) can be obtained from
Fig. 3.2, rate value 0.3 l/s = 0.085m/m Run

Column 9: Head consumed is equal to effective length of pipe x loss of head in metres per meter run

= (22.6 x .0.085) m = 1.92 m

Column 10: Total head consumed = total head consumed in pipe No.2 + head consumed in pipe No.3

= 3.04m + 1.921m = 4.96 m

Column 11: Head available at point of discharge (m)
Is equal to the head available at the source
On the public water main line.

P = water pressure from the Main supply line =2.0 bar.
Data available can be obtained from the Formula

$$h = \frac{p}{\rho g}$$

P = 2.0 bar = 2.0 x 10^5 N/m^2

ρ = Density of water = 1 x 10^3 kg/m^2

g = Acceleration due to gravity = 9.81m/s^2

h = Head of water available at the point of discharge (m)

$$:.\ h = \frac{p}{\rho g} = \frac{2.0\ x\ 10^5}{1\ x\ 10^3}\ x\ 9.81 \qquad = 20m$$

Appliances are installed 1m above floor level

So h = (20 – 1) m = 19 m

Column 12: Final pipe size (outside diameter) mm since the head of water available at the point of discharge is greater than the total head of water consumed, then the estimated pipe diameter of 19mm is satisfactory.

Therefore the diameter of pipe number 3 selected is = 19 mm

Column 1: Pipe Number 4

Column 2: Loading Units

Table 3.4: Quantity and Loading units of appliances for pipe Number 4

Description of Appliances	Quantity	Loading Units (LU)	Sub-Total
Water Closet (WC)	1	2	2 LU
Wash Hand Basin (WHB)	1	1.5	1.5 LU
Shower Tray	1	3	3LU
Total Loading Units			6.5LU

Column 3: From Fig. 3.1, the flow rate = 0.3 l/s

Column 4: Estimated pipe diameter (mm) = 19mm

Column 5: Measured pipe run (m);
This is the actual total length of pipe
Number 4 = 18.5 m

Column 6: Length of pipe equal to all fittings resistance
= 4 No. 19mm diameter elbows + 3No. 25mm dia.
Tee = (4 x 0.6) + (3x 1.4) m = 6.6 m

Column 7: Effective length of pipe equal to the
Measured pipe run and length of pipe equal
To all resistances = (18.5+6.6) m = 25.1 m

Column 8: Loss of Head in meters per meter run
of pipe (m/m run) can be obtained from
Fig. 3.2, rate value 0.3 l/s = 0.085m/m Run

Column 9: Head consumed is equal to effective length
of pipe x loss of head in metres per meter run
= (25.1 x .0.085) m = 2.13m

Column 10: Total head consumed = total head consumed in pipe No.2 + head consumed in pipe No.3

= 3.04m + 2.13m = 5.17m

Column 11: Head available at point of discharge (m)

Is equal to the head available at the source on the public water main line.

P = water pressure from the Main supply line = 2.0 bar.

Data available can be obtained from the Formula

$$h = \frac{p}{\rho g}$$

P = 2.0 bar = 2.0 x 10^5 N/m^2

ρ = Density of water = 1 x 10^3 kg/m^2

g = Acceleration due to gravity = 9.81m/s^2

h = Head of water available at the point of discharge (m)

$$:.\ h = \frac{p}{\rho g} = \frac{2.0x10^5}{1x10^3} x\ 9.81 \qquad = 20m$$

Appliances are installed 1m above floor level

So h = (20 – 1) m = 19m

Column 12: Final pipe size (outside diameter) mm since the head Of water available at the point of discharge is greater Than the total head of water consumed, then the Estimated pipe diameter of 19mm is satisfactory.

Therefore the diameter of pipe number 4 selected is = 19mm

Column 1: Pipe Number 5

Column 2: Loading Units

Table 3.5: Quantity and Loading units of appliances for pipe Number 5

Description of Appliances	Quantity	Loading Units (LU)	Sub-Total
Kitchen Sink	1	4	4 LU
Total Loading Units			4LU

Column 3:	From graph A1, the flow rate	= 0.34LU
Column 4:	Estimated pipe diameter (mm)	=19mm
Column 5:	Measured pipe run (m); i.e. the actual length of pipe number 5	= 7.6m
Column 6:	Length of pipe equal to all fittings Resistances =2 No. 19mm diameter elbows + 1No. 25mm dia. Tee = (2 x 0.6) + (1 x 1.4) m	=2.6m
Column 7:	Effective length of pipe (m)	= 10.2m
Column 8:	Loss of head (m/m run) can be obtained from graph A2 using flow rate value 0.34L/S	= 0.17m/m run
Column 9:	Head consumed (m) = Effective length of pipe x loss of head = (10.2 x 0.17)	= 1.73m
Column 10:	Total head consume (m) = Total head consumed in pipe number 4 plus head consumed in pipe number 5 = (5.17+ 1.73) m	= 6.90m
Column 11:	Head available at point of discharge (m) is equal to the head available at the source from the public water main line.	
	Assuming the water pressure on the water main line = 2.0 bar,	

$$h = \frac{p}{\rho g}$$

Where

P = water pressure from the main line, 2.0 bar = 2.0 x 10^5 N/m^2

ρ = density of water = 1 x 10^3 kg/m^3

g = acceleration due to gravity = $9.81 m/s^2$

h = head of water available at the point of discharge (m)

$$\frac{p}{\rho g} = \frac{2.0 \ x \ 10^5}{1 \ x \ 10^3} x \ 9.81$$ = 20m

Appliance are installed 1m above floor level

So h = (20 – 1) m = 19m.

Column 12: Final pipe size since the head available at the point of discharge is greater than the total head consumed, then the estimated pipe diameter of 19mm is satisfactory. Therefore, the diameter of pipe number 5 selected is 19mm

Column 1: Pipe Number 6

Column 2: Loading Units

Table 3.6: Quantity and Loading units of appliances for pipe Number 6

Description of Appliances	Quantity	Loading Units (LU)	Sub-Total
Water Closet (WC)	1	2	2 LU
Wash Hand Basin (WHB)	1	1.5	1.5 LU
Shower Tray	1	3	3LU
Total Loading Units		6.5LU	

Column 3: From graph A1, the flow rate = 0.3 l/s

Column 4: Estimated pipe diameter (mm) = 19mm

Column 5: Measured pipe run (m); i.e. the actual length of pipe number 6 =16.8m

Column 6: Length of pipe equal to all fittings resistance
= 4 No. 19mm diameter elbows + 3No. 25mm dia.
Tee = (2 x 0.6) + (3x 1.4) m = 5.4m

Column 7: Effective length of pipe (m)
= (16.8 + 5.4) = 22.2m

Column 8: Loss of head (m/m run) can be obtained from graph A2 using flow rate value 0.3L/S = 0.085m/m run

Column 9: Head consumed (m)
= Effective length of pipe x loss of head = 1.89m

Column 10: Total head consume (m)
= Total head consumed in pipe number 5

plus head consumed in pipe number 6
= (6.90 + 1.89) = 8.79m

Column 11: Head available at point of discharge (m)

Is equal to the head available at the source

From the public water main line.

From Data, water pressure on the water main line = 2.0 bar,

$$h = \frac{p}{\rho g}$$

Where:

P = water pressure from the main line

P = 2.0 bar = 2.0 x 10^5 N/m^2

ρ = Density of water = 1 x 10^3 kg/m^3

g = Acceleration due to gravity = 9.81m/s^2

h = Head of water available at the point of discharge (m)

$$\therefore\ h = \frac{p}{\rho g} = \frac{2.0\ x\ 10^5}{1\ x\ 10^3}\ x\ 9.81 \qquad = 20\text{m}$$

Appliances are installed 1m above floor level

So h = (20 – 1) m = 19m.

Column 12: Final pipe size

Since the head available at the point of discharge is greater than the total head consumed, then the estimated pipe diameter of 19mm is satisfactory.

Therefore, the diameter of pipe number 6 selected is = 19mm

Column 1: Pipe Number 7

Column 2: Loading Units

Table 3.7: Quantity and Loading units of appliances for pipe Number 7

Description of Appliances	Quantity	Loading Units (LU)	Sub-Total
Bath Tub (BT)	1	10	10 LU
Water Closet (WC)	1	2	2 LU
Wash Hand Basin (WHB)	1	1.5	1.5 LU
Total Loading Units		13.5 LU	

Column 3: From graph A1, the flow rate = 0.37l/s
Where l = Litre and s = second

Column 4: Estimated pipe diameter (mm) = 25mm

Column 5: Measured pipe run (m); i.e. the actual length of pipe number 7 = 10m

Column 6: Length of pipe equal to all fittings
Resistances = 4No. 25mm diameter elbows = 8.4m

Column 7: Effective length of pipe (m) = 18.4m

Column 8: Loss of head (m/m run) can be obtained from graph A2 using flow rate value 0.37l/s = 0.05m/m run

Column 9: Head consumed (m)
= Effective length of pipe x loss of head
=(18.4 x 0.05) = 0.92m

Column 10: Total head consume (m)
= Total head consumed in pipe number 6 plus head consumed in pipe number 7
(8.79 + 0.92) = 9.71m

Column 11: Head available at point of discharge (m) is equal to the head available at the source from the public water main line.

From Data, water pressure
on the water main line = 2.0 bar,

$$h = \frac{p}{\rho g}$$

P = water pressure from the main line

P = 2.0 bar = 2.0 x 10^5 N/m^2

ρ = Density of water = 1 x 10^3 kg/m^3

g = Acceleration due to gravity = 9.81m/s^2

h = Head of water available at the point of discharge (m)

$$\therefore\ h = \frac{p}{\rho g} = \frac{2.0\ x\ 10^5}{1\ x\ 10^3}\ x\ 9.81$$ = 20m

Appliance are installed 1m above floor level

So h = (20 – 1) m = 19m.

Column 12: Final pipe size

Since the head available at the point of discharge is greater than the total head consumed, then the estimated pipe diameter of 25mm is satisfactory.

Therefore, the diameter of pipe number 7 selected is = 25mm

To determine the diameters of branched pipes discharging to sanitary appliances, we use the relation (Graham, 2010):

$$d = \frac{5\sqrt{D^5}}{N^5}$$

Where, N = Number of branched pipes to appliances

D = Diameter of main pipe discharging to branched pipes

d = Diameter of branched pipes discharging to appliances.

For the diameters of branched pipes numbers 8, 9 and 10,
D = 19mm, N = 3

$$d = \frac{5\sqrt{19^5}}{3^5} = 12.243\text{mm} \qquad = 13\text{mm}$$

:. The standard pipe of 13mm diameter is selected.

For the diameter of branched piped pipe number 11, D = 19mm, N = 1

$$d = \frac{5\sqrt{D^5}}{N^5} = \frac{5\sqrt{19^5}}{1^5} = 19mm$$

:. The standard pipe of 19mm diameter is selected.

For the diameters of branched pipes numbers 12, 13and 14,
D = 19mm, N = 3

$$d = \frac{5\sqrt{19^5}}{3^5} = 12.243\text{mm} = 13\text{mm}$$

:. The standard pipe of 13mm diameter is selected.

For the diameters of branched pipes numbers 15, 16 and 17,
D = 19mm, N = 3

$$d = \frac{5\sqrt{19^5}}{3^2} = 12.243\text{mm} = 13\text{mm}$$

:. The standard pipe of 13mm diameter is selected.

For the diameters of branched pipes numbers 18 and 19, D = 19mm, N = 2

$$d = \frac{5\sqrt{19^5}}{2^2} = 12.243\text{mm} = 13\text{mm}$$

:. The standard pipe of 13mm diameter is selected.

3.4.3 Hot Water Supply Calculations

Pipe sizing for hot water system is the same as cold water, except cold feed pipemustalso be considered.

Refer to Figures 3.1 and 3.2:

All pipes shall be PPR to BS 1010

Column 1: Pipe Number 20

Column 2: Loading Units

Table 3.8: Quantity and Loading units of appliances for pipe Number 20

Description of Appliances	Quantity	Loading Units (LU)	Sub-Total
Shower Tray	1	3	3LU
Wash Hand Basin (WHB)	1	1.5	1.5LU
Total Loading Units			4.5 LU

Column 3: From graph A1, the flow rate (l/s) = 0.3l/s

Column 4: Estimated pipe diameter (mm) = 19 mm

Column 5: Measured pipe run (m), i.e. the actual length of pipe number 20 = 9.7m

Column 6: Length of pipe equal to all fittings
Resistances = 4No. 25mm diameter elbow
+ 1No 25mm dia. Tee
= (4 x 0.7) + (1 x1.8) m = 4.6m

Column 7: Effective length of pipe equals to the measured pipe run and length of pipe equal to all resistances = (9.7+4.6) m = 14.3m

Column 8: Loss of head in meters per meter run of pipe (m/m run) can be obtained from graph A2 using flow rate value 0.3L/S = 0.085m/m run

Column 9: Head consumed is equal to effective length of pipe x loss of head in meters per meter run of pipe = (14.3 x 0.085) m = 1.21m

Column 10: Total head consume (m) = 1.21m

Column 11: Head available at the point of discharge (m) is equal to the difference in height between the water heater and the point of hot water discharge, i.e. height of water heater above point of water discharge
= (1.8 - 0) m = 1.8m

Column 12: Final Pipe Size:
The head available at the point of discharge is greater than the total head consumed, then the estimated pipe diameter of 19mm is satisfactory.

Column 1: Pipe Number 21

Column 2: Loading Units

Table 3.9: Quantity and Loading units of appliances for pipe Number 21

Description of Appliances	Quantity	Loading Units (LU)	Sub-Total
Kitchen Sink	1	4	4LU
Total Loading Units		4LU	

Column 3: From graph A1, the flow rate (L/S) = 0.30 l/s

Column 4: Estimated pipe diameter (mm) = 19mm

Column 5: Measured pipe run (m), i.e. the actual length of pipe number 21 = 1.8m

Column 6: Length of pipe equal to all fittings resistances

	= 2 No. 19mm diameter elbows	
	= (2 x 0.6) m	= 1.2 m
Column 7:	Effective length of pipe equals to the measured pipe run and length of pipe equal to all resistances = (1.8+1.2) m	= 3.0m
Column 8:	Loss of head in meters per meter run of pipe (m/m run) can be obtained from graph A2 using flow rate value 0.30l/s	= 0.14m/m run
Column 9:	Head consumed is equal to effective length of pipe x loss of head in meters per meter run of pipe = (3.0 x 0.140) m	= 0.42 m
Column 10:	Total head consume (m) = Total Head consumed in Pipe Number 21	= 0.42m
Column 11:	Head available at the point of discharge (m) is equal to the difference in height between the water heater and the point of hot water discharge, i.e. height of water above point of water discharge = (1.8–0.65) m	= 1.25m
Column 12:	Final Pipe Size: Since the head available at the point of discharge is greater than the total head consumed, then the estimated pipe diameter of 19mm is satisfactory.	

Column 1: Pipe Number 22

Column 2: Loading Units

Table 3.10: Quantity and Loading units of appliances for pipe Number 22

Description of Appliances	Quantity	Loading Units (LU)	Sub-Total
Shower Tray	1	3	3LU
Wash Hand Basin (WHB)	1	1.5	1.5LU
Total Loading Units			4.5LU

Column 3:	From graph A1, the flow rate (l/s)	=0.3l/s
Column 4:	Estimated pipe diameter (mm)	= 19 mm
Column 5:	Measured pipe run (m), i.e. the actual length of pipe number 20	= 11.7m
Column 6:	Length of pipe equal to all fittings Resistances = 4No. 25mm diameter elbow + 1No 25mm dia. Tee = (4 x 0.7) + (1 x1.8) m	= 4.6m
Column 7:	Effective length of pipe equals to the measured pipe run and length of pipe equal to all resistances = (9.7+4.6) m	= 14.3m
Column 8:	Loss of head in meters per meter run of pipe (m/m run) can be obtained from graph A2 using flow rate value 0.3l/s	= 0.085m/m run
Column 9:	Head consumed is equal to effective length of pipe x loss of head in meters per meter run of pipe = (14.3 x 0.085)m	= 1.22m
Column 10:	Total head consume (m)	= 1.22m
Column 11:	Head available at the point of discharge (m) is equal to the difference in height Between the water heater and the point of hot water discharge, i.e. height of water Heater above point of water discharge = (1.8 - 0) m	= 1.8m

Column 12: Final Pipe Size:
the head available at the point of discharge
is greater than the total head consumed, then the
estimated pipe diameter of 19mm is satisfactory.

Column 1: Pipe Number 23

Column 2: Loading Units

Table 3.11: Quantity and Loading units of appliances for pipe Number 23

Description of Appliances	Quantity	Loading Units (LU)	Sub-Total	
Bath Tub	1	10	10LU	
Wash Hand Basin (WHB)	1	1.5	1.5LU	
Total Loading Units				11.5LU

Column 3: From graph A1, the flow rate (l/s) = 0.35/s

Column 4: Estimated pipe diameter (mm) = 25 mm

Column 5: Measured pipe run (m), i.e. the
actual length of pipe number 23 = 8.3m

Column 6: Length of pipe equal to all fittings
Resistances = 4No. 25mm diameter elbow
+ 1No 25mm dia. Tee
= (4 x 0.7) + (1 x1.8) m = 4.6m

Column 7: Effective length of pipe equals to the
Measured pipe run and length of pipe
Equal to all resistances = (9.7+4.6)m = 12.9m

Column 8: Loss of head in meters per meter run
of pipe (m/m run) can be obtained from
graph A2 using flow rate value 0.35L/S = 0.045m/m run

Column 9: Head consumed is equal to effective length

	Of pipe x loss of head in meters per meter	
	Run of pipe = (12.9 x 0.045)m	= 0.58m
Column 10:	Total head consume (m)	= 0.58m
Column 11:	Head available at the point of discharge (m) is equal to the difference in height Between the water heater and the point Of hot water discharge, i.e. height of water Heater above point of water discharge	
	= (1.8–0.65) m	= 1.25m
Column 12:	Final Pipe Size: the head available at the point of discharge is greater than the total head consumed, then the estimated pipe diameter of 25mm is satisfactory.	

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Results

Tables 4.1 – 4.2 show the results obtained for cold water supply to the bungalow and the calculated diameters of branched cold water supply pipes discharging to sanitary appliances respectively, while Figure 4.3 shows the results obtained for hot water supply to the building.

Table 4.1: Summary of Cold Water Supply Calculations

1	2	3	4	5	6	7	8	9	10	11	12
Pipe No	Loading Units	Flow Rate L/S	Estimated Dia Pipe (mm)	Measured Pipe Run(m)	Length of Pipe equal to all resistances (m)	Effective Pipe length (m)	Loss of Head (M/M Run)	Head Consumed (m)	Total Head Consumed (m)	Head available at point of discharge (m)	Final Pipe Size (dd) (mm)
1	34	0.6	32	6	1	7	0.08	0.20	0.20	20	23
2	34	2	25	92	9.3	101.3	0.02	2.84	3.04	20	25
3	3.5	0.6	19	20	2.6	22.6	8	1.92	4.96	20	19
4	6.5	2	19	18.5	6.6	25.1	0.08	2.13	5.17	20	19
5	4	0.3	19	7.6	2.6	10.2	5	1.73	6.90	20	19
6	6.5	0.3	19	16.8	5.4	22.2	0.08	1.89	8.79	20	19

7	13.5	0.3	25	10	8.4	18.4	5	0.92	9.71	20	25
		4					0.17				
		0.3					0.08				
		0.3					5				
		7					0.05				

Table 4.2:Summary of Calculated Diameters of Branched Cold Water Supply Pipes Discharging to Sanitary Appliances

Pipe Number	8	9	10	11	12	13	14	15	16	17	18	19
Diameter of Branched Pipes (mm)	13	13	13	19	13	13	13	13	13	13	13	13

Table 4.3: Summary of Hot Water Supply Calculation

1	2	3	4	5	6	7	8	9	10	11	12
Pipe No	Loading units	Flow rate L/S	Estimated pipe Dia (mm)	Measured pipe Run (m)	Length of pipe equal to all resistances (m)	Effective pipe length (m)	Loss of head (m/m Run)	Head consumed (m)	Total head consumed (m)	Head available at point of discharge (m)	Final pipe size (DD) (mm)
20	4.5	0.30	19	9.7	4.6	14.3	0.083	1.21	1.21	1.80	19
21	4	0.34	19	1.8	1.2	3.0	0.14	0.42	0.42	1.25	19
22	4.5	0.30	19	11.7	4.6	14.3	0.085	1.21	1.21	1.80	19
23	11.5	0.35	25	8.3	4.6	12.9	0.045	0.58	0.58	1.25	25

4.2 Discussion of Results

Table 4.1 shows the summary of cold water supply design estimates for the building. Table 4.1 comprises twelve (12) columns, numbered "1 – 12". Column 1 is the pipe number. The bungalow is designed to have seven (7) pipes altogether, numbered "1 – 7". Columns 2, 3, 4 … 12 comprises the loading units, flow rate, estimate of diameter, measure of pipe run up to column 12, which is the final pipe size (mm). Some of the major tasks of water systems design are piping layout and pipe sizing (Ho, 2010; Bratscht-Blundel, 2008). The final pipe size for the three bedroom bungalow was estimated to be 23 mm for pipe number 1; 25 mm for pipe number 2; 19 mm for pipes number 3, 4, 5, 6 and 25 mm for pipe number 7. The average pipe diameter of cold water supply to the building is 19 mm. This is estimated by using the procedure proffered by Ho (2010) for water systems design for buildings.

Column '2' gives the loading units for pipes 1, 2, 3 … 7 supplying water to the three bedroom bungalow. For the cold water supply, pipes number '1' and '2' have 34 loading units while pipes 3, 4, 5, 6 and 7 have respectively 3.5, 6.5, 4.0, 6.5 and 13.5 loading units (LU).

Table 4.2 shows the summary of calculated diameters of branched cold water supply pipes discharging to sanitary appliances. The diameters of branched pipe numbers 8, 9, 10 … 19 were estimated to be 13, 13, 19 … 13, and 13 mm respectively. It is obvious that the average diameter of branched pipes supplying water to the three bedroom bungalow is 13 mm.

The summary of hot water supply calculation for the three bedroom bungalow is shown in Table 4.3. Unlike the cold water supply to the building which has a total of seven pipes numbered 1–7, the design incorporates eight pipes numbered 20 – 23. In column 12, it is obvious that the average pipe size for hot water supply to the building is about 19 mm.

The loading units for hot water supply to the building for pipes number '20', '21', '22' and '23' are found to be 4.5, 4.0, 4.5 and 11.5 LU respectively.

4.3 Cost Analysis

Cost analysis is carried out between the materials used for piping: Polypropylene (PPR) pipes imported from Italy and Polyvinyl chloride (PVC) pipes made in Nigeria.

Table 4.4: Cost analysis of the materials used for piping

S/N	*Material*	*Specification*	*Quantity*	*Unit cost (₦)*	*Total cost (₦)*
1	*PPR pipe*	*ϕ32 mm*	*2*	*3500*	*7000*
2	*PPR pipe*	*ϕ25mm*	*22*	*2200*	*4800*
3	*PPR elbow*	*ϕ25mm*	*20*	*400*	*8000*
4	*PPR Tee*	*ϕ25mm*	*8*	*400*	*3200*
5	*Socket*	*ϕ25mm*	*4*	*400*	*1600*
6	*Reducer*	*32mm ×25mm*	*1*	*400*	*400*
7	*PPR pipe*	*ϕ19mm*	*20*	*1800*	*36000*
8	*PPR elbow*	*ϕ19mm*	*15*	*350*	*5250*
9	*PPR Tee*	*ϕ19mm*	*6*	*350*	*2100*
10	*PPR socket*	*ϕ19mm*	*4*	*350*	*1400*
11	*Reducer*	*32mm ×25mm*	*4*	*300*	*1200*
12	*Socket*	*ϕ19mm*	*4*	*300*	*1200*
13	*PPR pipe*	*ϕ13mm*	*10*	*1000*	*10000*
14	*PPR sanitary elbow*	*ϕ13mm*	*25*	*380*	*9500*
15	*Water heater*	*30 litres*	*5*	*45000*	*225000*
Total					*360250*

Table 4.5: Labour and overhead cost

S/N	*Type of labour*	*Amount (₦)*
1	*Cost of cold and hot water reticulation*	*40,000*
2	*Cost of transportation and miscellaneous*	*10,000*
3	*Total labour cost*	*50,000*

Grand total cost = ₦ 360,250 + ₦ 50,000 = ₦ 410,250

4.4 Polypropylene (PPR) versus Polyvinyl chloride (PVC) Pipes

From Table 4.4, it is obvious that pipes made of PPR are expensive. As noted by Bhatia (2012), Pipes made of PPR, though expensive, are durable and can last for over 100 years; are resistant to weather factors such as temperature and humidity. Pipes made of PPR can be used to run both cold and hot water supply to the building, while pipes made using PVC are used for running only cold water supply to buildings, and can be easily damaged.

PVC is locally available in Nigeria, whereas PPR can be obtained strictly on order. According to Ho (2010), it is not advisable to use pipes made of PVC to run water through super-structures (multi-storey buildings) because the maintenance cost is very high. The maintenance cost of PPR pipes is however very low compared to PVC pipes.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

From the discussions carried out, the following conclusion can be made:

i. The design analysis of cold and hot water supply to a 3 bedroom bungalow with 8 occupants has been successfully carried out.
ii. The adequate flow pressure required is found to be 20 Pa
iii. The standard pipe size for the supply of both cold and hot water has been found to be 19 mm while the average diameter of branched pipes supplying water to the three bedroom bungalow is 13 mm.
iv. For the cold water supply, pipes number '1' and '2' have 34 loading units while pipes 3, 4, 5, 6 and 7 have respectively 3.5, 6.5, 4.0, 6.5 and 13.5 loading units (LU).
v. The loading units for hot water supply to the building for pipes number '20', '21', '22' and '23' are found to respectively 4.5, 4.0, 4.5 and 11.5 LU.

5.2 Recommendation

At the end of the work, the following recommendations are made:

i. Copper pipes should be compared with pipes made of propylene for plumbing in terms of life expectancy, and to know which of them provide better form fitting.
ii. Further work should be targeted on estimating water demands, an estimate of the amount of water expected to be used by the customers

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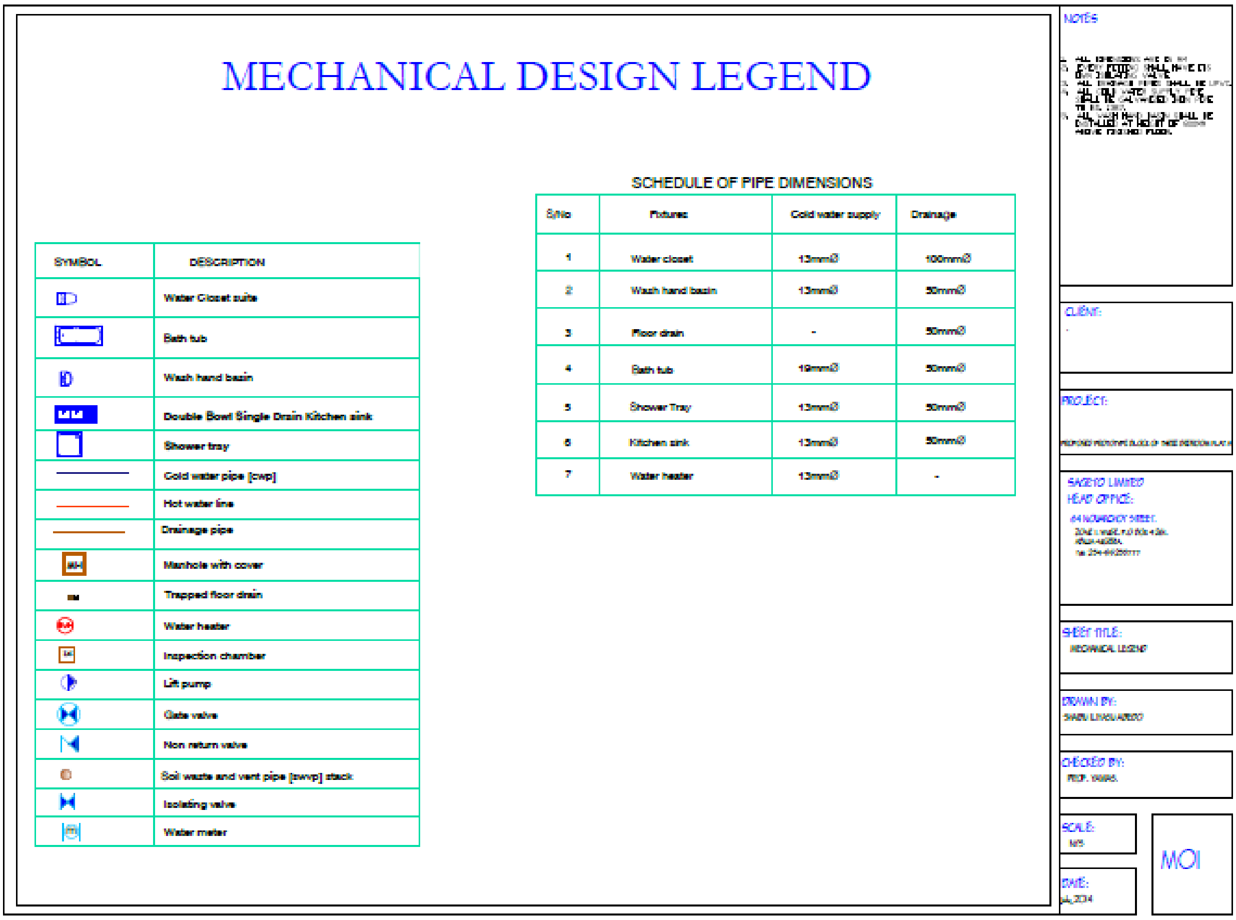
APPENDICES

Appendix 1: Mechanical Design Legend



`Appendix 2: Equivalent pipe lengths (copper, stainless steels and plastics)

Bore of pipe (mm)	Equivalent pipe length (m)			
	Elbow	Tee	Stopvalve	Check valve
12	0.5	0.6	4.0	2.5
20	0.8	1.0	7.0	4.3
25	1.0	1.5	10.0	5.6
32	1.4	2.0	13.0	6.0
40	1.7	2.5	16.0	7.9
50	2.3	3.5	22.0	11.5
65	3.0	4.5	---	---
73	3.4	5.8	34.0	---

Nominal size of tap	Flow rate (l/s)	Head loss (m)	Equiv. pipe length (m)
G1/2- DN 15	0.15	0.5	3.7
G1/2- DN 15	0.20	0.8	3.7
G3/4- DN 20	0.30	0.8	11.8
G1- DN 25	0.60	1.5	22.0

(Source: Garrett, R. H., 2008. *Hot and Cold Water Supply*)